

## CHAPTER I

### INTRODUCTION

Rice (*Oryza sativa* and *O. glaberrima*) is the 2<sup>nd</sup> most important cereal crop after wheat. It is a staple food for around 3.50 billion people of the world. Rice is the most important staple food in Bangladesh for about 165 million people. It shares about two-third of total calorie supply and about one-half of the total protein intakes of an average person in the country. The country is currently producing 37.61 million tons of clean rice from 11.70 million hectares of land (BBS, 2022). The production of rice in the country was only 9.77 million tons during 1971-72 (BRRI, 2022) meaning that rice production in 2020-21 increased by 3.89 folds than that in 1971-72. With this significant increase in rice production, largely due to concerted efforts from the farmers, rice researchers and scientists, and the government support, the country is now almost self-sufficient in rice. However, the current state of rice self-sufficiency is at risk because of a number of reasons. Firstly, population of the country is still increasing at the rate of 1.08% while the cultivable land in the country is decreasing at the rate of 0.29% (Alam *et al.*, 2015). Secondly, crop production including rice is challenged by a number of environmental factors, especially in the climate vulnerable areas of the country like salinity prone coastal area, drought prone Barind area and flood prone areas etc. Kabir *et al.* (2015) estimated that the population of Bangladesh will reach 215.4 million in 2050, when 44.6 MT of clean rice will be required. Development of rice varieties with higher yield potential and more ability of tolerate stress conditions like salinity, drought and submergence etc. is very vital to sustain rice self-sufficiency in the country.

Among the environmental factors limiting the growth and productivity of crops including rice, soil salinity and drought stresses are the major ones (Li *et al.*, 2004 and Munns, 2005). Soil salinity is the 2<sup>nd</sup> most important worldwide detrimental factors after drought for the rice producing areas of the world (Sabouri and Sabouri, 2008 and Islam *et al.*, 2011). Though salinity is a global problem, but it is more prominent in arid and semi-arid regions in Africa, Asia and Australia, due to decreased lixiviation of salt from soil resulting in increased salt accumulation (Funakawa *et al.*, 2000; Marie and Vengosh, 2001). At present, over 960 million ha of cultivable land is

adversely affected by salinity (Hoang *et al.*, 2016) and around 2 M ha of land become uncultivable due to excessive salinity added each year (Munns and Tester, 2008), resulting in reduction of yield (Eynard *et al.*, 2005) and economical losses of up to US\$ 27 billion per year (Qadir *et al.*, 2014). Salinity stress not only threatens world agriculture, but also jeopardizes food security of Bangladesh (Islam *et al.*, 2016). The sustainable livelihoods of millions of people of Bangladesh hinge on agriculture, which acts as a mainstay of the economy, are severely afflicted by salinity stress (Abdullah and Rahman, 2015; Haque and Haque, 2016; Islam *et al.*, 2016). In Bangladesh, more than 30 % of the net arable land lies in the coastal regions of Bay of Bengal, among them 53 % is already damaged by salinity (Petersen and Shireen, 2001; Haque, 2006; SRDI, 2010). The salinity affected area in Bangladesh has been gradually expanding adding on an average 400 ha of cultivated land annually as a result of climate change impact. While southern coastal areas of Bangladesh are being affected by increasing trend of salinity, rice is still widely grown in the area. Because of its sensitivity to salinity stress, yield of rice in the southern coastal area of the country is seriously affected. Although Bangladesh Rice Research Institute (BRRI) and Bangladesh Institute of Nuclear Agriculture (BINA) have developed some salinity tolerant rice cultivars like BRRI dhan47, Binadhan-8 and Binadhan-10 under the increasing intensity of salinity stress in the coastal area of the country, development of rice varieties with higher tolerance to salinity is very urgent. For developing salinity tolerant rice varieties it is necessary to recognize natural salinity tolerant rice species and cultivars and to understand how they are able to adapt to salinity stress.

Drought is another disastrous stress in crop production in all over the world including Bangladesh. It is an alarming global problem and one of the major constraints that severely limits the sustainable production of agricultural crops including rice. Worldwide, drought affects approximately 23 M ha of rainfed rice (Serraj *et al.*, 2011). Nearly 34 M ha of rain-fed lowland and 8 M ha of upland rice in Asia suffers from drought stress of varying intensities almost every year (Quampah *et al.*, 2011; Zain *et al.*, 2014; Singh *et al.*, 2016a, b).

In Bangladesh, about 20% area is affected by drought including drought prone Barind area causing a significant loss of crop production including rice. When rice plant is

subjected to drought, it is affected in various morpho-physiological and biochemical processes viz. photosynthesis, transpiration rate, turgor, respiration, stomatal closure, gas exchange, translocation, ion uptake, carbohydrates, nutrient metabolism and growth promoters, chlorophyll content in leaves, pigment degradation, stomatal conductance, relative water content (RWC), water use efficiency (WUE), reducing tiller number, leaf area and alter assimilate partitioning among the plant organs resulting in decrease of plant growth and grain yield (Zain *et al.*, 2014 and Zu *et al.*, 2017).

Rice is one of the most drought susceptible crops, especially at the reproductive stage (Agarwal *et al.*, 2016). In rice plant at early vegetative growth and flowering, if plants are unable to receive sufficient water, it drastically inhibits floret initiation, plant height, tiller number, leaf area, grain filling and ultimately low grain production (Zhang *et al.*, 2018; Yang, *et al.*, 2019). Drought stress also promotes the remobilization of stored carbon reserves and water deficit during grain-filling enhancing plant senescence and accelerated grain-filling. Plants have developed numerous mechanisms to overcome water scarcity in drought condition, including morphological, physiological, biochemical levels (Fang and Xiong, 2015). Different procedures permit plants to persist and even reproduce with a scanty water supply, viz., the up gradation of water uptake by deep, dense root systems, the minimization of water loss by stomatal closure and a reduction in leaf area, osmotic adjustment (OA) or changes in cell wall elasticity as well as other essential processes for sustaining physiological activities (Saha *et al.*, 2016a).

OA is a prime technique to maintain turgor pressure under drought stress condition for tolerant crop plant. Under this mechanism plant maintain osmotic potential (OP) inside the cells to be lower than outside the cells, thus preventing water loss and allowing plants to recommence their turgid pressure. Assembling of organic substances and inorganic ions such as sucrose, glucose, amino acids, proline and potassium ions by plants advocate to water stress is believed to be a mechanism participating in OA which could promote drought stress tolerance in plants (Szabadoz and Savoure, 2009 and Zivcak *et al.*, 2016). It has been well documented that drought tolerant plants had higher efficiency in protection of plant cells from ROS via producing antioxidant enzymes and non-enzymatic antioxidants (Farooq *et al.*, 2012).

Relative water content (RWC) is an important trait on which plant productivity depends. So for better growth and development of crop plant higher RWC and better OA is prime requisite under drought stress condition (Araus *et al.*, 2002). Pigments (chlorophyll and carotenoids) also play a key role in supporting plants to withstand adversaries of drought. Chlorophyll is an important component of photosynthetic apparatus absorbs light and transfers the light energy to the reaction centre of the photosystem, increase the photosynthetic rate and finally there are up gradation of dry matter production and grain yield.

Roots are essential organs for exploiting soil resources, such as water and mineral nutrients. The deeper, thicker and more branched root system with a high root to shoot ratio can enhance the tolerance of rice to water deficits higher root-to-shoot ratio, elasticity in leaf rolling, early stomatal closure and cuticular resistance are reported as component traits of drought avoidance (Gowda *et al.*, 2011; Henry *et al.*, 2011). The increase in length and thickness of root in rice is correlated with drought tolerance and grain yield (Jeong *et al.*, 2010). Variability in the root thickness, root depth, and root mass among the rice cultivars was observed under drought stress (Gowda *et al.*, 2011 and Henry *et al.*, 2011). The genus of rice is composed of two cultivated species, hence called cultivated rice (*Oryza. sativa* and *O. glaberrima*) and 22 wild species, hence called wild rice (Sanchez *et al.*, 2014). During the process of domestication, cultivated species of rice *O. sativa* and *O. glaberrima* have been selected for acquiring and partitioning resources efficiently. During the course of domestication from wild rice to cultivated rice, profound changes of agronomic traits and genetic diversity occurred, and the number of alleles of cultivated rice was only 60% that of wild rice, suggesting that many alleles of wild rice were lost during the course of domestication. Therefore, as compared to the wild *Oryza* species, genetic diversity in these cultivated species is limited (Atwell *et al.*, 2014). In contrast, the wild species are untapped reservoir of genetic diversity and they exhibit tremendous variation in morphological traits, height, tillering, flowering, growth habit, panicle, leaf, culm, and seed characteristics. There are several desirable alleles in these wild species which can be used in the crop improvement programs to cope up with the changing climate (Sengupta, 2014 and Singh *et al.*, 2016 a,b). Wild rice germplasm is considered a valuable source of genes for tolerance to biotic and abiotic stresses, which can be potentially used in rice breeding (Mishra *et al.*, 2016 and Menguer *et al.*, 2017). In a



study Prusty *et al.* (2018) identified three wild species of rice (*O. alta*, *O. latifolia*, and *P. coarctata*) as most salinity tolerant species. Based on the 2 years' data, seven accessions from *Oryza rufipogon*, four from *Oryza longistaminata* and one each from *Oryza officinalis* and *Oryza latifolia* were found tolerant to drought stress (Neelam *et al.*, 2017). Various research findings indicated the potentiality of selected wild species germplasm for conferring salinity and drought tolerance to the elite cultivars. These desirable traits of wild species of rice conferring tolerance to biotic and abiotic stresses are of significant importance that can be used to improve the cultivated rice varieties with multiple resistances.

By 2050, the world's population is predicted to reach 9.6 billion and food production needs to be increased approximately 70% by 2050 or 44 M MT annually to provide sufficient food for this population (UNPF, 2016). This is a challenge because there is a very little potential for future expansion of arable lands, whereas environmental stresses (salinity and drought) affecting crop production are increasing (Tester and Langridge, 2010 and Cominelli *et al.*, 2013). So, increasing of stress tolerant (salinity and drought) variety of rice is time demanding issue in the world as well as in Bangladesh. As salinity and drought problems are increasing, great effort has been devoted to understand the physiological aspects of tolerance to salinity and drought in plants, as a basis for plant breeders to develop salinity tolerant genotypes. Thus, it is urgent for the researchers and policy makers to search alternative techniques for better utilization of stress-prone areas, like screening of salt and drought tolerant species and cultivars might be the best approach to continue rice production in the stress prone area and also to bring stress prone areas under cultivation, which is very vital to ensure the country's food security. With the limited variability in cultivated germplasms of rice, it is impossible to reach the target level of production. So in this situation, the role of wild species of rice, the treasure of variability, is inevitable. With the advances in breeding techniques, the scope for utilization of wild species in genetic enhancement of rice seems more promising than before. At least more than 10 wild species of rice have been identified in Bangladesh which is available in Bangladesh Rice Research Institute, Bangladesh Agricultural University and Bangladesh Institute of Nuclear Agriculture. Morphological and physiological characterization of these wild species is very vital to use them for the improvement of cultivated rice. The screening of cultivars using salt and drought tolerance indices

may help assist in the evaluation of relative field performance of different rice genotypes. The proposed study has been undertaken to characterize the morphological and physiological behavior of the wild species along with their desirable traits conferring tolerance to abiotic stresses such as salinity and drought.

### **Objectives of the research**

- i) To characterize the morpho-physiological attributes of the collected accessions of the wild species of rice
- ii) To screen salinity and drought tolerant wild species of rice from the collected accessions
- iii) To identify the traits in the wild rice accessions conferring salinity and drought tolerance and
- iv) To conduct allelic diversity analysis of wild rice genotypes for salinity tolerance.

## CHAPTER II

### REVIEW OF LITERATURE

The present pieces of work ‘morpho-physiological characterization of wild relatives of rice conferring tolerance to salinity and drought’ have been carried out at Agronomy Research Field-1, Hajee Mohammad Danesh Science and Technology University, Dinajpur. Experimental outcomes have been reviewed and perceived that the wild rice varieties respond differently under salinity and drought stress. Some of the research works relevant to the present investigations have been discussed in this chapter under the following heads.

#### 2.1 Morphology of the wild rice species

Wild *Oryza* species are a prime reservoir of genetic diversity for the improvement of one the world’s most important food crops. The genus is composed of two domesticated species, *Oryza sativa* and *Oryza glaberrima*, and 22 wild species (Table 2.1) that represent between 15 and 25 million years of evolutionary diversification (Vaughan, 1994). Given these processes, just two of the 24 extant *Oryza* species have become agronomically productive commonly known as ‘Asian rice’ *Oryza sativa*, that is high yielding and cultivated worldwide and ‘African rice’ *Oryza glaberrima*, that is low yielding and grown in limited areas in West Africa (Vaughan *et al.*, 2003, Linares, 2002 and Vaughan, 1994,).

The genus *Oryza* can be grouped into four species complexes: (1) the primary gene pool, the *O. sativa* complex; (2) the *O. officinalis* complex; (3) the *O. ridleyi* complex; and (4) the *O. meyeriana* complex. The *O. sativa* complex comprises eight diploid species with AA genomes that encompasses two cultivated (*O. sativa* and *O. glaberrima*) and six wild rice species (*O. nivara*, *O. rufipogon*, *O. breviligulata*, *O. longistaminata*, *O. meridionalis*, and *O. glumaepatula*). These species are commonly used by breeders for the development of new rice variety. The most widely used ancestral wild rice, *O. rufipogon*, is found in regions of South Asia, Southeast Asia and Northern Australia, and has both annual and perennial types. Perennial *O. rufipogon* subtypes are found in deep swamps, while the annual subtypes are found in shallower, temporary swamps which are parched in the dry season (Morishima *et al.*, 1984). *O. nivara* is an annual grass within the *O. sativa* complex that is distributed in

India, Nepal, Cambodia, Laos, and Thailand. *Oryza longistaminata*, a perennial plant that is widely distributed in Africa, is closely related to its annual relative, *O. barthii* (Akimoto *et al.*, 1998). These two species are closely related to *O. glaberrima*, which is mainly distributed in Western Africa in upland, rain-fed and deep-water fields (Wang *et al.*, 2014 and Linares, 2002). *Oryza glaberrima* can be easily distinguished from *O. sativa* due to its short, rounded ligule and no secondary panicle branching (Vaughan *et al.*, 2003). *Oryza glaberrima* is tolerant to different biotic and abiotic stresses, but its yield is not high (Futakuchi *et al.*, 2012).

The *O. officinalis* complex comprises six diploid species (*O. punctata*, *O. minuta*, *O. officinalis*, *O. eichingeri*, *O. rhizomatis*, *O. australiensis*) and six allotetraploid species (*O. punctata*, *O. minuta*, *O. officinalis*, *O. latifolia*, *O. alta*, and *O. grandiglumis*) (Brar and Khush, 2018). This complex is distributed in Asia, Africa, and Latin America. In Asia, the most common species are *O. minuta* and *O. officinalis* (Vaughan, 1989); *O. punctata* (BB, annual, BBCC perennial) and *O. eichingeri* (CC) are mainly found in Africa (Vaughan *et al.*, 2003). The three allotetraploids, *O. latifolia*, *O. alta*, and *O. grandiglumis* (CCDD), are found in Latin America. *Oryza latifolia* is widely distributed in Central and South America, the Caribbean islands and the Amazon basin of South America (Bao and Ge, 2004). *Oryza australiensis* (EE) is commonly found in northern parts of Australia and survives as both rhizomes and seeds. This species has the largest genome in the genus, *Oryza*, due to a retrotransposon (Piegu *et al.*, 2006). The *O. ridleyi* complex comprises two tetraploid (HHJJ genomes) species, *O. ridleyi* and *O. longiglumis*, that are commonly found in Asia and have highly similar morphological and ecological characteristics. The *O. meyeriana* complex is composed of two species, *O. meyeriana* and *O. granulata*, both with diploid GG genomes. Compared to species in the other complexes, these plants are small with unbranched panicles and small spikelets. They thrive in shady or partial shady forest understory and cannot survive flooding (Vaughan *et al.*, 2003). Two of the 24 species are yet to be classified among the complexes: *O. schleteri* (HHKK), which is distributed in regions of Indonesia and Papua New Guinea; and *O. coarctata* (KKLL), which is commonly found in coastal areas of South Asia (Vaughan *et al.*, 2003).

**Table 2.1 The distribution and genomic classification of rice species throughout the world**

| Oryza species                        | Genome type | Number of chromosomes | Distribution                            |
|--------------------------------------|-------------|-----------------------|-----------------------------------------|
| <b><i>Oryza sativa</i> complex</b>   |             |                       |                                         |
| <i>O. sativa</i>                     | AA          | 24                    | Asia                                    |
| <i>O. glaberrima</i>                 | AA          | 24                    | Africa                                  |
| <i>O. breviligulata</i>              | AA          | 24                    | Africa                                  |
| <i>O. longistaminata</i>             | AA          | 24                    | Africa                                  |
| <i>O. glumaepatula</i>               | AA          | 24                    | Central or South America                |
| <i>O. meridionalis</i>               | AA          | 24                    | Oceania                                 |
| <i>O. nivara</i>                     | AA          | 24                    | Asia                                    |
| <i>O. rufipogon</i>                  | AA          | 24                    | Central or South America, Asia, Oceania |
| <b><i>O. officinalis</i> complex</b> |             |                       |                                         |
| <i>O. punctata</i>                   | BB          | 24                    | Africa                                  |
|                                      | BBCC        | 48                    |                                         |
| <i>O. malampuzhaensis</i>            | BBCC        | 48                    | Asia                                    |
| <i>O. minuta</i>                     | BBCC        | 48                    | Asia and Oceania                        |
| <i>O. eichingeri</i>                 | CC          | 24                    | Africa and Asia                         |
| <i>O. officinalis</i>                | CC          | 24                    | Asia and Oceania                        |
| <i>O. rhizomatis</i>                 | CC          | 24                    | Asia                                    |
| <i>O. alta</i>                       | CCDD        | 48                    | Central or South America                |
| <i>O. grandiglumis</i>               | CCDD        | 48                    | Central or South America                |
| <i>O. latifolia</i>                  | CCDD        | 48                    | Central or South America                |
| <i>O. australiensis</i>              | EE          | 24                    | Oceania                                 |
| <i>O. brachyantha</i>                | FF          | 24                    | Africa                                  |
| <b><i>O. ridleyi</i> complex</b>     |             |                       |                                         |
| <i>O. longiglumis</i>                | HHJJ        | 48                    | Oceania                                 |
| <i>O. ridleyi</i>                    | HHJJ        | 48                    | Asia and Oceania                        |
| <b><i>O. meyeriana</i> complex</b>   |             |                       |                                         |
| <i>O. granulate</i>                  | GG          | 24                    | Asia                                    |
| <i>O. meyeriana</i>                  | GG          | 24                    | Asia                                    |

Source: (Vaughan *et al.*, 2003)

### **i. *Oryza punctata***

*O. punctata* is locally quite important in some African countries but probably has a limited capacity to become invasive. It is listed as a noxious weed in the USA, *O. punctata* is distinguished from *O. longistaminata*, the commonest of the weedy rice in Africa, by the absence of rhizomes. It is an annual, grass / sedge, propagated by seed or vegetative plant parts. *O. punctata* grows in wet ground alongside streams and ponds from sea level to 1200 m (Ivens, 1989). At least some populations show some salt tolerance (Farooq *et al.*, 1996), although Farooq *et al.* (1992) indicate much variability for salt tolerance in wild rice. *O. punctata* is used as food in times of famine in western Sudan (Salih and Nour, 1992). Wild relatives of cultivated rice may be a useful source of genes for broadening the gene pool of cultivated rice (Khan *et al.*, 1989). *O. punctata* is an erect or spreading, robust annual grass, tufted, rarely stoloniferous and rarely geniculate. Plants are up to 130 cm tall, glabrous, smooth, usually over 4 mm in diameter at the base and have up to 8 nodes. The difference between two inter node distance of the upper portion is longer than the lower portion, about 85 cm. Maximum 8 leaves, leaf length 187.7 mm, leaf width 17.05 mm and ratio 12.59 and in flag leaf, leaf length 172.42 mm, leaf width 16.88 mm and ratio 10.16. Leaf angle 25-30. Leaf sheaths are pale-green to brownish, glabrous, with 15 mm long auricles at the junction with the blade. Bright to dark-green leaf blades are 10-75 cm long, 10-30 mm wide are broadest below the middle, triangulate, rough along the margins, glabrous with an indistinct mid-rib. The triangular, membranous ligule is less than 10 mm long. Root is fibrous with 23 cm length, often with rhizomes. *O. punctata* is a photosensitive species. It needs 215 days for 1<sup>st</sup> flowering after seed germination. Its inflorescence is a loose panicle 30 cm long which is composed of a few spreading branches, themselves up to 20 cm long. Panicle is erect or slightly dropping with a tuft of hairs at the base of branches, having narrowly oblong, one-flowered spikelets up to 6.2 mm long, laterally compressed, always hairy and always pedicelled. Spikelets disarticulated above the glumes. Pedicels 7-15 mm long and shed when mature. Glumes are only rudimentary. Sterile lemmas are 2-3.8 mm long, glabrous and smooth. Fertile lemmas are slightly shorter than the spikelet, with six stamens, a blackish stigma and have a 2.4 cm long awn. The filled grains are more than the sterile grain in a spikelet which are normally 115 and 60. The seeds are small, less than 5 mm long. *O. punctata* plant produced 62 tillers, 35 panicles and

thousand grain weight 8.85 g. Growth duration of *O. punctata* is about 250 days (seed germination to maturity stage). It is resistance to insect and pathogen attack (Khan *et al.*, 1989), bacterial leaf blight (*Xanthomonas oryzae*pv. *oryzae*) (Kaushal and Sidhu, 1998), Rice tungro spherical virus, Rice yellow mottle virus (Coloquio *et al.*, 1998 and Abo *et al.*, 1998), brown plant hopper (*Nilaparvata lugens*) (Velusamy, 1988), *Hydrellia philippina* (Heinrichs *et al.*, 1985) and resistance to the white backed planthopper (Velusamy, 1989).

## **ii. *Oryza rufipogon***

*O. rufipogon* is considered to be a progenitor of *O. sativa*, and together with *O. longistaminata* and *O. sativa* forms the *O. sativa* complex.(Takeoka, 1962). A native of Asia *O. rufipogon* is widely distributed in the tropics and subtropics except Africa (Takeoka, 1963). According to Hall (1990), *O. rufipogon*, which occur in Florida, *O. rufipogon* is a perennial, tufted wild rice. It grows in shallow water, irrigated fields, pools, ditches and sites with stagnant or slow, running water. It occurs at altitudes from 0 to 1000 m. *O. rufipogon* is resistance to stem rot disease (Tseng and Oster, 1994), rice tungro viruses (Angeles *et al.*, 1998) and submergence tolerance. It is also resistant to rice blast (Reimers *et al.*, 1993), white leaf virus (Martinez *et al.*, 1998) and bacterial leaf blight (Sun *et al.*, 1992; Kaushal *et al.*, 1998). *O. rufipogon* is an erect, perennial tufted grass, 170-180 cm tall; with culms spongy below, the lower parts floating and rooting at the nodes, the upper parts sub-erect, have up to 10 nodes. Culm and nodes are glabrous and hollow. Maximum 11 leaves, leaf length 267.56 mm, leaf width 12.15 mm and ratio 23.20 and in case of flag leaf: leaf length 162.31 mm, leaf width 11.84 mm and ratio 14.04. Its leaf angle is 25-30, leaf blades linear, 15-18 cm long, and 10-25 mm wide, leaf sheaths loose, cylindrical, glabrous with distinct auricles at the junction with the blade. Auricles 1-7 mm long, narrow, curved, glabrous with long hairs to 2 mm long. Ligule, triangular, an unfringed membrane up to 17 mm long, divided into acute points. Root fibrous, 27 cm long, often with rhizomes. It is a photosensitive species. It requires 235 days to 1<sup>st</sup> flowering after seed germination. Inflorescence is terminal and panicle well exerted, up to 30.20 cm long, initially concealed in the spathe-like sheath of the upper leaf, ultimately nodding; the main axis is long and slender, laterally compressed, flexuous; branches angular, rough on the angles. *O. rufipogon* has many bisexual spikelets, always awned, one flowered; lower glume lanceolate, upper glume similar to lower but

narrower, 2.4 mm long, lemma 7 mm long, boat-shaped, oblong, rounded, 3-nerved. Lemma and palea green to yellowish, often dark red at apex, covered with stiff transparent hairs. It has six stamens, anthers 5 mm long, linear, yellow or brown, two styles, free, two stigmas, plumose, laterally exerted from the spikelets. Number of filled grain panicle<sup>-1</sup> is 105 and sterile grain panicle<sup>-1</sup> 50. Caryopsis is narrow, red-brown, enclosed by a stiff lemma and palea. *O. rufipogon* plant produce 107 tillers, 82 panicles and thousand grain weight 24.26 g. Growth duration of *O. rufipogon* is about 265 days (seed germination to maturity stage). ). It is tolerant to flood and acid soils. *O. rufipogon* has a valuable gene pool that can be used to broaden the genetic background of cultivated rice in breeding program. Introgression of certain genes from *O. rufipogon* may contribute to yield increase in improved rice cultivars (Martinez *et al.*, 1998). In deepwater rice fields in Khulna, Bangladesh, an annual weed type of wild rice 'Jhora-dan' is one of the major weeds. It is sometimes used as food. It is also eaten in times of drought or famine (Baksha *et al.*, 1979).

### **iii. *Oryza alta***

It is closely related to other two species of the *Officinalis* complex, namely *O. latifolia* and *O. grandiglumis* (Gireesh, 2018). It is widely distributed in South American regions and grows along the river basins, canals in open and sunny areas. Found mainly in savanna and sometimes in woodland (Vaughan, 1994). Grows in wet places such as along streams, rivers, lake edges, or canals in deep water and may form floating mats. Usually grows in open, sunny locations. Altitude: sea level to 120 m. *Oryza alta* is an annual, perennial plant with short rhizomes. It is an erect, robust annual grass, tufted, rarely stoloniferous and rarely geniculate. Plants are up to 182 cm tall, smooth, usually over 4 mm in diameter at the base and have up to 4 nodes and spongy with adventitious root developing from lower nodes. Maximum 7 leaves, broad type, leaf length 210.68 mm, leaf width 21.66 mm and ratio 9.64 and in case of flag leaf: leaf length 143.56 mm, leaf width 37.32 mm and ratio 4.13, leaf angle 25-30. Leaf sheaths are pale-green to brownish, glabrous, with 15-mm-long auricles at the junction with the blade. Root fibrous, root length 50 cm, with short rhizomes. *O. alta* is photo insensitive species requires 110 days for 1<sup>st</sup> flowering after seed germination. Inflorescence is loose panicle 41 cm long which is composed of a few spreading branches, themselves up to 20 cm long. Panicle is erect or slightly dropping with a tuft of hairs at the base of branches. It has narrowly oblong, one-flowered



spikelets up to 7-8 mm long and 2.4-3 mm laterally compressed, always hairy and always pedicelled. Spikelets disarticulated above the glumes. Pedicels 7-15 mm long and shed when mature and anthers 2-3.8 mm long. Glumes are only rudimentary. Sterile lemmas are 2-3.8 mm long, glabrous and smooth. Fertile lemmas are slightly shorter than the spikelet, stiffly hispid, with 6 stamens, a bluish stigma and awns 2.6-7.5 cm, usually pink or purplish when fresh. The number of filled grain panicle<sup>-1</sup> is 120 and sterile grain 195 (max). The seeds are 7.5-8.5 mm long, oblong, glabrous, light-brown. It produces 64 tillers, 22 panicles and thousand grain weight 8.32 g. Its growth duration is about 140 days (seed germination to maturity stage). They are a source of resistance to or tolerance of biotic and abiotic stresses, the most important use of the various species of wild rice is probably in breeding program to improve the species of cultivated rice (Vaughan, 1994).

#### **iv. *Oryza nivara***

*Oryza nivara* is the closest annual wild progenitor of *O. sativa* subspecies *indica* distributed in South and Southeast Asia (Harithaet *al.*, 2018). The accessions of *O. nivara* are well known to contribute genes for resistance to biotic stresses; grassy stunt virus, bacterial leaf blight, sheath blight, neck blast, brown plant hopper and tolerance to abiotic stresses; drought, salinity and heat for rice improvement. Its distribution includes Bangladesh, Cambodia, China, India, Laos, Malaysia, Myanmar, Nepal, Sri Lanka, Thailand, and Vietnam. Recently, the genome of *O. nivara* was sequenced (Zhanget *al.*, 2014). *O. nivara* is found growing in swampy areas, at edge of pond and tanks, beside streams, in ditches, in or around rice fields. It grows in shallow water up to 0.3 m and seasonally dry and open habitats. The grains are often cooked with herbs to make a medicinal gruel. Resistance to biotic stresses: grassy stunt virus, bacterial leaf blight, sheath blight, neck blast, brown plant hopper and tolerance to abiotic stresses: drought, salinity and heat for rice improvement. (De, 2021). *Oryza nivara* is an erect, usually annual grass though, not stoloniferous. It is short to intermediate height grass plant, culm semi-erect to decumbent up to 138.8 cm tall, smooth and has up to six nodes. Average leaf 9, leaf length 116.61 mm, leaf width 14.66 mm and ratio 24.59 and in flag leaf, leaf length 164.23 mm, leaf width 11.76 mm and ratio 12.14. Leaf angle 30-35. Leaf sheaths are pale-green to brownish, glabrous, long auricles at the junction with the blade. Bright to dark-green leaf blades are 10-75 cm long, 10-30 mm wide are broadest below the middle, triangulate, rough

along the margins, glabrous with an indistinct mid-rib. Ligule is 14-45 mm long, triangular, membranous. Root fibrous, root length 18.5 cm. It is photosensitive species and requires 230 days to reach 1<sup>st</sup> flowering after seed germination. Panicle length 22.6 cm, panicle less branched than in *O. sativa*; panicles usually compact, rarely open. It has large spikelets with 6-10.4 mm long and 1.9-3.4 mm wide. Fertile lemma with thick, with strong awn (4-10 cm long); anthers 1.5-3 mm long and has number of filled grain panicle<sup>-1</sup> 61 and sterile grain 4. Caryopsis is deciduous at maturity and with strong seed dormancy. It produces 135 tillers, 85 panicles and thousand grain weight 26.64 g and having growth duration is about 265 days (seed germination to maturity stage).

#### **v. *Oryza longistaminata***

*Oryza longistaminata*, a wild species of rice originated in middle Africa, develops rhizomes and proliferates vigorously. *Oryza longistaminata*, containing the AA genome, which is the same as that of *Oryza sativa*, can be crossed with *O. sativa* and set fertile seeds, controlling rhizome development in grass species. *O. longistaminata* occurs in swamp and floodplain grasslands, generally growing in shallow water, but also found along edges of rivers, dams or on river banks. It can be found from sea-level to a height of 1400 m (Clayton, 1970). Both *O. longistaminata* and *O. barthii* evolved in West Africa (Khush, 1997) and are restricted to the African continent. *O. longistaminata* is sometimes used to supplement cultivated rice as a food grain in the Niger Valley of Mali (Nyoka, 1983). As it is a member of the primary gene pool, sharing the AA genome with *O. sativa*, the transfer of useful traits, including resistance genes, from *O. longistaminata* to the crop can be accomplished through conventional hybridization and selection procedures (Khush, 1997). Accessions of the species with immunity to rice yellow mottle sobemo virus, resistance to bacterial blight (*Xanthomonas oryzae* pv. *oryzae*) and rice blast (*Magnaporthe grisea*) have been described and have potential for use as parents in breeding program (Vales, 1985; Thottapilly and Rossel, 1993; Zhang *et al.*, 1994). *O. longistaminata* is an erect, robust perennial grass with extensive creeping, branched rhizomes. Glabrous, smooth culms are up to 130 cm tall, up to 2.5 cm diameter at the base, have up to 7 nodes, are erect and spongy with adventitious roots developing from lower nodes. The difference between two inter node distance of the upper portion is longer than the lower portion, about 75 cm. Maximum 8 leaves, leaf length 267.73 mm, leaf width 17

mm and ratio 15.91 and in flag leaf, leaf length 145.91 mm, leaf width 25.86 mm and ratio 5.71. Leaf angle 30-35. Leaf sheaths are pale-green to brownish, glabrous, nearly as long as the internodes, with 15 mm long auricles at the junction with the blade. The triangular ligule is often split down the middle, 0.8-5.5 cm long with an acute tip. Leaf blades are bright to dark green, 10-75 cm long, 0.5-2.5 cm wide. Root fibrous, root length 32.8 cm, develops rhizomes underground and exhibits a typical rice growth pattern at ground level. It is a photosensitive species. 1<sup>st</sup> flowering is in 215 days after seed germination. The panicle is 40 cm (max) long, erect or slightly drooping with a tuft of hairs at the base of branches. Narrowly oblong spikelets, with 0.5-4 mm long pedicels, are 7-15 mm long, scabrid to hispid and shed when mature. 12-15 spikelets are present in a panicle. Glumes are reduced to a narrow membranous rim. Sterile lemmas are 2-3.8 mm long, glabrous and smooth. Fertile lemmas are slightly shorter than the spikelet, stiffly hispid, with 6 stamens, a blackish stigma and awns 2.6-7.5 cm, usually pink or purplish when fresh. The filled grains are more than the sterile grain in a spikelet. It is normally 171 and 151, respectively. It produces 49 tillers, 29 panicles and thousand grainweight 8.94 g. Growth duration of *O. longistaminata* is about 250 days (seed germination to maturity stage).

#### **vi. *Oryza officinalis***

*O. officinalis* complex consists of diploid and tetraploid species found throughout the tropics. All the species in this complex are perennials found in seasonal wetlands. Australia, Bangladesh; Brunei, Cambodia, China, India, Indonesia, Laos, Malaysia, Myanmar, Nepal, Papua New Guinea, Philippines, Thailand, and Vietnam. The red pericarp present in nearly all wild species is favored by ethnic tribes and some urban people as having nutritional increments or is used for decorative purpose during festivities. On the other hand, it was found in commercial lots, the red seed-coat carried by primitive cultivars lowers the grade of milled rice. *Oryza officinalis* is a clump-forming, perennial grass, tufted, culms are up to 124.6 cm long, up to 2.5 cm diameter at the base, have up to 8 nodes. The difference between two inter node distance of the upper portion is longer than the lower portion, about 70 cm. Maximum 9 leaves, leaf length 36.03 cm, leaf width 22.4 mm and ratio 16.03 and in flag leaf, leaf length 18.04 cm, leaf width 18.69 mm and ratio 9.54. Leaf angle 30-32. Leaf sheaths are pale-green to brownish, tight, with 15 mm long auricles at the junction with the blade. Ligule is collar-shaped to triangular, 1-8 mm long and 2-5

mm wide, glabrous or hairy and nodes glabrous. Leaf blade is linear, 15-80 cm long, 1-2 cm wide, glabrous or hairy. Root fibrous, root length 23 cm, some are rhizomatous and others form runners. It is a light photosensitive species. 1<sup>st</sup> flowering is in 205 days after seed germination. Panicles open, panicle up to 32.8 cm long, whorled at base, spikelet 4-6.4 mm long, wider than 2 mm, anthers around 1.5-4.5 mm long and 5-6 spikelets are present in a panicle. Sterile lemmas are 3.4 mm long, glabrous and smooth. It has fertile lemma without or with up to 1.0 cm long awn. The filled grains are less than the sterile grain in a spikelet. It is normally 96 and 131, respectively. Caryopsis is 2.3-4.4 mm long and 1.3-2.3 mm wide and orange-brown. It produces 62 tillers, 24 panicles and thousand grain weight 8.21 g which having growth duration of about 235 days (seed germination to maturity stage). *Oryza officinalis* is resistant to yellow stem borers, tungro virus and several plant hoppers (Tropical plant database, 2023).. Because they are a source of resistance to or tolerance of biotic and abiotic stresses, the most important use of the various species of wild rice is probably in breeding program to improve the species of cultivated rice (Vaughan, 1994)..

#### **vii. *Oryza barthii***

*O. barthii* is a plant of wetlands and a natural weed of lowland rice. *O. barthii* is an African species, not reliably known to occur elsewhere. There are some records from Japan, samples of *O. breviligulata* maintained in the National Institute of Genetics in Shizuoka Province and it seems likely that these samples were in cultivation only (GBIF, 2013). *O. barthii* grows in stagnant water, slowly flowing water or pools, shallow ponds, seasonally flooded land, rice fields and similar habitats, often forming pure dominant stands but usually scattered with other aquatic grasses, up to 1500 m altitude. It is also found in mopane or savanna woodland, savanna or fadama (Knowledge bank, 2013). *O. barthii* can be an important component of natural pastures, as reported by Kulich and Kaluba (1985) from Zambia, and as such has a positive economic impact. *O. barthii* has potential as a source of useful genes for transfer to cultivated *O. sativa* or *O. glaberrima*. Harlan (1989) recorded that *O. barthii* is used as famine food in some parts of Africa. *O. barthii* provides a food source for waterbuck in Benin (Kassa *et al.*, 2008) and for Kafue lechwe antelope in Zambia (Rees, 1978). The plant is related to the cultivated African rice (*Oryza glaberrima*) and can be used in breeding program with both that species and the Asian

rice (*Oryza sativa*). It has potential as a source of resistance to blast (*Pyricularia grisea*) (Eizenga *et al.*, 2004), sheath blight (*Rhizocytionia solani*) (Prasad and Eizenga, 2008), bacterial leaf blight (*Xanthomonas oryzae*) (Kaushal and Ravi, 1998), the nematode *Heterodera sacchari/schactii* (Reversat and Destombes, 1998), stem borer attack (Africa Rice, 2013) and rice tungro virus (Jain *et al.*, 1989). *O. barthii* is generally behaves as an annual aquatic grass growing ,occasionally perennial,Culms are maximum 130.8 cm tall, 4-8-noded, rather weak, erect or geniculately ascending, producing aerial roots from the lower nodes. The difference between two inter node distance of the upper portion is longer than the lower portion.Maximum 10 leaves , leaf length 184.95 mm, leaf width 12.19 mm and ratio 14.28 and in flag leaf, leaf length 118.17 mm, leaf width 6.73 mm and ratio 7.09. Leaf angle 25-30. Leaf-sheath smooth, glabrous, produced into short auricles at the mouth.Ligule is 3-6 mm long, thinly membranous, truncate, or rounded.Leaf-laminae is linear to very narrowly elliptic. Root fibrous, root length 23 cm (max.) *O. barthii* is photosensitive species. It requires 215 days to reach 1<sup>st</sup> flowering stage after seed germination. Panicle 29.2 cm (max.) long, erect or more rarely somewhat nodding; rhachis stout, angular, sulcate, glabrous, smooth, branches usually erect or obliquely ascending, angular, scaberulous. Pedicels are 1-6 mm long, stout, striate, scaberulous or smooth, glabrous. Glumes reduced to a tiny 2-lobed rim, remaining at the pedicel. Spikelets 8-10.5 mm long (excluding the awn), up to 3.4 mm wide, deciduous, obliquely inserted on the pedicel, pale green to straw colored. 5-6 spikelets are present in a panicle. Awn 6.5- 7 cm long, stiff, salmon-pink to purplish when fresh.Palea is about as long as the lemma but much narrower, similar in texture and indument, with the apex drawn out in a short blunt purplish point. The number of filled grain panicle<sup>-1</sup> 40 and sterile grain is 10.The seeds are large and 1.0 cm long.It produces 62 tillers, 55 panicles and thousand grain weight 33.75 g. It has about is 250 days life cycle (seed germination to maturity stage).

#### **viii. *Oryza latifolia***

This species is closely related to *O. alta* and *O. grandiglumis*. *O. latifolia* is a tetraploid wild *Oryza* species with a CCDD genome that has been reported to harbor resistance to bacterial blight (BB), brown plant hopper, and white backed plant hopper. Aside from these traits, *O. latifolia* is also being tapped as a new source of resistance to lodging and high biomass production. It is found in Argentina, Belize,

Bolivia, Brazil, Colombia, Cuba, Dominican Republic, Ecuador, El Salvador, French Guiana, Guatemala, Guyana, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Surinam, Trinidad and Venezuela. To explore the genetic potential of *O. latifolia* as a novel genetic resource for the improvement of existing *O. sativa* cultivars, 27 disomic derivatives of *O. latifolia* monosomic alien addition lines (MAAL) were characterized for alien chromosome segment introgressions and evaluated for yield components, BB resistance, and strong stem characteristics. The species is a secondary genetic relative of cultivated rice and African rice. *O. latifolia* is a clump-forming perennial grass. Erect culms/plants are up to 197.8 cm tall, usually over 4 mm in diameter at the base and have up to seven nodes. The difference between two inter node distance of the upper portion is longer than the lower portion. It has long broad leaves, average leaf no. 7, leaf length 563.70 mm, leaf width 30.8 mm and ratio 18.18 and in flag leaf, leaf length 472.97 mm, leaf width 30.66 mm and ratio 11.38. Leaf angle 15-20. Leaf sheaths are pale-green to brownish, glabrous, with 15 mm long auricles at the junction with the blade. Root fibrous, root length 50 cm. *O. latifolia* is a photo insensitive species. 1<sup>st</sup> flowering is in 110 days after seed germination. Inflorescence is a loose panicle 50 cm long which is composed of a few spreading branches, themselves up to 20 cm long. Panicle is erect or slightly dropping with a tuft of hairs at the base of branches, open. 16-17 spikelets are present in a panicle. Spikelets are 5-9.5 mm long and 2-2.7 mm wide; anthers 1.5-5.1 mm long, having a 4.5 cm long awn. The filled grains are less than the sterile grain in a spikelet. It is normally 44 and 310, respectively. The seeds are medium, 5 mm long. *O. latifolia* plant produced 30 tillers, 19 panicles and thousand grain weight 11.38 g. Growth duration of *O. latifolia* is about 140 days (seed germination to maturity stage). It has been used as a potential gene donor for biotic stress (Vaughan, 1994).

#### **ix. *Porteresia coarctata***

*P. coarctata* is considered by some botanists to be the only species in the genus *Porteresia*. Other authors maintain instead that it should belong in the rice genus *Oryza*, as *Oryza coarctata* Roxb (Tropicos.org, 2015). It is a form of wild rice that grows in saline estuaries in Bangladesh and India and is harvested and eaten as a delicacy (Kabir, 2012). It is closely related to *O. australiensis* (Ranganet al., 2002). *Porteresia coarctata* is a species of grass in the family *Poaceae*, native to India, Sri Lanka, Bangladesh, and Myanmar. *Porteresia coarctata* is an erect,

perennial grass, short to intermediate height grass plant, plants up to 58.83 cm tall, and have up to 5 nodes. *Porteresia* locally called "Uri dhan", grows happily and completes its life cycle in an average 20 - 40 dS/m of salinity. It is a tetraploid ( $2n = 48$ ) and sets grains on a single unbranched panicle only once a year around October or November. It is a tufted herbaceous species that grows in the coastal and tidal regions and also it is a monotypic genus occurring as an associate of mangroves along the coastal belts and endemic halophytic nature present. The plant growth is more luxurious in its native habitat on the coastal mud flooded by saline water twice a day. The leaves of this species secrete salt through special microhair like structures that have three morphotypes, and a method to isolate these structures has been developed. The leaves of *Porteresia* are waxy unlike those of rice, and the surfaces display alternate ridges and furrows. Its leaf-blades were coriaceous with prickly tuberculate margins, narrowly linear, leathery and had a peculiar arrangement of vascular bundles that were not found in any other oryzoid grass. It has a highly differentiated underground rhizome system from the nodes of which a number of leafy shoots arise to make a complex association. Rhizoid-like thin rootlets arise from the rhizome serving the purpose of absorption and anchorage. Maximum 5 leaves, leaf length 104.79 mm, leaf width 6.47 mm and ratio 16.9 and in flag leaf, leaf length 27.26 cm, leaf width 5.03 mm and ratio 5.08. Leaf angle 15-20. Root fibrous, root length 20.5 cm. develops underground rhizomes and exhibits a typical rice growth pattern at ground level. It is photosensitive species. 1<sup>st</sup> flowering is in 230 days after seed germination. Panicle length is 12 cm, single unbranched panicle, panicles usually compact, rarely open. Spikelets are large, 6-10.4 mm long and 1.9-3.4 mm wide. It carries fertile lemma with thick, with strong awn (4-10 cm long); anthers 1.5-3 mm long. Number of filled grain panicle<sup>-1</sup> is 20 and sterile grain is 3. It has large caryopses (>1 cm), with a big embryo relative to the endosperm and with a short petiole-like attachment at the base. The seeds get readily dehydrated, dehisce prematurely, do not germinate and are non-viable. So it propagates naturally through rhizomes. Germination- recalcitrant and longevity is short. *P. coarctata* plant produced 78 tillers, 29 panicles and thousand grain weight 13.52 g. Growth duration of *P. coarctata* is about 265 days (seed germination to maturity stage). The plant is salt-tolerant, and is seen as a possibly important source of salt-tolerance genes for transfer to other rice species (Flowerset *al.*, 1990).

#### **x. *Oryza glaberrima***

African rice, red rice or rice of Casamance, *Oryza glaberrima* Steud is the main and the only cultivated rice among the whole African rice species. African rice has potential for breeding for climate resilience and adapting rice cultivation to climate change. However, *O. glaberrima* has some unfavorable characteristics, such as grain shattering and lodging (Jones *et al.*, 1994; Dingkuhn *et al.*, 1998) and is considered to have a low yield potential. In rice breeding, therefore, *O. glaberrima* has mostly been considered a genetic resource to improve *O. sativa*. To the south-east its range is bordered by the river basins of the Benue, Logone and Chari, but it has also been recorded from the islands of Pemba and Zanzibar (Tanzania). The areas of most intensive cultivation of African rice are the floodplains of northern Nigeria, the inland delta of the Niger River in Mali, parts of Sierra Leone and the hills on the Ghana-Togo border. African rice was probably introduced into the New World during the slave trade era, and it is still occasionally cultivated there, *e.g.* in Brazil, Guyana, El Salvador and Panama. *O. glaberrima* is resistance to various indigenous biotic constraints such as RYMV, rice blast (*Pyricularia grisea*), hispa (*Trichispa sericea*), rice gall midge (*Orseolia oryziphora*), weeds, and to several stem-borers and nematodes; including *Heterodera sacchari*, *Meloidogyne graminicola* and *Meloidogyne incognita*. It is resistance to abiotic stresses such as salinity, drought, iron toxicity and low phosphorus availability in acid soils. *Oryza glaberrima* is an annual grass up to 157 cm tall and more in upland or irrigated conditions, culms tend to be weak. The rooting system is fibrous. Dry land types possess simple culm often rooting at lower nodes and floating types are often branching and rooting at upper nodes. It has maximum 8 leaves, leaf length 407.24 mm, leaf width 17.37 mm and ratio 23.44 and in flag leaf, leaf length 161.69 cm, leaf width 13.52 mm and ratio 9.27. Leaf angle 30-35. Leaves alternate, simple; sheath terete, up to 25 cm long. Its inflorescence is a terminal, ellipsoid, stiff and compact panicle up to 28.8 cm long, with ascendent racemose branches. The flower or spikelet, bisexual upper floret by a stipe is made up of an ovary prolonged by two plumose stigmas, and is surrounded by six stamens. Spikelets are ellipsoid, 9 mm long and 4 mm wide more or less persistent reduced to sterile lemmas (glumes absent or strongly rudimentary) separated from the fertile lemma of the fertile. 8-10 Spikelets are present in a panicle. Lemma is hispidulous, 5-veined, usually without apical awn; palea 3-veined; lodicules 2;



stamens 6; ovary superior, with 2 plumose stigmas. Fruit a laterally compressed caryopsis (grain) up to 9 mm long and 3 mm wide, often reddish, tightly enveloped by lemma (glume inferior) and palea (glume superior) which is usually without apical awn and can be colored. *O. glaberrima* is photosensitive species. 1<sup>st</sup> flowering is in 215 days after seed germination. The filled grains are more than the sterile grain in a spikelet. It is normally 175 and 142, respectively. *O. glaberrima* plant produces 75 tillers, 50 panicles and thousand grain weight 8.95 g. Growth duration of *O. glaberrima* is about 250 days (seed germination to maturity stage). African rice (*O. glaberrima*) has a pool of genes for resistance to diverse biotic and abiotic stresses, making it an important genetic resource for rice improvement.

Phan *et al.* (2012) estimated the out crossing rate for annual Asian wild rice under field conditions. Out crossing rate of annual form of *O. rufipogon*, two backcross lines (Lines R<sub>1</sub> and R<sub>2</sub>) between *O. sativa* Nipponbare and *O. rufipogon* W630 were examined under field conditions. The out crossing rates of line R<sub>2</sub> plants also varied, however, no significant difference was observed between the averages of Lines R<sub>1</sub> and R<sub>2</sub>, suggesting that the glume sizes are not critical for out crossing ability.

Waheed *et al.* (2012) conducted a research at experimental field block of Genetics department, Hazara university garden campus during 2008-11 by using two wild species *i.e.*, *O. longistaminata* and *O. rufipogon*, having 62 genotypes each) and four cultivated varieties of rice of Pakistan. *O. longistaminata* was found not suitable due to its late booting and flowering (occurring in November-December) which does not coincide with that of the local cultivars. Again, the time is close to freezing point. The maturity period of the local cultivars is shorter than *O. longistaminata*.

Moukoubi (2011) characterized 60 lowland NERICA varieties and 18 promising lines of their genetic inheritance 23 morphological characters and found significant variation for all the characters evaluated.

Nascimento *et al.* (2011) characterized 146 accessions of upland rice (*O. sativa* L.), based on qualitative and quantitative agro-morphological descriptors. Polymorphism was observed among 12 of 14 qualitative characters evaluated, whereas significant differences were observed for 11 of the 14 analyzed quantitative traits.

Sarawgi *et al.* (2011) carried out studies to characterize seven hundred eighty-two rice germplasm accessions on the basis of twenty-nine morphological and eight agronomical traits. After evaluation of 782 accessions for eight quantitative characters, on the basis of mean values, top ten accessions were identified for the yield ancillary traits. These can be used to identify phenotypically divergent sources for traits of interest in breeding programs.

Song *et al.* (2009) showed that flag leaf area was greater for improved genotypes than traditional genotypes. In this study flag leaf area had positive and poor correlation with grain yield. Flag leaf area was greatest in Minghui-63, hybrid was intermediate and *O. rufipogon* had the smallest area.

Bisne and Sarawgi (2008) carried out studies to characterize thirty-two aromatic rice accessions of Badshah bhog group. These germplasm accessions were evaluated for twenty-two morphological, six agronomical and eight quality characters. The specific genotypes B: 1340, B: 2039, B: 2495, B: 2816, B: 16930 B: 2354, B: 1639, B: 2094 were identified for quality and agronomical characteristics. These may be used in hybridization program to achieve desired segregants for good grain quality with higher yield.

Aidy *et al.* (2000) studied 23 rice cultivars belonging to *japonica* and *indica* groups and suggested that each group can be differentiated from others by different characters such as 50% flowering, leaf, plant height, thousand grain weight, grain length and width, phenol test.

## **2.2 Drought tolerance of wild species of rice**

Soil drought occurrence during dry season has been the main constraint, besides prolonged flooding during rainy season, in increasing cropping intensity and rice productivity in tropical riparian wetland. Use of drought tolerant rice genotype might be a suitable option for overcoming such problem. This study was evaluated by Kartika *et al.* (2020) to focus on the effects of gradual soil drying during early vegetative growth stage on morphological and physiological traits of five *Oryza glaberrima* genotypes, namely RAM12, RAM14, RAM59, RAM97 and RAM101, and two *Oryza sativa* sub sp. *japonica* genotypes, *i.e.*, Koshihikari and Minamihatamochi. The plants were subjected to 6 d of gradual soil drying condition

from 15 days after transplanting (DAT) to 20 DAT, and were allowed to recover until 22 DAT. The results of the study revealed that, under control condition the maximum root length (203.40 cm) was produced by Minamihatamochi genotype and the minimum root length (25.80 cm) was produced by Koshihikari genotype. Under drought stress condition the maximum root length (104.30 cm) was produced by RAM12 genotype and the minimum root length (8.90 cm) was produced by genotype Koshihikari. Under control condition the maximum leaf area (28.90 cm<sup>2</sup>) was produced by RAM97 genotype and the minimum leaf area (5.00 cm<sup>2</sup>) was produced by Koshihikari genotype. Under drought stress condition the maximum leaf area (32.70 cm<sup>2</sup>) was produced by RAM59 genotype and the minimum leaf area (3.70 cm<sup>2</sup>) was produced by genotype Koshihikari. The maximum total dry weight (217.10 mg) was produced by RAM97 genotype and the minimum total dry weight (51.10 mg) was produced by Koshihikari genotype. Under drought stress condition the maximum total dry weight (202.60 mg) was produced by RAM59 genotype and the minimum total dry weight (37.20 mg) was produced by genotype Koshihikari. All the genotypes showed comparable response on stomatal conductance, but *O. glaberrima* genotypes performed higher in leaf rolling recovery. Meanwhile, *O. sativa* genotypes decreased total leaf area and specific leaf area, but increased specific leaf weight in order to avoid further damages due to drought stress. Drought tolerance mechanisms in RAM101, RAM12, RAM59 and RAM14 were associated with leaf morpho-physiological responses, root traits and dry biomass accumulation.

A study was conducted by Bhavyasree *et al.* (2019) using two cultivated and four wild genotypes of the *Oryza* species, analyzed for the seed quality parameters and antioxidant enzyme activities during the polyethylene glycol (PEG) induced water stress and no stress conditions. All the *Oryza* species except *O. sativa* among the studied genotypes performed well during the induced water stress. *O. glumaepatula* and *O. barthii* showed better seed quality parameters in the stress condition. The reduction in the  $\alpha$ -amylase activity was also found to be lower in the wild genotypes. There was a significant rise in the antioxidant enzymes in all the genotypes except *O. sativa*. So these wild *Oryza* genotypes along with *O. glaberrima* can be utilized for the improvement of drought tolerance in *O. sativa*. *O. barthii* produced the longest root (19.50 cm) followed by *O. glumaepatula* (18.90 cm) while *O. sativa* produced the shortest one (16.50 cm) in non stress conditions. Again *O. glaberrima* produced

the longest root (18.70 cm) followed by *O. barthii* (18.50 cm) while *O. sativa* produced the shortest one (10.60 cm) in stress conditions. Minimum decrease in root length was observed in *O. nivara*.

A two-year study was conducted by Dien *et al.* (2019) to explore the effects of various drought stresses and subsequent recovery on the accumulation and degradation of proline, total soluble sugar and starch in different rice varieties at vegetative stage. A pot experiment was conducted using six rice varieties included DA8, Malagkit Pirurutong, Thierno Bande, Pate Blanc MN1, Kinandang Patong and Moroberekan. DA8 and Thierno Bande expressed as drought tolerant varieties while Malagkit Pirurutong and Pate Blanc MN1 were drought sensitive varieties. The results showed that under control condition, there was no significant difference in leaf proline content between experimental varieties in both years of experiments. However, there was a large variation in proline accumulation between varieties under moderate and severe droughts. Under moderate and severe droughts of 2015 experiment, leaf proline content was highest in DA8 (24.13 and 27.67  $\mu\text{mol g}^{-1}$  DW, respectively), followed by Thierno Bande (16.13 and 16.86  $\mu\text{mol g}^{-1}$  DW, respectively); these proline contents were significantly higher than those in other varieties. The leaf proline content of DA8 increased significantly from 24.13  $\mu\text{mol g}^{-1}$  DW under moderate drought to 27.67  $\mu\text{mol g}^{-1}$  DW under severe drought. Similarly, an increase in the leaf proline content of Moroberekan was observed, from 6.53  $\mu\text{mol g}^{-1}$  DW under moderate drought to 9.17  $\mu\text{mol g}^{-1}$  DW under severe drought. Similar to 2015, proline content in leaves of varieties in 2017 were significantly increased under drought stress conditions compared to control condition. Sheath proline content of varieties in 2017 significantly increased under moderate and severe droughts compared to control condition.

Kikuta *et al.* (2019) conducted an experiment to clarify the effects of different water management strategies on dry matter production and yield performance of New Rice for Africa (NERICA) varieties. Dry matter production of NERICA 1 and NERICA 5 was compared with that of Yumenohatamochi, a Japanese upland variety, and Hinohikari, a Japanese lowland variety under three water regimes, i.e. continuously flooded, supplemental irrigation, and non-irrigation (rainfed). Result revealed that, under continuous flooded condition the maximum grain yield (508.00  $\text{g m}^{-2}$ ) was produced by Hinohikari rice variety and the minimum grain yield (413.00  $\text{g m}^{-2}$ ) was

produced by NERICA 1 rice variety. Under supplemental irrigation condition the maximum grain yield ( $406.00 \text{ g m}^{-2}$ ) was produced by Hinohikari rice variety and the minimum grain yield ( $346.00 \text{ g m}^{-2}$ ) was produced by NERICA 1 rice variety. Under non irrigated condition the maximum grain yield ( $402.00 \text{ g m}^{-2}$ ) was produced by Hinohikari rice variety and the minimum grain yield ( $287.00 \text{ g m}^{-2}$ ) was produced by NERICA 1 rice variety.

Cal *et al.* (2018) studied on tropical japonica and aus diversity panels (170–220 genotypes), the degree of leaf rolling under drought was more affected by leaf morphology than by stomatal conductance, leaf water status, or maintenance of shoot biomass and grain yield. A range of canopy temperature and leaf rolling (measured as change in normalized difference vegetation index combinations were observed among aus genotypes, indicating that some genotypes continued transpiration while rolled. This study highlights the large range of physiological responses to drought among rice genotypes and emphasizes that drought response processes should be understood in detail before incorporating them into a species selection program.

Larkunthod *et al.* (2018) investigated the physiological responses related to drought tolerance in CSSL lines (CSSL1-16 and CSSL1-18) compared to parents were used and twenty one old hydroponically grown plants were subjected to 20% PEG for 0, 7, 14 days. The results indicated that CSSL1-16 showed better performance under drought stress compared to their recurrent parent. Drought tolerance superior CSSL1-16 line was indicated by high water status (high relative water content and leaf water potential), good osmotic adjustment, high proline and greater membrane stability. It would be interesting to go further into introgressed section in CSSL1-16 to identify potential candidate genes in DT-QTL for breeding drought tolerant rice in the future.

Drought is the major abiotic constraint to the rice production in the rain-fed areas across Asia and sub-Saharan Africa. Wild species of *Oryza* offer a wide spectrum of adaptive traits and can serve as potential donors of biotic and abiotic stress tolerance. At the Punjab Agricultural University, we are maintaining an active collection of 1630 accessions of wild species germplasm (AA, CC, BBCC and CCDD) of rice. These accessions were screened by Neelam *et al.* (2018) to assess genetic variation for drought tolerance under field conditions. Severe water stress was imposed at vegetative stage by withholding water initially for 25 d and then extended further to

35 d during the month of May to June. The maximum root length (79.50 cm) was produced by *O. rufipogon* (IRGC 89006) followed by *O. latifolia* (IRGC 80769) (79.00 cm), *O. rufipogon* (IRGC 106422) (78.50 cm) and *O. rufipogon* (IRGC 89230) (78.00 cm) and the minimum root length (31.50 cm) was produced by *Oryza sativa* cv. PR121 followed by *Oryza longistaminata* (IRGC 105200) (36.00 cm).

Study conducted by Singh *et al.* (2018) reported that the total chlorophyll content varied in rice genotypes. Drought stress reduced the total chlorophyll content. Highest reduction in chlorophyll content was recorded in Swarna Sub-1 (33.33%) and lowest in Nagina 22 (7.93%). Energetic status of the chloroplast increases as a consequence of the water stress which has a direct relationship to that of increased amount of total chlorophyll and Chl a and Chl b among the stressed induced varieties (Pandey and Shukla, 2015).

Verma *et al.* (2018) reported that deep and thick root systems have been correlated with better grain yield under drought stress in rice. Many QTLs have been identified under upland and rainfed lowland conditions for various root traits as well as grain yield under drought stress. The successful introgressions of these QTLs through Marker Assisted Breeding (MAB) followed by precise phenotype have resulted in the development of several drought tolerant varieties. To be more effective, the breeding program should aim at introgression QTLs for root traits as well as grain yield under drought stress for development of drought tolerant high yielding rice variety.

Rice domestication was performed by Menguer *et al.* (2017) with a narrow genetic diversity, and the other *Oryza* species are a virtually untapped genetic resource for rice stress tolerance improvement. They reported that the origin of domesticated *Oryza sativa* from wild progenitors, the ecological and genomic diversity of the *Oryza* genus, and the stress tolerance variation observed for wild *Oryza* species, including the genetic basis underlying the tolerance mechanisms.

Experiment conducted by Khan *et al.* (2017) to visualize the physiological performance of two contrasting rice varieties under water stress. Two rice (*Oryza sativa* L.) varieties namely PR-115 and Super-7 were procured from Directorate of Seed Research Institute, Mau (Uttar Pradesh, India). Plants were subjected to water stress after one month from the day of transplantation (2 months after germination).

During water stress the controlled plants were watered daily with 750 ml of water while in drought treated plants watering was restricted by giving 200 ml of water every day. The plants were subjected to 10 days of water stress and later on watered normally and harvested. The results showed that under normal condition Super-7 variety produced maximum thousand grain weight (25.30 g) whereas PR-115 variety produced minimum thousand grain weight (23.40 g). Under drought stress condition PR-115 variety produced maximum thousand grain weight (21.80 g) whereas Super-7 variety produced minimum thousand grain weight (17.00 g). The maximum carotenoid content ( $0.280 \text{ mg g}^{-1} \text{ FW}$ ) was scored by Super-7 variety and the minimum carotenoid content ( $0.265 \text{ mg g}^{-1} \text{ FW}$ ) was scored by PR-115 variety at control condition. But under drought stress condition, maximum carotenoid content ( $0.250 \text{ mg g}^{-1} \text{ FW}$ ) was scored by Super-7 and minimum carotenoid content ( $0.225 \text{ mg g}^{-1} \text{ FW}$ ) was scored by PR-115 variety.

Drought is an alarming issue limiting crop production worldwide and is becoming increasingly severe with the passage of time in Bangladesh. Rice production in Bangladesh is thus, being adversely hampered by drought. Therefore, a pot experiment was carried out by Moonmoon *et al.* (2017) with six rice genotypes to assess the effect of drought stress on grain dry weight, photosynthesis and chlorophyll content during July to December 2013-2014 at Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh. Drought stress (control and 40% FC) was imposed on Binadhan-13, Kalizira, BRRI dhan-34, Ukunimodhu, RM-100-16 and NERICA mutant rice genotypes at grain filling stage (anthesis to maturity) and discontinued when the specific stage was over. The experiment was laid out in a Complete Randomized Design with three replications. It was evident that, the higher grain dry weight was observed in genotypes NERICA (13.33) and Binadhan-13 (8.64) and lesser was observed in rest of the genotypes RM-100-16 (8.02), Kalizira (7.04), BRRI dhan-34 (6.80) and Ukunimodhu (6.59). Grain dry weight reduction was lesser in genotypes Binadhan-13 and NERICA mutant (average of 4.89%) compared to others (average of 7.01%) while in 2014, it was also smaller in Binadhan-13 and NERICA (average of 5.33%) compared to the rest (average of 7.03%).

Neelam *et al.* (2017) conducted a research work based on wild species of *Oryza* at the Punjab Agricultural University. Based on the 2 years' data, seven accessions

from *Oryza rufipogon*, four from *Oryza longistaminata* and one each from *Oryza officinalis* and *Oryza latifolia* were found tolerant to drought stress. The average root length among the selected accessions ranges between 36 and 80 cm and the number of primary roots vary from 30 to 87 cm. The *O. rufipogon* accession IRGC 106433, *O. longistaminata* accession IRGC 92656A, *O. officinalis* accession IRGC 101152 and *O. latifolia* accession IRGC 80769 showed approximately 2–2.5 times longer root length and number than the *indica* rice elite cultivar PR121. The results indicated potentiality of selected wild species germplasm for conferring drought tolerance to the elite cultivars.

Four libraries were constructed and sequenced by Zhang *et al.* (2017) for shoot and root tissues from 3-week-old common wild rice seedlings that were exposed to solutions with and without 16% PEG<sub>6000</sub> for 24h. They reported that, in total, 77 known miRNAs that belong to 23 families, including 40 up-regulated and 37 down-regulated in the shoot, and 85 known miRNAs that belong to 46 families, including 65 up regulated and 20 down-regulated in the root were identified as differentially expressed. In addition, we predicted 26 new miRNA candidates from the shoot and 43 from the root that were differentially expressed during drought stress. Furthermore, target genes of the differentially expressed miRNAs provided further evidence for their possible involvement in drought tolerance. These findings may provide new information for the identification of miRNAs in CWR (*O.rufipogon* Griff.) shoots and roots that respond to drought.

Field experiment was carried out by Ahmadikhah and Marufinia (2016) to evaluate the effect of reduced plant height on drought tolerance in rice in research farm of Gorgan University of Agricultural Sciences and Natural Resources in 2013 in a split block design with three replications. Three genotypes [Neda, MT58 (M5), and MTA (M5)] were sown in three blocks of irrigation (S<sub>0</sub>: full irrigation; S<sub>1</sub>: 1 day irrigation followed by 1 day no irrigation; S<sub>2</sub>: 1 day irrigation followed by 2 days no irrigation). Result showed that 41 SSR markers showed that dwarf line MT58 had significant molecular difference with two other lines. ISSR assay also proved the considerable mutational effect of EMS on two mutant lines compared with the original wild line. Field experiments revealed that limited irrigation caused mild-to severe decrease in all the studied traits, including chlorophyll contents. In mild water-stress mutant line,



MT58 showed a low (3 %) yield loss as compared with cultivar Neda with a high (14 %) yield loss. Interestingly, in severe water-stress mutant line, MT58 showed a low (19 %) yield loss as compared with mutant line MTA and cv. Neda with high (33 and 31 %, respectively) yield loss. In severe stress, mutant MT58 had the highest values of panicle length, total kernels per panicle, fertile kernels, and chlorophyll contents, while cv. Neda had the highest values of plant height, tiller number, and plant yield, and reduction in chlorophyll content at drought stress condition was correlated with yield loss (0.64 and 0.697 for Chl. 'a' and Chl. 'b' respectively). The results of this research obviously confirm that mutant line MT58 despite of its stunt figure shows a low yield loss due to drought stress and hence is a promising line for cultivation under drought condition.

Drought stress has now become a severe threat to ensure food security in the developing world as well as in Malaysia. To determine physiological and molecular determinants of drought stress and screening of drought tolerant rice varieties, an experiment was conducted by Fen *et al.* (2015) in a greenhouse at University Putra Malaysia using eleven rice varieties viz., MR4, MR9, MR84, MR219, MR220, Dular, Siam, Puteh Perak, BRRI Dhan 56, IRRI 2011-IRLON Plot No: 50 and IRRI 2011-IRLON Plot No: 64) and two irrigation regimes (well irrigated and water stressed). The present study indicated that, all the varieties showed higher chlorophyll content during well-watered condition compared with water stress except Puteh Perak and Dular. MR 4, MR 84, Siam and IRRI 2011- IRLON Plot no: 050 showed the highest chlorophyll content while MR 220 showed the lowest chlorophyll content during water stress. The proline accumulation was higher under water stress condition compared with well watered condition in all the rice varieties. Among the rice varieties, MR 219 showed the highest increase in proline accumulation (389.05%), followed by MR 9, BRRI Dhan 56, IRRI 2011- IRLON Plot no: 050, MR 4, Dular, MR 220, MR 84, IRRI 2011- IRLON Plot no: 064, Puteh Perak and Siam. Puteh Perak showed the lowest value of proline activity during water stress.

Drought is the most important limiting factor for the sustainability of rice production. The research was carried out by Maisura *et al.* (2014) to identify the physiological character of drought tolerant rice varieties in a paddy system under greenhouse conditions. The experimental design used was split plot design with three replications,

with drought stress as the main plot and variety as sub-plot. The main plots consisted of a control (normal irrigation) and drought stress (drought imposed three weeks after transplant up to harvest). The sub plots consisted of eight rice varieties: IR 64, Ciherang, IPB 3S, Way Apo Buru, Jatiluhur, Menthik Wangi, Silugonggo, and Rokan. Results showed that, the maximum chlorophyll a content ( $3.83 \text{ mg g}^{-1} \text{ FW}$ ) was obtained from Silugonggo cultivar and the minimum chlorophyll a content ( $2.78 \text{ mg g}^{-1} \text{ FW}$ ) was obtained from Ciherang cultivar. The maximum chlorophyll a content ( $3.41 \text{ mg g}^{-1} \text{ FW}$ ) was obtained from control treatment and the minimum chlorophyll a content ( $2.75 \text{ mg g}^{-1} \text{ FW}$ ) was obtained from drought stress condition. The maximum chlorophyll b content ( $1.51 \text{ mg g}^{-1} \text{ FW}$ ) was obtained from Rokan cultivar and the minimum chlorophyll b content ( $0.97 \text{ mg g}^{-1} \text{ FW}$ ) was obtained from Jatiluhur cultivar. The maximum chlorophyll b content ( $1.47 \text{ mg g}^{-1} \text{ FW}$ ) was obtained from control treatment and the minimum chlorophyll b content ( $1.00 \text{ mg g}^{-1} \text{ FW}$ ) was obtained from drought stress condition.

Eight accessions of *Oryza rufipogon* and one accession of *O. officinalis* were evaluated by Feng *et al.* (2012) for measuring the morphological and physiological traits under drought stress situation. The result of the investigation revealed that, the accession of *O. officinalis* had much stronger drought tolerance than all *O. rufipogon* accessions. Two *O. rufipogon* accessions (Or03, Or08) from Hainan (as a tropical island) had the best performance under drought stress, while two other accessions of (Or15, Or33) from Guangdong and Jiangxi provinces were sensitive to water deficit. The results revealed the preliminary evidences that *O. rufipogon* accessions from tropical area have stronger drought resistance than accessions from sub-tropical areas.

Three sets of field experiments were conducted by Ndjondjop *et al.* (2012) between 2006 and 2008 at Africa Rice Center research station, Togoudo, Benin to evaluate the effect of drought on some traits of rice (*Oryza* sp.). Three genotype types including 202 inter-specific lines, from a cross between WAB56-104 (*O. sativa* subsp. japonica) and CG14 (*O. glaberrima*), adapted to upland conditions, 60 chromosome segment substitution lines made for lowland conditions and 211 accessions of *O. glaberrima* Steud., were evaluated using a split plot design replicated twice or thrice and an alpha lattice design with four blocks. There was a consistent negative effect of drought on plant height and grain yield across genotypes' drought-tolerance levels and across

genotype/types. Plant height and grain yield were more reduced for sensitive genotypes than for moderately tolerant and tolerant genotypes. Flowering and maturity were consistently delayed across genotype types and tolerance levels. Mean delays of 6.5, 21.8 and 9.4 days were observed for start, 50 and 100% flowering, respectively. Maturity was also delayed, with consistency across genotype types. However, no clear picture of drought effect on flowering and maturity was observed in terms of differences among drought-tolerance levels. The effects of drought on the number of tillers and on leaf temperature were not consistent. Plant height and grain yield showed the clearest differences between genotype-tolerance levels. Genotypes 151-3-8, 104-3-5, 116-2-4, 117-2-6, MPL-15-3, MPL-202-3, SENL-21-2, SENL-10-1, SENL-17-2, SENL-26-3, TOG5691, TOG6679 and TOG5591 yielded higher than the parents and checks.

A series of three screen house experiments were conducted by Liul *et al.* (2004) to compare the leaf water status, stomatal conductance, membrane stability, and root development in several wild *Oryza* accessions and *O. sativa* cultivars, when grown under well watered or water-deficient conditions. *O. longistaminata* had greater stomatal conductance and maintained leaf elongation better under stress than most other genotypes. Japonica subspecies also maintained greater conductance and leaf expansion than an indica cultivar or *O. rufipogon* accessions. Leaves of an accession of *O. latifolia* were particularly sensitive to water deficit. *Oryzalongistaminata* and several *O. rufipogon* accessions had greater membrane stability, measured as electrolyte leakage from leaf disks after heat treatment, than cultivated rice. Wild species had levels of osmotic adjustment under stress that were similar to *O. sativa*. These studies indicate that *O. longistaminata* and *O. rufipogon* may serve as sources of novel alleles for improved leaf traits under drought stress—specifically, for maintenance of leaf elongation, stomatal conductance, and membrane stability. Alleles for improved root growth and distribution under water deficit exist in some japonica rice cultivars.

### **2.3 Salinity tolerance of wild species of rice**

The study was investigated by Nguyen *et al.* (2021) to find out the relationship between proline accumulation and salt tolerance in an accession of Australian wild rice *Oryza australiensis* Domin using morphological, physiological, and molecular

assessments. Seedlings of *O. australiensis* wild rice accession JC 2304 and two other cultivated rice *Oryza sativa* L. cultivars, Nipponbare (salt-sensitive), and Pokkali (salt-tolerant), were screened at 150 mM NaCl for 14 days. The results showed that *O. australiensis* was able to rapidly accumulate free proline and lower osmotic potential at a very early stage of salt stress compared to cultivated rice. The qRT-PCR result revealed that *O. australiensis* wild rice JC 2304 activated proline synthesis genes OsP5CS1, OsP5CS2, and OsP5CR and depressed the expression of proline degradation gene OsProDH as early as 1 h after exposure to salinity stress. Wild rice *O. australiensis* and Pokkali maintained their relative water content and cell membrane integrity during exposure to salinity stress, while the salt-sensitive Nipponbare failed to do so. An analysis of the sodium and potassium contents suggested that *O. australiensis* wild rice JC 2304 adapted to ionic stress caused by salinity by maintaining a low Na<sup>+</sup> content and low Na<sup>+</sup>/K<sup>+</sup> ratio in the shoots and roots. This demonstrates that *O. australiensis* wild rice may use a rapid accumulation of free proline as a strategy to cope with salinity stress.

Yichie (2020) conducted two distinct screening experiments, investigated variation in salinity tolerance among accessions of two wild rice species endemic to Australia, *O. meridionalis* and *O. australiensis*, with *O. sativa* cultivars Pokkali and IR29 providing salt-tolerant and sensitive controls, respectively. The results of the study revealed that rice plants were grown on soil supplemented with field-relevant concentrations of NaCl (0, 40, 80, and 100 mM) for 30 days, a period sufficient to reveal differences in growth and physiological traits. Two complementary screening approaches were used: destructive phenotyping and high-throughput image-based phenotyping. All genotypes displayed clear responses to salt treatment. In the first experiment, both salt-tolerant Pokkali and an *O. australiensis* accession (Oa-VR) showed the least reduction in biomass accumulation, SES score and chlorophyll content in response to salinity. Average shoot Na/K values of these plants were the lowest among the genotypes tested. In the second experiment, plant responses to different levels of salt stress were quantified over time based on projected shoot area calculated from visible red-green-blue (RGB) and fluorescence images. Pokkali grew significantly faster than the other genotypes. Pokkali and Oa-VR plants displayed the same absolute growth rate under 80 and 100mM, while Oa-D grew significantly slower with the same treatments.

Conclusion: The combination of our two screening experiments uncovered striking levels of salt tolerance diversity among the Australian wild rice accessions tested and enabled analysis of their growth responses to a range of salt levels. Our results validate image-based phenotyping as a valuable tool for quantitative measurement of plant responses to abiotic stresses. They also highlight the potential of exotic germplasm to provide new genetic variation for salinity tolerance in rice.

Soil salinity is one of the most distressing ecological stresses which reduce the agrarian production. However, the impact of salinity varies among species and genotypes. The experiment was carried out by Channa *et al.* (2019) to evaluate the salt tolerance of ten rice genotypes including, four aromatic (DR-67, Latiffee, Super Basmati and DR-66) and six non-aromatic genotypes (DR-92, DR-51, IR-6 Shahkar, NIA-19A and Shua-92 check). The two factorial completely randomized design (CRD) experiment with four salinity levels ( $T_1$ -2.3 (control),  $T_2$ -6.0,  $T_3$ -9.1 and  $T_4$ -12.8 EC dS m<sup>-1</sup>) was performed at Green house, Department of Botany, Shah Abdul Latif University Khairpur. The results of the study revealed that, the maximum tillers hill<sup>-1</sup> (83.30) was produced by DR-92 rice genotype and the minimum tillers hill<sup>-1</sup> (46.00) was produced by DR-66 rice genotype.

Malumpong *et al.* (2019) conducted an experiment regarding the salinity stress; critical point and phenotypic parameter of the reproductive stage were identified for screening a large fast neutron mutant population. The results showed a 150 mM NaCl treated in irrigated water at the early booting stage had the greatest effect on flag leaf and panicle damage, and it also reduced seed setting, especially in susceptible genotype. Finally, the validated screening, M1145 showed a stable tolerance under salt stress and produced the highest seed setting at 48%, which was not significantly different from the standard salinity tolerant (Pokkali, FL496 and FL530). In conclusion, seed setting during salinity stress at reproductive stage was representative of salinity tolerance and can be used as a screening parameter for salinity tolerance on a large scale. In addition, the fast neutron mutant population showed variations in salinity tolerance levels, and M1145 was identified as salinity tolerant and is a potential genetic stock for use in a salinity tolerance breeding program.

The tolerance potential of 63 rice genotypes was evaluated by Tariq *et al.* (2019) at seedling stage under different levels of salt stress (0, 50, 100 and 150 mM). Among

screened genotypes, six were found tolerant, 37 moderately tolerant and 20 were sensitive under tested levels of salt stress. Tolerant genotypes showed less reduction in root shoot length, fresh weight and dry weight, compared with FL478 (positive control). Sensitive genotypes showed ~90% reduction in all growth parameters at 150 mM. Selected genotypes, representing all three groups, were further assessed for salinity tolerance at molecular level using 21 simple sequence repeat (SSR) markers, residing within *SalTol* QTL region on chromosome 1 and 19 SSR markers were found polymorphic among salt tolerant and sensitive genotypes. Results revealed that tolerant genotypes can be identified on the basis of growth parameters like root shoot length, root shoot fresh and dry weight at seedling stage under salt stress conditions. Moreover, molecular markers were able in differentiating the identified salt tolerant and sensitive genotypes.

The experiment was conducted by Polash *et al.* (2018) in the Plant Physiology laboratory, Department of Crop Botany, Bangladesh Agricultural University, Mymensingh from December 2016 to January 2017 to investigate the effect of salinity on osmolytes and relative water content of selected rice genotypes. There were seven rice genotypes viz., Pokkali, Ashfal, Benapol, Jamainaru, Gunshi, Mohini and BRRIdhan 29 and two salinity level viz., 0 (control) and 100 mM NaCl. The result revealed that, shoot dry weight significantly ( $P < 0.05$ ) decreased with the increasing salinity. The pokkali genotype showed maximum dry matter production (1.89 g) at control which gradually decreased with the increase of salinity and at 100 mM salt concentration it showed minimum (1.35 g) dry matter production with 28.57% reduction. The other varieties Ashfal, Benapol, Jamainaru, Gunshi and Mohini with a treatment of 100 mM salinity exhibited a decrease in shoot dry matter at 30, 30, 39.07, 40, 46.09 and 54.76 %, respectively over corresponding control.

Prusty *et al.* (2018) conducted an experiment to identify wild rice accessions conferring high salt tolerance using tissue tolerance mechanism in leaf 22 wild *Oryza* species along with the cultivated tolerant lines including Pokkali, Nona Bokra, and FL478, and sensitive check varieties under high salinity (240 mM NaCl). Based on the visual salt injury score, three species (*O. alta*, *O. latifolia*, and *O. coarctata*) and four species (*O. rhizomatis*, *O. eichingeri*, *O. minuta*, and *O. grandiglumis*) showed higher and similar level of tolerance compared to the salt tolerant check varieties,

respectively. The newly isolated wild rice accessions will be valuable materials for both rice improvement to salinity stress and the study of salt tolerance mechanism in plants. They suggest that the wild species employ tissue tolerance mechanism to manage salt stress.

Investigation conducted by Yichie *et al.* (2018) to screening salinity tolerance in Australian wild *Oryza* species. Five wild accessions chosen from two Australian endemic wild rice species, *O. meridionalis* and *O. australiensis*, were tested along with two cultivated varieties of *O. sativa*, Pokkali and IR29. The wild accessions were selected from a wide range of sites, including transiently saline waterways in the north and northwest of Australia. The final NaCl concentrations were 0, 40, 80 and 100 mM NaCl a total electrolyte concentration resulting in an electrical conductivity (EC) of 0.0, 0.5, 4.5, and 8.7 dS m<sup>-1</sup>, respectively. They concluded that, *O. sativa*, *O. meridionalis* and *O. australiensis* shoot dry biomass ranged from 11.5 (IR29) to 22 g (Pokkali), with the exception of Oa-KR for which dry biomass reached 34 g by the end of the experiment.

10 rice lines and varieties viz., OM7347, OM8104, IR93340, IR93343, IR5040, IR93350, IR87832-303-1-B and IR86385-8D-1-2-B including the salt tolerant variety (Pokkali) and salt susceptible variety (IR29) as control were used in an experiment for screening rice salinity tolerance at seedling stage was carried out by Sen *et al.* (2017) in hydroponic system using five different salinity concentrations (0, 4, 6, 8 and 10 dS m<sup>-1</sup>). The results of the investigation revealed that, dry matter weight of all the rice lines/varieties declined with increasing salt concentrations. Different lines/varieties were pronounced in this character. OM7347 was dead at 10 dS m<sup>-1</sup> salt concentration. The lowest dry weight was found in IR29 and it was dead at 8 dS m<sup>-1</sup>. At all salinity levels varieties, Pokkali produced significantly high dry weight as compared to other lines/varieties. IR5040 had the lowest dry weight in comparison to others at all salinity levels. Almost all of the varieties reduced their pollen viability due to salinity stress, resulting into poor grain yield, such as OM7347 (1.32 g plant<sup>-1</sup>), IR87832-303-1-B (1.11 g plant<sup>-1</sup>) and IR29 (0.70 g plant<sup>-1</sup>) at EC = 8 dSm<sup>-1</sup>. Pokkali has the highest grain yield in both control (7.56 g plant<sup>-1</sup>) and saline conditions (5.23 g plant<sup>-1</sup>). Next, there was non-significantly statistical difference of IR86385-8D-1-2-B (5.02 g plant<sup>-1</sup>) and IR5040 (4.69 g plant<sup>-1</sup>), in comparison with Pokkali. Plants of IR29 and OM7347

were dead at the electrical conductivity (EC) = 10 dS m<sup>-1</sup>, whereas Pokkali (the tolerant variety) and IR93350 were evaluated at score 5. Rice lines/varieties were classified to salinity tolerance levels as following: IR5040, IR93350, IR86385-8D-1-2-B and Pokkali (tolerant); OM8104, IR93340 and IR93343 (moderate susceptible); OM7347, IR87832-303-1-B and IR29 (susceptible).

A field experiment was conducted by Puvanitha and Mahendran (2017) at the Agronomy farm of the Eastern University which is located in the Batticaloa district of Sri Lanka. The experiment was carried out during 2015. This experiment was carried out with six treatments and four replications and the treatments were as follows: T<sub>1</sub> (S<sub>0</sub>V<sub>1</sub>) = “Pachaiperumal” rice cultivar grown in non -saline soil (Control), T<sub>2</sub> (S<sub>1</sub>V<sub>1</sub>) = “Pachaiperumal” cultivar grown in saline soil, T<sub>3</sub> (S<sub>0</sub>V<sub>2</sub>) = “At 307” cultivar grown in non-saline soil (Control), T<sub>4</sub> (S<sub>1</sub>V<sub>2</sub>) = “At 307” cultivar grown in saline soil, T<sub>5</sub> (S<sub>0</sub>V<sub>3</sub>) = “At 308” cultivar grown in non –saline soil (Control) and T<sub>6</sub> (S<sub>1</sub>V<sub>3</sub>) = “At 308” cultivar grown in saline soil. The results of the experiment revealed that, salinity have significantly reduced the yield of all the tested rice cultivars. The highest yield (2.2 t.ha<sup>-1</sup>) was obtained in “At 307” and the lowest one (0.4 t.ha<sup>-1</sup>) was recorded in “Pachaiperumal” under saline condition.

Sengupta (2014) reported that *P. coarctata* is important from ecological point of view as its salt and mechanical stress tolerance is an integral part of the mangrove ecosystem. The subterranean part of *Porteresia* provides a high anchorage and binds soil, thus stabilizing the mangrove vegetation. The root system architecture of *Porteresia* is unique, with a rhizome and rhizoid-like rootlets. The root system interacts with both salinity and mechanical threat directly, and thus it is important to understand the molecular ecophysiology of *Porteresia* root and rhizomes to understand the nature of overlap between salinity and mechanical stress in a mangrove ecosystem, which is still elusive.

Sengupta and Majumder (2010) concluded that *Porteresia coarctata* is a tetraploid wild rice having salt tolerance mangrove associate. Report evident that some pathways critical to salt tolerance are in operation in *Porteresia* of which the inositol metabolic pathway has been recently elaborated. Some of the enzymes of *Porteresia* have been shown to function as salt-tolerant under *in vitro* studies giving a clue that this wild halophytic rice may have evolved genes and proteins capable of functioning



under asalt environment. Bio-prospecting of such genes and proteinscoupled with genomic and proteomic approachesremain is an exciting area of research in evaluating these plants a model for salt tolerance for the rice plant.

After reviewing the above experiments findings it may be concluded that the wild rice relatives have great potentiality to overcme the natural clamities like salinity and drought. At this stage finding some of the potential species is very much crutial that could be beneficiary steak to fight against these natural disestar.

## **CHAPTER III**

### **MATERIALS AND METHODS**

The study was carried out to evaluate 40 accessions of wild species of rice through assessing their morpho-physiological behaviour conferring tolerance to salinity and drought stresses. The whole work consisted of four pot and one laboratory experiments conducted during 2018-2020. The pot experiments were conducted at Agronomy Research Field-1, Hajee Mohammad Danesh Science and Technology University, Dinajpur and the laboratory experiment at Molecular Breeding Laboratory of Genetics and Plant Breeding Division, Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. Detailed materials used and methodologies followed for the research works have been described in this chapter.

#### **A. Experimental site and period**

The pot experiments were conducted at Agronomy Research Field-1 Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, Bangladesh. Geographically, the location of the experimental was 25°38' N Latitude and 88°41' E longitude at an elevation of 37.5 m above the mean sea level. The pot experiments were conducted during 2018-2020 (Appendix I).

#### **B. Soil of the experimental site**

The soil was collected within 6 cm, from the top soil of the Agronomy Research Field-1, Department of Agronomy, HSTU, Dinajpur, Bangladesh. This soil belongs to Ranishankail series under Old Himalayan Piedmont Plain (AEZ 1). The soil was sandy loam in texture having pH 5.52 and medium in organic matter. The morphological, physical and chemical characteristics of the soil have been presented in Appendix II.

#### **C. Weather and Climate**

The experimental area experiences a subtropical climate where the kharif season starts with high temperature, high humidity and heavy rainfall with occasional gusty winds and it decreases when the season proceeds towards rabi. The mean maximum temperature rises in the month of April, whereas in winter, the mean maximum

temperature downs in January. Usually scanty rainfalls in rabi season (October to March) and heavy rainfall during kharif season (April to September). The relative humidity increases from June to September (80% or above) and declined to a minimum in winter. The weather information regarding temperature, relative humidity, rainfall and sunshine hours prevailed at the experimental site during the cropping season of the study is presented in Appendix III.

### **3.1 Experiment 1: Morphological characterization of wild species of rice**

#### **Objective**

- To characterize morphological traits of all the accessions of wild species of rice

#### **3.1.1 Location**

The pot experiment was conducted in the Net House of Agronomy Research Field-1, Department of Agronomy, HSTU, Dinajpur, Bangladesh during the month of March to December, 2018.

#### **3.1.2 Pot preparation**

The earthen pots having 17 cm diameter at the top and 15 cm at the bottom were used. The depth of the pots was 11 cm. Top surface of each pot measured 615.44 cm<sup>2</sup>. The soil was collected from the Agronomy Research Field-1 at 6 cm depth. After collecting the soil, it was sun dried and well grounded. Then the soil debris was removed by sieving and the soil was put into pots after mixing with fertilizer. The pot was filled with 10.1 kg sun dried soil. The pots were placed in Agronomy Research Field-1. Each pot contained one hill and denotes a replication. Considerable spacing was maintained among pots for convenience of cultural operations. There were 120 pots used for the experiment.

### 3.1.3 Plant materials

Forty accessions under 10 wild species of rice were used in the experiment. Sources of these accessions together with their place of collection are shown in Table 3.1.1.

**Table 3.1.1 List of the accessions of wild species of rice collected**

| Sl. No. | Species Name             | Accession No. | Collection area |
|---------|--------------------------|---------------|-----------------|
| 1       | <i>O. rufipogon</i>      | Accession 1   | BAU             |
| 2       | <i>O. rufipogon</i>      | Accession 2   | BINA            |
| 3       | <i>O. rufipogon</i>      | Accession 3   | BRRI            |
| 4       | <i>O. rufipogon</i>      | Accession 4   | BINA            |
| 5       | <i>O. rufipogon</i>      | Accession 5   | BAU             |
| 6       | <i>O. rufipogon</i>      | Accession 6   | BRRI            |
| 7       | <i>O. rufipogon</i>      | Accession 7   | BRRI            |
| 8       | <i>O. latifolia</i>      | Accession 8   | BAU             |
| 9       | <i>O. latifolia</i>      | Accession 9   | BAU             |
| 10      | <i>O. latifolia</i>      | Accession 10  | BRRI            |
| 11      | <i>O. latifolia</i>      | Accession 11  | BRRI            |
| 12      | <i>O. nivara</i>         | Accession 12  | BRRI            |
| 13      | <i>O. nivara</i>         | Accession 13  | BRRI            |
| 14      | <i>O. nivara</i>         | Accession 14  | BRRI            |
| 15      | <i>O. nivara</i>         | Accession 15  | BAU             |
| 16      | <i>O. nivara</i>         | Accession 16  | BAU             |
| 17      | <i>O. nivara</i>         | Accession 17  | BAU             |
| 18      | <i>O. officinalis</i>    | Accession 18  | BRRI            |
| 19      | <i>O. officinalis</i>    | Accession 19  | BRRI            |
| 20      | <i>O. officinalis</i>    | Accession 20  | BAU             |
| 21      | <i>O. longistaminata</i> | Accession 21  | BAU             |
| 22      | <i>O. longistaminata</i> | Accession 22  | BAU             |
| 23      | <i>O. longistaminata</i> | Accession 23  | BRRI            |
| 24      | <i>O. longistaminata</i> | Accession 24  | BRRI            |

**Table 3.1.1 Continued**

| Sl. No. | Species Name                | Accession No. | Remarks/Collection area |
|---------|-----------------------------|---------------|-------------------------|
| 25      | <i>O. alta</i>              | Accession 25  | BAU                     |
| 26      | <i>O. alta</i>              | Accession 26  | BRRI                    |
| 27      | <i>O. alta</i>              | Accession 27  | BRRI                    |
| 28      | <i>O. glaberrima</i>        | Accession 28  | BAU                     |
| 29      | <i>O. glaberrima</i>        | Accession 29  | BAU                     |
| 30      | <i>O. glaberrima</i>        | Accession 30  | BRRI                    |
| 31      | <i>O. glaberrima</i>        | Accession 31  | BRRI                    |
| 32      | <i>O. barthii</i>           | Accession 32  | BRRI                    |
| 33      | <i>O. barthii</i>           | Accession 33  | BRRI                    |
| 34      | <i>Porterecia coarctata</i> | Accession 34  | DU                      |
| 35      | <i>Porterecia coarctata</i> | Accession 35  | BAU                     |
| 36      | <i>Porterecia coarctata</i> | Accession 36  | BINA                    |
| 37      | <i>O. punctata</i>          | Accession 37  | BAU                     |
| 38      | <i>O. punctata</i>          | Accession 38  | BAU                     |
| 39      | <i>O. punctata</i>          | Accession 39  | BRRI                    |
| 40      | <i>O. punctata</i>          | Accession 40  | BRRI                    |

**3.1.4 Experimental design**

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The total number of pots were used in this study was 120 (40×3).

**3.1.5 Treatments under investigation**

The, single factor, experiment consisted of 40 wild species of rice as treatments. The wild species of rice are listed in table 3.1.1.

**3.1.6 Description of the wild species of rice****i. *Oryza punctata***

*O. punctata* is an erect or spreading, annual grass, tufted, rarely stoloniferous and rarely geniculate. Plants are up to 130 cm tall, glabrous, smooth and have up to 8

nodes. The difference between two inter node distance of the upper portion is longer than the lower portion, about 85 cm. Maximum 8 leaves, leaf length 187.7 mm, leaf width 17.05 mm and ratio 12.59 and in flag leaf, leaf length 172.42 mm, leaf width 16.88 mm and ratio 10.16. Leaf angle 25-30. *O. punctata* is a photosensitive species. It needs 215 days for 1<sup>st</sup> flowering after seed germination. Its inflorescence is a loose panicle 30 cm long which is composed of a few spreading branches. Panicle is erect or slightly dropping with a tuft of hairs at the base of branches. Spikelets disarticulated above the glumes. Pedicels 7-15 mm long and shed when mature. Glumes are only rudimentary. The filled grains are more than the sterile grain in a spikelet which are normally 115 and 60. The seeds are small, less than 5 mm long. *O. punctata* plant produced 62 tillers, 35 panicles and thousand grain weight 8.85 g. Growth duration of *O. punctata* is about 250 days (seed germination to maturity stage).

## **ii. *Oryza rufipogon***

*O. rufipogon* is an erect, perennial tufted grass, 170-180 cm tall, have up to 10 nodes. Culm and nodes are glabrous and hollow. Maximum 11 leaves, leaf length 267.56 mm, leaf width 12.15 mm and ratio 23.20 and in case of flag leaf: leaf length 162.31 mm, leaf width 11.84 mm and ratio 14.04. Its leaf angle is 25-30, leaf blades linear, 15-18 cm long, and 10-25 mm wide, leaf sheaths loose, cylindrical, glabrous with distinct auricles at the junction with the blade. Root fibrous, 27 cm long, often with rhizomes. It is a photosensitive species. It requires 235 days to 1<sup>st</sup> flowering after seed germination. Inflorescence is terminal and paniculate well exerted, up to 30.20 cm long. *O. rufipogon* has many bisexual spikelets, always awned. It has six stamens, two styles, two stigmas, laterally exerted from the spikelets. Number of filled grain panicle<sup>-1</sup> is 105 and sterile grain panicle<sup>-1</sup> 50. Caryopsis is narrow, red-brown, enclosed by a stiff lemma and palea. *O. rufipogon* plant produce 107 tillers, 82 panicles and thousand grain weight 24.26 g. Growth duration of *O. rufipogon* is about 265 days (seed germination to maturity stage).

## **iii. *Oryza alta***

*Oryza alta* is an annual, perennial plant with short rhizomes. It is an erect, rarely stoloniferous and rarely geniculate. Plants are up to 182 cm tall, smooth, usually over

4 mm in diameter at the base and have up to 4 nodes . Maximum 7 leaves, broad type, leaf length 210.68 mm, leaf width 21.66 mm and ratio 9.64 and in case of flag leaf: leaf length 143.56 mm, leaf width 37.32 mm and ratio 4.13, leaf angle 25-30. Root fibrous, root length 50 cm, with short rhizomes. *O. alta* is photo insensitive species requires 110 days for 1<sup>st</sup> flowering after seed germination. Inflorescence is loose panicle 41 cm long .Panicle is erect or slightly dropping with a tuft of hairs at the base of branches. Spikelets disarticulated above the glumes. Glumes are only rudimentary. Sterile lemmas are 2-3.8 mm long, glabrous and smooth. Fertile lemmas are slightly shorter than the spikelet, with 6 stamens, a blackish stigma and awns 2.6-7.5 cm. The number of filled grain panicle<sup>-1</sup> is 120 and sterile grain 195 (max). The seeds are 7.5-8.5 mm long, oblong, glabrous, light-brown. It produces 64 tillers, 22 panicles and thousand grain weight 8.32 g. Its growth duration is about 140 days (seed germination to maturity stage).

#### **iv. *Oryza nivara***

*Oryza nivara* is an erect, usually annual grass though. It is short to intermediate height grass plant, culm semi-erect up to 138.8 cm tall, smooth and has up to six nodes. Average leaf 9, leaf length 116.61 mm, leaf width 14.66 mm and ratio 24.59 and in flag leaf, leaf length 164.23 mm, leaf width 11.76 mm and ratio 12.14. Leaf angle 30-35 .Root fibrous, root length 18.5 cm. It is photosensitive species and requires 230 days to reach 1<sup>st</sup> flowering after seed germination. Panicle length 22.6 cm. It has large spikelets with 6-10.4 mm long and 1.9-3.4 mm wide. Fertile lemma with thick, with strong awn (4-10 cm long); anthers 1.5-3 mm long and has number of filled grain panicle<sup>-1</sup> 61 and sterile grain 4. Caryopsis is deciduous at maturity and with strong seed dormancy. It produces 135 tillers, 85 panicles and thousand grain weight 26.64 g and having growth duration is about 265 days (seed germination to maturity stage).

#### **v. *Oryza longistaminata***

*O. longistaminata* is an erect, perennial grass with extensive creeping, branched rhizomes. Culms are up to 130 cm tall, up to 2.5 cm diameter at the base, have up to 7 nodes, are erect and spongy with adventitious roots developing from lower nodes. The difference between two inter node distance of the upper portion is longer than the lower portion, about 75 cm. Maximum 8 leaves, leaf length 267.73 mm, leaf width 17

mm and ratio 15.91 and in flag leaf, leaf length 145.91 mm, leaf width 25.86 mm and ratio 5.71. Leaf angle 30-35. Root fibrous, root length 32.8 cm, develops rhizomes underground. It is a photosensitive species. 1<sup>st</sup> flowering is in 215 days after seed germination. The panicle is 40 cm (max) long, erect or slightly drooping with a tuft of hairs at the base of branches. 12-15 spikelets are present in a panicle. Glumes are reduced to a narrow membranous rim. The filled grains are more than the sterile grain in a spikelet. It is normally 171 and 151, respectively. It produces 49 tillers, 29 panicles and thousand grainweight 8.94 g. Growth duration of *O. longistaminata* is about 250 days (seed germination to maturity stage).

#### **vi. *Oryza officinalis***

*Oryza officinalis* is a clump-forming, perennial grass, culms are up to 124.6 cm long, up to 2.5 cm diameter at the base, have up to 8 nodes. The difference between two inter node distance of the upper portion is longer than the lower portion, about 70 cm. Maximum 9 leaves, leaf length 36.03 cm, leaf width 22.4 mm and ratio 16.03 and in flag leaf, leaf length 18.04 cm, leaf width 18.69 mm and ratio 9.54. Leaf angle 30-32. Root fibrous, root length 23 cm. It is a light photosensitive species. 1<sup>st</sup> flowering is in 205 days after seed germination. Panicles open, panicle up to 32.8 cm long, spikelet 4-6.4 mm long, wider than 2 mm and 5-6 spikelets are present in a panicle. Caryopsis is 2.3-4.4 mm long and 1.3-2.3 mm wide and orange-brown. It produces 62 tillers, 24 panicles and thousand grain weight 8.21 g which having growth duration of about 235 days (seed germination to maturity stage).

#### **vii. *O. barthii***

*O. barthii* is generally behaves as an annual aquatic grass. Culms are maximum 130.8 cm tall, 4-8-noded. The difference between two inter node distance of the upper portion is longer than the lower portion. Maximum 10 leaves, leaf length 184.95 mm, leaf width 12.19 mm and ratio 14.28 and in flag leaf, leaf length 118.17 mm, leaf width 6.73 mm and ratio 7.09. Leaf angle 25-30. Root fibrous, root length 23 cm (max.) *O. barthii* is photosensitive species. It requires 215 days to reach 1<sup>st</sup> flowering stage after seed germination. Panicle 29.2 cm (max.) long, erect or more rarely somewhat nodding. Spikelets 8-10.5 mm long (excluding the awn), up to 3.4 mm wide, deciduous, 5-6 spikelets are present in a panicle. Awn 6.5- 7 cm long. The



number of filled grain panicle<sup>-1</sup> 40 and sterile grain is 10. The seeds are large and 1.0 cm long. It produces 62 tillers, 55 panicles and thousand grain weight 33.75 g. It has about 250 days life cycle (seed germination to maturity stage).

#### **viii. *Oryza latifolia***

*O. latifolia* is a perennial grass. Erect culms/plants are up to 197.8 cm tall, usually over 4 mm in diameter at the base and have up to seven nodes. The difference between two inter node distance of the upper portion is longer than the lower portion. It has long broad leaves, average leaf no.7, leaf length 563.70 mm, leaf width 30.8 mm and ratio 18.18 and in flag leaf, leaf length 472.97 mm, leaf width 30.66 mm and ratio 11.38. Leaf angle 15-20. Root fibrous, root length 50 cm. *O. latifolia* is a photo in-sensitive species. 1<sup>st</sup> flowering is in 110 days after seed germination. Inflorescence is a loose panicle 50 cm long which is composed of a few spreading branches, themselves up to 20 cm long. Panicle is erect or slightly dropping with a tuft of hairs at the base of branches, open. 16-17 spikelets are present in a panicle. Spikelets are 5-9.5 mm long, having a 4.5 cm long awn. The filled grains are less than the sterile grain in a spikelet. It is normally 44 and 310, respectively. The seeds are medium, 5 mm long. *O. latifolia* plant produced 30 tillers, 19 panicles and thousand grain weight 11.38 g. Growth duration of *O. latifolia* is about 140 days (seed germination to maturity stage).

#### **ix. *Porteresia coarctata***

*Porteresia coarctata* is an erect, perennial grass, short to intermediate height grass plant, plants up to 58.83 cm tall, and have up to 5 nodes. It has a highly differentiated underground rhizome system from the nodes of which a number of leafy shoots arise to make a complex association. Rhizoid-like thin rootlets arise from the rhizome serving the purpose of absorption and anchorage. Maximum 5 leaves, leaf length 104.79 mm, leaf width 6.47 mm and ratio 16.9 and in flag leaf, leaf length 27.26 cm, leaf width 5.03 mm and ratio 5.08. Leaf angle 15-20. Root fibrous, root length 20.5 cm. develops underground rhizomes and exhibits a typical rice growth pattern at ground level. It is photosensitive species. 1<sup>st</sup> flowering is in 230 days after seed germination. Panicle length is 12 cm. It has large caryopses (>1 cm), with a big embryo relative to the endosperm and with a short petiole-like attachment at the base.

*P. coarctata* plant produced 78 tillers, 29 panicles and thousand grain weight 13.52 g. Growth duration of *P. coarctata* is about 265 days (seed germination to maturity stage).

#### **x. *Oryza glaberrima***

*Oryza glaberrima* is an annual grass up to 157 cm tall and more in upland or irrigated conditions, culms tend to be weak. The rooting system is fibrous. Dry land types possess simple culm often rooting at lower nodes. It has maximum 8 leaves, leaf length 407.24 mm, leaf width 17.37 mm and ratio 23.44 and in flag leaf, leaf length 161.69 cm, leaf width 13.52 mm and ratio 9.27. Leaf angle 30-35. Leaves alternate, simple, up to 25 cm long. Its inflorescence is a terminal, panicle up to 28.8 cm long. The flower or spikelet, bisexual upper floret by a stipe is made up of an ovary prolonged by two plumose stigmas, and is surrounded by six stamens. Spikelets are ellipsoid, 9 mm long and 4 mm wide more or less persistent reduced to sterile lemmas (glumes absent or strongly rudimentary). *O. glaberrima* is photosensitive species. 1<sup>st</sup> flowering is in 215 days after seed germination. The filled grains are more than the sterile grain in a spikelet. It is normally 175 and 142, respectively. *O. glaberrima* plant produces 75 tillers, 50 panicles and thousand grain weight 8.95 g. Growth duration of *O. glaberrima* is about 250 days (seed germination to maturity stage).

### **3.1.7 Procedure of crop cultivation**

#### **i) Seed treatment and raising of seedling for crop cultivation**

Seeds of the wild species of rice were collected from the Department of Agronomy, Bangladesh Agricultural University, Mymensingh. Seed treatment and germination were done using the methods described by Timple *et al.*, (2018) and Waheed *et al.* (2012)

#### **Alternating temperatures and dry heat treatment**

Initially preserved (4-5°C) healthy seeds of each accession was kept in laboratory normal temperature (26+°C) for 24 h. Then the seeds were kept in oven for alternating temperature treatment *i.e.*, 45°C for 12 hours then 30°C for 12 h. After alternating temperature treatment then the seeds were incubated at 50°C for 7 days for

heat treatment. Then the seeds were taken out and kept in normal room temperature for 24 h. Seeds were soaked in water into a pettridish for 48 h and finally soaked seeds put into pettridish with blotting paper in air tide glass house for germination. After soaking in water the lemma and palea of *O. barthii* and *O. latifolia* varieties' seeds were opened. Seeds of maximum variety started sprouting after 48-72 h but in *O. barthii* and *O. latifolia* species needed 8-10 days for sprouting and the seeds were counted as germinated seed when both plumule and radicle had emerged up to 5 mm.

## **ii) Fertilizer application**

The experimental pots were filled up with soil (10.1 kg) and leveled earlier. Puddled soils were fertilized according to the recommendation viz., urea ( $1.7 \text{ g pot}^{-1}$ ), TSP ( $0.40 \text{ g pot}^{-1}$ ), MoP ( $0.71 \text{ g pot}^{-1}$ ), gypsum ( $0.25 \text{ g pot}^{-1}$ ), and zinc sulphate ( $\text{ZnSO}_4$ ) ( $0.035 \text{ g pot}^{-1}$ ). The full amount of TSP, MoP, gypsum and zinc sulphate ( $\text{ZnSO}_4$ ) and one third urea were applied during the final pot preparation and rest of the urea was top dressed at 30 and 50 days after transplanting (DAT). All the fertilizers were incorporated in the top most soil within 6 inch of the pot.

## **iii) Transplanting of seedling**

Seedlings of 10 day old were transplanted into the experimental pot. One seedling was transplanted in the puddled soil of each pot.

### **3.1.8 Intercultural operations**

The following intercultural operations were done for ensuring the normal growth of the crop.

#### **i) Gap filling**

Seedlings of some pot died off, and those were replaced by gap filling at 10 DAT with the seedlings taken from the same source.

#### **ii) Weeding and irrigation**

The hand weeding was done as when necessary to keep the pots free from weeds. Mainly yellow mutha (*Cyperous esculentus*) and shama (*Echinochloa crusgalli*) were

prominent weeds found in the experimental pots. Irrigation was given as per requirement to keep the pots' soil moist for normal growth and development.

### **iii) Plant protection measures**

There was negligible infestation of insect-pests during growth period. Yet to keep the crop growth in normal, Basudin was applied at tillering stage @ 17 kg ha<sup>-1</sup> while Diazinon 60EC @ 850 ml ha<sup>-1</sup> were applied to control stem borer and rice bug. The experiment was netted from maximum tillering onwards to protect from the birds.

### **iv) Harvesting and post harvest operation**

The maturity of crop was determined when 80 % to 90% of the grains were reached to their maturity color. The harvested crop of each pot was separately bundled, properly tagged and then brought to the threshing floor. The bundles were dried in open sunshine and threshed. The grains were cleaned and sun dried to a moisture content of 12%. At harvest, each pot hill was uprooted and the root was washed properly then the shoot and root were placed separately into an oven for drying at 70 °C till stable weight and dry weights of root and shoot were measured (Shimadzu, AUW 220). Straws were also sun dried properly.

#### **3.1.9 Collection of data**

Data collection on the following parameters from the experiment on different growth stages was done:

- Plant height (cm)
- Leaves hill<sup>-1</sup> (no.)
- Nodes plant<sup>-1</sup> (no.)
- Chlorophyll content on leaves (%)
- Length of normal leaf (cm)
- Breadth of normal leaf (cm)
- Length breadth ratio of normal leaf
- Normal leaf area (cm<sup>2</sup>)
- Length of flag leaf (cm)
- Breadth of flag leaf (cm)
- Length breadth ratio of flag leaf

- Flag leaf area (cm<sup>2</sup>)
- Root length (cm)
- Root dry weight hill<sup>-1</sup> (g)
- Shoot dry weight hill<sup>-1</sup> (g)
- Total dry weight hill<sup>-1</sup> (g)
- Days to 1<sup>st</sup> flowering
- Growth duration (days)
- Tillers hill<sup>-1</sup> (no.)
- Effective tillers hill<sup>-1</sup> (no.)
- Non-effective tillers hill<sup>-1</sup> (no.)
- Panicle length (cm)
- Grains panicle<sup>-1</sup> (no.)
- Filled grains panicle<sup>-1</sup> (no.)
- Unfilled grains panicle<sup>-1</sup> (no.)
- Thousand grain weight (g)
- Grain yield hill<sup>-1</sup> (g)
- Biological yield hill<sup>-1</sup> (g)
- Harvest index (%)

#### **i. Plant height (cm)**

Plant height was taken as the length between the bases of the plant to the tip of the top most leaf or panicle of hill at maturity stage and the data were recorded and values were expressed in cm.

#### **ii. Leaves hill<sup>-1</sup>**

The leaves of each hill were counted for each species and data was recorded.

#### **iii. Nodes plant<sup>-1</sup> (no.)**

The nodes of each plant of each hill were counted for each species and average data was recorded.

#### **iv. Chlorophyll content on leaves (%)**

The Soil and Plant Analyzer Development (SPAD) meter is a chlorophyll meter used worldwide due to its convenience. Chlorophyll content of the flag leaf was determined by chlorophyll meter (SPAD-502 plus, Konica Minolta, Inc., Made in Japan) from the middle portion of the leaf. Data was collected from three flag leaf of a hill and average value was recorded and expressed in percentage (%).

#### **v. Normal leaf length, breadth, ratio and leaf area plant<sup>-1</sup>**

The normal leaf length, leaf breadth, ratio and leaf area hill<sup>-1</sup>, from the each species was measured with the help of a leaf area meter (LI-Cor, Model LT-3000, Portable Area Meter, Made in USA). The measurement was taken of 5 leaves hill<sup>-1</sup> of each species at maximum tillering to reproductive stage and then the average data were recorded.

#### **vi. Flag leaf length, breadth, ratio and leaf area plant<sup>-1</sup>**

The flag leaf length, leaf breadth, ratio and leaf area hill<sup>-1</sup>, from the each species was measured with help of a leaf area meter (LI-Cor, Model LT-3000, Portable Area Meter, Made in USA). The measurement was taken of 5 leaves hill<sup>-1</sup> of each species at maximum tillering to reproductive stage and then the average data were recorded.

#### **vii. Root length (cm)**

After harvest the root was collected from the pot and then measured from base to tip of the root with a meter scale of each species and the data was recorded and it was expressed in centimeter (cm).

#### **viii. Root and shoot dry weight hill<sup>-1</sup> (g)**

After harvest the plant samples the root and shoot were separated of each species and the collected samples were kept in an oven and then dried separately. The temperature was fixed at 70°C for 72 h until attained a constant level. After drying the samples were kept in an air for few minutes to cool down and then the dry weights of root and shoot were measured with a weighing machine separately and the data were recorded and it was expressed in g.

**viii. Total dry weight hill<sup>-1</sup> (g)**

The calculated value of root and shoot dry weight hill<sup>-1</sup> of each species was added to determine the value of total dry weight hill<sup>-1</sup> then the data were recorded and it was expressed in g.

**ix. Days to 1<sup>st</sup> flowering (day)**

Number of days required for starting of flowering after seed germination was observed of each species and data were recorded and expressed in days.

**x. Growth duration (day)**

Number of days required after seed germination to maturity (80% of the grains panicle<sup>-1</sup>) was observed of each species and data were recorded and expressed in days.

**xi. Tillers hill<sup>-1</sup> (no.)**

Tillers hill<sup>-1</sup> was counted from each hill<sup>-1</sup> of each species at harvest and then the data was recorded.

**xii. Effective and non-effectivetillers hill<sup>-1</sup> (no.)**

The productive and unproductive tillers of each hill of each species were counted and the data were recorded separately for effective and non-effectivetillers hill<sup>-1</sup>, respectively.

**xiii. Panicle length (cm)**

Panicle length was recorded from the basal node of the rachis to the apex of each panicle. After measuring randomly selected 5 panicle length, the values were averaged and data were recorded expressing the values in cm.

**xiv. Grains panicle<sup>-1</sup> (no.)**

After harvesting grains of randomly selected five panicles of each hill of each species were counted and averaged values were recorded.

**xv. Filled and unfilled grains panicle<sup>-1</sup> (no.)**

Number of filled grains and unfilled grains from randomly selected 5 panicles of each hill of each species were counted and averaged values were recorded separately. Presence of any food material in the grains was considered as filled grain and lacking of any food material in the grains was considered as unfilled grains.

**xvi. Thousand grain weight (g)**

One thousand cleaned dried grains were randomly collected from each hill of each species and were sun dried properly at 12% moisture content and weight by using an electric balance and the data were recorded expressed in g.

**xvii. Grain yield hill<sup>-1</sup> (g)**

Grains obtained from each hill of each species were threshed, cleaned, dried and then weighted. The yield of grain adjusted to 12% moisture content and then it was expressed as g hill<sup>-1</sup>.

**xviii. Biological yield hill<sup>-1</sup> (g)**

Biological yield was calculated by using the following formula:

Biological yield= Grain yield + straw yield

**xix. Harvest index (%)**

Harvest index is the relationship between grain yield and biological yield. It was calculated by using the following formula:

$$HI (\%) = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$





**Plate 3.1.1 Determination of chlorophyll by using SPAD meter**



**Plate 3.1.2 Measuring leaf area of wild rice genotypes using leaf area meter**

### **3.1.10 Statistical analysis**

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program MSTAT-C and then mean difference were adjusted by Least Significance difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).



**Plate 3.1.3 Experimental view of morphological characterization of wild relatives of rice**

## **3.2 Experiment 2: Physiological characterization of wild species of rice**

### **Objective**

- To characterize physiological behaviors of the wild species of rice.

### **3.2.1 Location**

The pot experiment was conducted in the Net House of Agronomy Research Field-1, Department of Agronomy, HSTU, Dinajpur, Bangladesh during the month of March to December, 2019.

### **3.2.2 Pot preparation**

As described in experiment 1.

### **3.2.3 Plant materials**

Ten wild rice species (*O. rufipogon*, *O. alta*, *O. latifolia*, *O. officinalis*, *O. punctata*, *O. barthii*, *O. glaberrima*, *O. nivara*, *Poterricia coactata*, and *O. longistaminata*) were selected for this study on the basis of performance of the growth, yield and yield contributing traits from previous experiment.

### **3.2.4 Experimental design**

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The total number of pots were used in this study was 150 (10 × 5 × 3).

### **3.2.5 Treatments under investigation**

The experiment comprised ten treatments (ten wild rice genotypes) viz.,  $V_1 = Oryza$  *rufipogon*,  $V_2 = O. alta$ ,  $V_3 = O. nivara$ ,  $V_4 = O. latifolia$ ,  $V_5 = Poterricia coactata$ ,  $V_6 = O. glaberrima$ ,  $V_7 = O. longistaminata$ ,  $V_8 = O. officinalis$ ,  $V_9 = O. punctata$  and  $V_{10} = O. barthii$ . The best accession of each species based on the results from the 1<sup>st</sup> experiment was used in the study.

### **3.2.6 Procedure of crop cultivation**

#### **i. Seed treatment and raising of seedling for crop cultivation**

As described in experiment 1.

#### **ii. Germination and vigor test**

The seeds were considered germinated when both plumule and radicle had emerged to 5 mm while the germination percentage was recorded after 8-12 days of treatment. To know the seed health condition the germination as well as the vigour test were done using following formula-

##### **➤ Germination percentage**

Germination percentage was calculated after 10 days by using following formula:

$$\text{Germination percentage} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds}} \times 100$$

##### **➤ Seed vigor index**

Seed vigor index was calculated after 10 days by using following formula:

$$\text{SVI} = \text{Germination \%} \times (\text{Shoot length} + \text{Root length})$$

#### **iii) Fertilizer application**

As described in experiment 1.

#### **iv) Transplanting of seedling**

Seedlings of 10 day old were transplanted into the experimental pot. One seedling was transplanted in the puddle soil of each pot.

### **3.2.7 Intercultural operations**

As described in experiment 1.

### 3.2.8 Collection of data

Data collection on the following parameters from the experiment on different growth stages was done:

- Plant height (cm)
- Normal leaf length (cm)
- Normal leaf breadth (cm)
- Normal leaf length breadth ratio
- Normal leaf area (cm<sup>2</sup>)
- Flag leaf length (cm)
- Flag leaf breadth (cm)
- Flag leaf length breadth ratio
- Flag leaf area (cm<sup>2</sup>)
- Leaves hill<sup>-1</sup> (no.)
- Nodes plant<sup>-1</sup> (no.)
- Days to 1<sup>st</sup> flowering
- Growth duration (day)
- Leaf area hill<sup>-1</sup> (cm<sup>2</sup>)
- Leaf area index
- Chlorophyll content on leaf (%)
- Shoot dry weight hill<sup>-1</sup> (g)
- Root dry weight hill<sup>-1</sup> (g)
- Total dry weight hill<sup>-1</sup> (g)
- Dry matter weight hill<sup>-1</sup> (g)
- Crop growth rate (g m<sup>-2</sup>d<sup>-1</sup>)
- Relative growth rate (g g<sup>-1</sup>d<sup>-1</sup>)
- Net Assimilation Rate (g cm<sup>-2</sup> d<sup>-1</sup>)
- Leaf area duration (dm<sup>2</sup> days)
- Absolute growth rate (g day<sup>-1</sup> hill<sup>-1</sup>)
- Specific leaf area (cm<sup>2</sup> g<sup>-1</sup>)
- Tillers hill<sup>-1</sup> (no.)
- Effective tillers hill<sup>-1</sup> (no.)
- Non-effective tillers hill<sup>-1</sup> (no.)



- Panicle length (cm)
- Grains Panicle<sup>-1</sup> (no.)
- Filled grains panicle<sup>-1</sup> (no.)
- Unfilled grains panicle<sup>-1</sup>(no.)
- Thousand-grain weight (g)
- Grain yield hill<sup>-1</sup> (g)
- Biological yield hill<sup>-1</sup> (g)
- Harvest index (%)

#### **i. Plant height (cm)**

Plant height was taken as the length between the bases of the plant to the tip of the top most leaf or panicle of hill at 25, 50, 75, 100 DAT and harvest, respectively and the data were recorded and values were expressed in cm.

#### **ii. Normal leaf length, breadth, ratio and leaf area hill<sup>-1</sup> (cm<sup>2</sup>)**

The normal leaf length, leaf breadth, ratio and leaf area hill<sup>-1</sup>, from the each species was measured with help of a leaf area meter (LI-Cor, Model LT-3000, Portable Area Meter, Made in USA). The measurement was taken of 5 leaves hill<sup>-1</sup> of each species at maximum tillering to reproductive stage and then the average data were recorded.

#### **iii. Flag leaf length, breadth, ratio and leaf area hill<sup>-1</sup> (cm<sup>2</sup>)**

The flag leaf length, leaf breadth, ratio and leaf area hill<sup>-1</sup>, from the each species was measured with help of a leaf area meter (LI-Cor, Model LT-3000, Portable Area Meter, Made in USA). The measurement was taken of 5 leaves hill<sup>-1</sup> of each species at maximum tillering to reproductive stage and then the average data were recorded.

#### **iv. Leaves hill<sup>-1</sup>**

The leaves of each hill were counted for each species and data was recorded.

#### **v. Nodes plant<sup>-1</sup> (No.)**

The nodes of each plant of each hill were counted for each species and average data was recorded.

#### **vi. Days to 1<sup>st</sup> flowering (day)**

Number of days required for starting of flowering after seed germination was observed of each species and data were recorded and expressed in days.

#### **vii. Growth duration (day)**

Number of days required after seed germination to maturity (80% of the grains panicle<sup>-1</sup>) was observed of each species and data were recorded and expressed in days.

#### **viii. Leaf area hill<sup>-1</sup> (cm<sup>2</sup>)**

The leaf area hill<sup>-1</sup> from the each species was measured with help of a leaf area meter (LI-Cor, Model LT-3000, Portable Area Meter, Made in USA). The measurement was taken of the leaves hill<sup>-1</sup> of each species at 25, 50, 75, 100 DAT and harvest and then the data were recorded expressing in cm<sup>2</sup>.

#### **ix. Leaf area index (LAI)**

Leaf area index were estimated using the following formula (Hunt, 1978). It was done at 25, 50, 75, 100 DAT and harvest.

$$\text{Leaf area index} = \frac{\text{Leaf area per plant (cm}^2\text{)}}{\text{Ground coverage per plant (cm}^2\text{)}}$$

#### **x. Chlorophyll content on leaves (%)**

The Soil and Plant Analyzer Development (SPAD) meter is a chlorophyll meter used worldwide due to its convenience. Chlorophyll content of the flag leaf was determined by SPAD meter from the middle portion of the leaf. Data was collected from three flag leaf of a hill at 25, 50, 75, 100 DAT and harvest and average value was recorded and expressed in percentage (%).

#### **xi. Root and shoot dry weight hill<sup>-1</sup> (g)**

After harvest the plant samples the root and shoot were separated of each species and the collected samples were kept in an oven and then dried separately. The temperature was fixed at 70°C for 72 h until attained a constant level. After drying the samples were kept in an air for few minutes to cool down and then the dry weights of root and

shoot were measured with a weighing machine separately and the data were recorded and it was expressed in g.

#### **xii. Total dry weight hill<sup>-1</sup> (g)**

The calculated value of root and shoot dry weight hill<sup>-1</sup> of each species was added to determine the value of total dry weight hill<sup>-1</sup> then the data were recorded and it was expressed in g.

#### **xiii. Dry matter weight hill<sup>-1</sup> (g)**

The above ground plant parts were collected of each hill of each species at 25, 50, 75, 100 DAT and harvest and the collected samples were kept in an oven and then dried separately. The temperature was fixed at 70<sup>0</sup>C for 72 h until attained a constant level. After drying in an oven the samples were kept in an air for few minutes to cool down and then the dry weights of root and shoot were measured with a weighing machine and the data were recorded and it was expressed in g.

#### **xiv. Crop growth rate (g m<sup>-2</sup> d<sup>-1</sup>)**

The crop growth rate (CGR) values at different growth stages were calculated using the following formula (Brown, 1994).

$$CGR = \frac{1}{GA} \times \frac{W_2 - W_1}{T_2 - T_1} \text{ g m}^{-2} \text{ d}^{-1}$$

Where,

W<sub>1</sub>= Total dry matter production at previous sampling date

W<sub>2</sub>= Total dry matter production at current sampling date

T<sub>1</sub>= Date of previous sampling

T<sub>2</sub>= Date of current sampling

GA= Ground area (m<sup>2</sup>)

#### **xv. Relative growth rate (g g<sup>-1</sup> d<sup>-1</sup>)**

The relative growth rate (RGR) values at different growth stages were calculated using the following formula (Brown, 1994).



$$RGR = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{T_2 - T_1} \text{ (g g}^{-1} \text{ d}^{-1}\text{)}$$

Where,

$W_1$ = Total dry matter production at previous sampling date

$W_2$ = Total dry matter production at current sampling date

$T_1$ = Date of previous sampling

$T_2$ = Date of current sampling

$\text{Log}_e$ = Natural logarithm

#### **xvi. Net assimilation rate (g cm<sup>-2</sup> d<sup>-1</sup>)**

The net assimilation rate (NAR) is calculated at different growth stages with the following formula:

$$NAR = \frac{RGR}{LAR} \text{ (g cm}^{-2} \text{ d}^{-1}\text{)}$$

This value represents the efficiency of production.

#### **xvii. Leaf area duration (dm<sup>2</sup> days)**

The leaf area duration (LAD) is calculated at different growth stages with the following formula:

$$LAD = \frac{LAI_1 + LAI_2}{t_2 - t_1} \times 2 \text{ (dm}^2 \text{ days)}$$

Where,  $LA_1$  and  $LA_2$  are the leaf area at time  $t_1$  and  $t_2$ , respectively.

#### **xviii. Absolute growth rate (AGR)**

The absolute growth rate (AGR) is calculated at different growth stages with the following formula:

$$AGR = \frac{W_2 - W_1}{T_2 - T_1} \text{ (g day}^{-1} \text{ hill}^{-1}\text{)}$$

Where,

$W_2$ = Total plant dry matter at time  $T_2$

$W_1$ = Total plant dry matter at time  $T_1$

**xiv. Absolute growth rate (cm day<sup>-1</sup>)**

$$AGR = \frac{h_2 - h_1}{t_2 - t_1} \text{ (cm day}^{-1}\text{)}$$

Where h<sub>1</sub> and h<sub>2</sub> are the plant height at time t<sub>1</sub> and t<sub>2</sub>

**xx. Specific leaf area (cm<sup>2</sup> g<sup>-1</sup>)**

The specific leaf area (SLA) is calculated at different growth stages with the following formula:

$$SLA = \frac{LA}{LW} \text{ (cm}^2 \text{ g}^{-1}\text{)}$$

Where, LA = leaf area

LW = Leaf dry weight

**xxi. Tillers hill<sup>-1</sup> (no.)**

Tillers hill<sup>-1</sup> was counted from each hill<sup>-1</sup> of each species at harvest and then the data was recorded.

**xxii. Effective and non-effective tillers hill<sup>-1</sup> (no.)**

The productive and unproductive tillers of each hill of each species were counted and the data were recorded separately for effective and non-effective tillers hill<sup>-1</sup>, respectively.

**xxiii. Panicle length (cm)**

Panicle length was recorded from the basal node of the rachis to the apex of each panicle. After measuring randomly 3 selected panicle length, the values were averaged and data were recorded expressing the values in cm.

**xxiv. Grains panicle<sup>-1</sup> (no.)**

After harvesting grains of randomly 3 selected panicles of each hill of each species were counted and averaged values were recorded.

#### **xxv. Filled and unfilled grains panicle<sup>-1</sup> (no.)**

Number of filled grains and unfilled grains from randomly selected 3 panicles of each hill of each species were counted and averaged values were recorded separately. Presence of any food material in the grains was considered a filled grain and lacking of any food material in the grains was considered as unfilled grains.

#### **xxvi. Thousand grain weight (g)**

One thousand cleaned dried grains were randomly collected from each hill of each species and were sun dried properly at 12% moisture content and weight by using an electric balance and the data were recorded expressed in g.

#### **xxvii. Grain yield hill<sup>-1</sup> (g)**

Grains obtained from each hill of each species were threshed, cleaned, dried and then weighted. The yield of grain adjusted to 12% moisture content and then it was expressed as g hill<sup>-1</sup>.

#### **xxviii. Biological yield hill<sup>-1</sup> (g)**

Biological yield was calculated by using the following formula:

Biological yield= Grain yield + straw yield

#### **xxix. Harvest index (%)**

Harvest index is the relationship between grain yield and biological yield. It was calculated by using the following formula:

$$HI (\%) = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

### **3.2.9 Statistical analysis**

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program MSTAT-C and then mean difference were adjusted by Least Significance difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).



**Plate 3.2.1 Experimental view of physiological characterization of wild species of rice**

### **3.3 Experiment 3: Growth and yield dynamics of selected rice genotypes under drought stress condition**

#### **Objectives**

- To know the tolerance level of the selected accessions against drought stress.
- To identify the characters of the selected accessions conferring drought tolerance.

#### **3.3.1 Location**

The pot experiment was conducted in the Net House of Agronomy Research Field-1, Department of Agronomy, HSTU, Dinajpur, Bangladesh during July to December, 2020.

#### **3.3.2 Pot preparation**

As described in experiment 1.

#### **3.3.3 Plant materials**

Ten accessions of wild species of rice namely *O. rufipogon*, *O. alta*, *O. latifolia*, *O. officinalis*, *O. punctata*, *O. barthii*, *O. glaberrima*, *O. nivara*, *O. potanica coactata*, and *O. longistaminata*, and 2 cultivated rice varieties (viz., FR13 as drought tolerant and BRRI dhan29 as drought sensitive) were used for screening of wild species of rice for salinity tolerance for the study.

##### **i. FR13A**

The FR13A also known as Dhalputtia is local landrace accession from Odisha, India and Sri Lanka's Kurkaruppan, Goda Heenati and Thavalu were recognized for their resistance to complete submergence. FR13A stood out as highly tolerant to submergence; 100% of the 10-day-old seedlings survived complete submergence for 7 days. FR13A, however, lacks other agronomic characteristics. It is photoperiod sensitive and offers low grain yields of poor quality. It is the source of the Submergence1 (Sub1) locus that confers submergence tolerance by limiting the growth of underwater elongation, which is a potent feature for the development of submergence tolerance rice variety in breeding program.

### **3.3.4 Experimental design**

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The total number of pots were used in this study was 72 (12 × 3 × 2).

### **3.3.5 Treatments under investigation**

The experiment consisted of two factors; Factor A: 12 rice genotypes viz., V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potrericia coaractata*, V<sub>11</sub>= *O. latifolia* and V<sub>12</sub>= *O. officinalis* and Factor B: 2 drought stress level viz., D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity.

### **3.3.6 Procedure of crop cultivation**

#### **i) Seed treatment and raising of seedling for crop cultivation**

As described in experiment 1.

#### **ii) Fertilizer application**

As described in experiment 1.

#### **iii) Transplanting of seedling**

Seedlings of 10 day old were transplanted into the experimental pots. One seedling was transplanted in the puddle soil of each pot.

#### **iv. Soil Moisture**

The moisture content of the soil in the pots was determined and maintained by three way soil moisture meter, model name: AB0543, Jenshri India Pvt. Ltd., New Delhi until harvest.

#### **Maintaining field capacity of soil**

Soil sample was taken in earthen pot. The soil was saturated with water and the pot was kept on a shade net house for 72 h. Then the pot was weighed by an electric

balance and again the pot was kept in an oven at 105 °C for 72 h. Weight of oven dry soil was taken and moisture content of the soil sample was determined by gravimetric method. The percent of moisture present in the soil sample was the field capacity of the soil.



A



B

**Plate 3.3.1 A. Soil moisture determination during pot preparation using three-way moisture meter and B. Maintaining soil moisture at 40-45% field capacity using three-way moisture meter during drought stress experiment**

### 3.3.7 Intercultural operations

As described in experiment 1.

### 3.3.8 Collection of data

Data collection on the following parameters from the experiment at harvest was done:

- Plant height (cm)
- Leaves plant<sup>-1</sup> (no.)
- Nodes plant<sup>-1</sup> (no.)
- Root length (cm)
- Normal leaf length (cm)
- Normal leaf breadth (cm)
- Normal leaf length breadth ratio
- Normal leaf area (cm<sup>2</sup>)
- Flag leaf length (cm)
- Flag leaf breadth (cm)
- Flag leaf length breadth ratio
- Flag leaf area (cm<sup>2</sup>)
- Shoot dry weight hill<sup>-1</sup> (g)
- Root dry weight hill<sup>-1</sup> (g)
- Total dry weight hill<sup>-1</sup> (g)
- Days to 1<sup>st</sup> flowering (nays)
- Growth duration (nays)
- Tillers hill<sup>-1</sup> (no.)
- Effective tillers hill<sup>-1</sup> (no.)
- Non-effective tillers hill<sup>-1</sup> (no.)
- Panicle length (cm)
- Grains panicle<sup>-1</sup> (no.)
- Filled grains panicle<sup>-1</sup> (no.)
- Unfilled Grains panicle<sup>-1</sup> (no.)
- Grain fertility percentage (%)
- Grain sterility percentage (%)
- Thousand grain weight (g)



- Grain yield hill<sup>-1</sup> (g)
- Biological yield hill<sup>-1</sup> (g)
- Harvest index (%)
- Relative water content (%)
- Water saturation deficit (%)
- Water retention capacity
- Water uptake capacity
- Chlorophyll 'a' content on leaf (mg g<sup>-1</sup> FW)
- Chlorophyll 'b' content on leaf (mg g<sup>-1</sup> FW)
- Carotenoid content (mg g<sup>-1</sup> FW)
- Proline content on leaf (μmol g<sup>-1</sup> FW)

#### **i. Plant height (cm)**

Plant height was taken as the length between the bases of the plant to the tip of the top most leaf or panicle of hill and the data were recorded and values were expressed in cm.

#### **ii. Leaves hill<sup>-1</sup>**

The leaves of each hill were counted for each species and data was recorded.

#### **iii. Nodes plant<sup>-1</sup> (no.)**

The nodes of each plant of each hill were counted for each species and average data was recorded.

#### **iv. Root length (cm)**

After harvest the root was collected from the pot and then measured from base to tip of the root with a meter scale of each species and the data was recorded and it was expressed in centimeter (cm).

#### **v. Normal leaf length, breadth, ratio and leaf area hill<sup>-1</sup>**

The normal leaf length, leaf breadth, ratio and leaf area hill<sup>-1</sup>, from the each species was measured with help of a leaf area meter (LI-Cor, Model LT-3000, Portable Area

Meter, Made in USA). The measurement was taken of 5 leaves hill<sup>-1</sup> of each species at maximum tillering to reproductive stage and then the average data were recorded.

**vi. Flag leaf length, breadth, ratio and leaf area hill<sup>-1</sup>**

The flag leaf length, leaf breadth, ratio and leaf area hill<sup>-1</sup>, from the each species was measured with help of a leaf area meter (LI-Cor, Model LT-3000, Portable Area Meter, Made in USA). The measurement was taken of 5 leaves hill<sup>-1</sup> of each species at maximum tillering to reproductive stage and then the average data were recorded.

**vii. Root and shoot dry weight hill<sup>-1</sup> (g)**

After harvest the plant samples the root and shoot were separated of each species and the collected samples were kept in an oven and then dried separately. The temperature was fixed at 70°C for 72 h until attained a constant level. After drying the samples were kept in an air for few minutes to cool down and then the dry weights of root and shoot were measured with a weighing machine separately and the data were recorded and it was expressed in g.

**viii. Total dry weight hill<sup>-1</sup> (g)**

The calculated value of root and shoot dry weight hill<sup>-1</sup> of each species was added to determine the value of total dry weight hill<sup>-1</sup> then the data were recorded and it was expressed in g.

**ix. Days to 1<sup>st</sup> flowering (day)**

Number of days required for starting of flowering after seed germination was observed of each species and data were recorded and expressed in days.

**x. Growth duration (day)**

Number of days required after seed germination to maturity (80% of the grains panicle<sup>-1</sup>) was observed of each species and data were recorded and expressed in days.

**xi. Tillers hill<sup>-1</sup> (no.)**

Tillers hill<sup>-1</sup> was counted from each hill<sup>-1</sup> of each species at harvest and then the data was recorded.

#### **xii. Effective and non-effective tillers hill<sup>-1</sup> (no.)**

The productive and unproductive tillers of each hill of each species were counted and the data were recorded separately for effective and non-effective tillers hill<sup>-1</sup>, respectively.

#### **xiii. Panicle length (cm)**

Panicle length was recorded from the basal node of the rachis to the apex of each panicle. After measuring randomly 3 selected panicle length, the values were averaged and data were recorded expressing the values in cm.

#### **xiv. Grains panicle<sup>-1</sup> (no.)**

After harvesting grains of randomly 3 selected panicles of each hill of each species were counted and averaged values were recorded.

#### **xv. Filled and unfilled grains panicle<sup>-1</sup> (no.)**

Number of filled grains and unfilled grains from randomly selected 3 panicles of each hill of each species were counted and averaged values were recorded separately. Presence of any food material in the grains was considered a filled grain and lacking of any food material in the grains was considered as unfilled grains.

#### **xvi. Grain fertility and sterility percentage (%)**

Grain fertility and sterility percentage were determined using following formula:

$$\text{Grain fertility percentage (\%)} = \frac{\text{Filled grains per panicle}}{\text{Total grains per panicle}} \times 100$$

$$\text{Grain sterility percentage (\%)} = \frac{\text{Unfilled grains per panicle}}{\text{Total grains per panicle}} \times 100$$

#### **xvii. Thousand grain weight (g)**

One thousand cleaned dried grains were randomly collected from each hill of each species and were sun dried properly at 14% moisture content and weight by using an electric balance and the data were recorded expressed in g.

#### **xviii. Grain yield hill<sup>-1</sup> (g)**

Grains obtained from each hill of each species were threshed, cleaned, dried and then weighted. The yield of grain adjusted to 12% moisture content and then it was expressed as g hill<sup>-1</sup>.

#### **xix. Biological yield hill<sup>-1</sup> (g)**

Biological yield was calculated by using the following formula:

Biological yield= Grain yield + straw yield

#### **xx. Harvest index (%)**

Harvest index is the relationship between grain yield and biological yield. It was calculated by using the following formula:

$$HI (\%) = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

#### **xxi. Determination of water relation behavior procedures**

##### **Measurement of relative water content (RWC) in leaves of rice plants**

##### **Procedure:**

The plant samples (flag leaf) were excised just prior to sun set and after taking fresh weight, their base immediately placed in glass jar containing 5 to 6 cm water height. The jars were enclosed with plastic cover to maintain 100% relative humidity and the leaves were allowed to watered 24 h at 25°C (room temperature) in dark. The following day, the saturated leaves were removed from jars and immediately the turgid weight of leaves was recorded. After that the leaves were dried at 80°C for 72 h in an oven. Then dry weight was also taken. All type of weights (fresh, turgid and dry weight) of the leaves were recorded with the help of a precise electronic balance and used to determine RWC, WSD, WRC and WUC following the procedure of Baque *et al.* (2002):

$$\text{Relative water content (WRC) (\%)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

Water saturation deficit (WSD) (%) =  $100 - \text{Relative water content}$

Water retention capacity (WRC) =  $\frac{\text{Turgid weight}}{\text{Dry weight}}$

Water Uptake Capacity (WUC) =  $\frac{\text{Turgid weight} - \text{Fresh weight}}{\text{Dry weight}}$

## **xxii. Chlorophyll and carotenoids determination**

Extraction and determination of chlorophyll and carotenoids were performed according to the method of Arnon (1949). Five hundred milligrams of fresh leaf material was ground with 10 ml of 80% acetone at 4°C and centrifuged at 2500 rpm for 10 minutes at 4°C. This procedure was repeated until the residue became colorless. The extract was transferred to a graduated tube and made the volume up to 10 ml with 80% acetone and assayed immediately. Three milliliters aliquots of the extract were transferred to a cuvette and the absorbance was read at 645, 663 and 480 nm with a spectrophotometer (UV-1800, Shimadzu, Japan) against 80% acetone as blank. Chlorophyll content was calculated using the formula of Arnon (1949) and expressed in mg g<sup>-1</sup> FW.

Chlorophyll a (mg g<sup>-1</sup> FW) =  $\{12.7 (D_{663}) - 2.69 (D_{645})\} \times V / (1000 \times w)$

Chlorophyll b (mg g<sup>-1</sup> FW) =  $\{22.9 (D_{645}) - 4.68 (D_{663})\} \times V / (1000 \times w)$

Carotenoids content was estimated using the formula of Kirk and Allen (1965) and expressed in mg g<sup>-1</sup> FW.

Carotenoids (mg g<sup>-1</sup> FW) =  $\{(1000 \times (D_{470}) \times V / w / 1000) - (1.9 \times \text{Chl a}) - (63.14 \times \text{Chl b})\} / 214$

Where D = optical density, V = final volume of 80% acetone (ml) and w = fresh weight of sample taken (g)

## **xxiii. Estimation of proline**

Proline content of the leaves during the anthesis stage in wild rice was estimated. Leaves from each replication of each species was collected and immediately kept in the ice-bag and was brought to the laboratory of Crop Physiology and Ecology

Department, Hajee Mohammad Danesh Science and Technology University for proline estimation. One gram fresh weight of the leaf was taken for proline estimation. Subsequently proline was estimated as Troll and Lindsley (1955) as follows.

At first, ninhydrin reagent was prepared in such a way so that it was utilized for proline estimation within two hours of preparation. For preparing ninhydrin reagent, addition of 30 ml glacial acetic acid and 30 ml 6 M orthophosphoric acid were mixed with 1.25 g of ninhydrin. It was subsequently heated and stirred gently to dissolve but the temperature was not allowed to exceeding 70°C. Proline standards were prepared for 0, 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20 ppm with distilled water.

The fresh samples were crushed in mortar and pestle and homogenized the material in 10 ml 3% sulphosalicylic acid until no large segments of plant material remained. Homogenate was filtered through Whatman No. 2 filter paper and washed with 3% sulphosalicylic acid and the volume was set to 25 ml. Two ml of the filtrate and each standard proline solutions were then reacted with 2 ml of ninhydrin reagent and 2 ml of glacial acetic acid in a pyrex test tube and boil for one hour at 100°C in water bath covering the tube with aluminium foil to prevent excess evaporation. Subsequently, it was cool in ice bath and 4 ml of toluene was added to each tube using a dispenser. Each tube was then shaken vigorously for 15 to 20 seconds in an electrical shaker and was allowed the layer to separate for 30 minutes. The absorbance of layer was measured through spectrophotometer at 520 nm with pure toluene as a blank. Proline content was expressed on a fresh weight basis from the standard curve, using standard L-proline according to the method developed by Troll and Lindsley (1955).

### **3.3.9 Statistical analysis**

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program MSTAT-C and then mean difference were adjusted by Least Significance difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).



A



B

**Plate 3.3.2 Experimental view of screening of wild relatives of rice conferring to drought: A. Early stage and B. Impact of drought stress**

### **3.4 Experiment 4: Growth and yield performance of selected rice genotypes as affected by salinity stress**

#### **Objectives**

- To know the tolerance level of the selected accessions to salinity stress.
- To identify the characters of the selected accessions conferring salinity tolerance.

#### **3.4.1 Location**

The pot experiment was carried out in the Net House of Agronomy Research Field-1, Department of Agronomy, HSTU, Dinajpur, Bangladesh during July to December, 2020.

#### **3.4.2 Pot preparation**

As described in experiment 1.

#### **3.4.3 Plant materials**

Ten wild rice species (*O. rufipogon*, *O. alta*, *O. latifolia*, *O. officinalis*, *O. punctata*, *O. barthii*, *O. glaberrima*, *O. nivara*, *Potrericia coactata*, and *O. longistaminata*) and 2 cultivated rice varieties (viz., Pokkali as salt tolerant and BRRI dhan29 as salt sensitive) were used as plant materials.

#### **i. Pokkali**

Pokkali is a unique saline tolerant rice species that is cultivated using extensive aquaculture in an organic way in the water-logged coastal regions, spread in about 5000 hectares area in Alappuzha, Thrissur and Ernakulam districts of Kerala in Southern India. The brand *Pokkali* has received a GI tag from the Geographical Indications Registry Office, Chennai. Its resistance to salinity is remarkable. The rice is cultivated from June to early November when the salinity level of the water in the fields is low and from mid November to mid April, when the salinity is high. In order to survive in the water-logged field, the rice plants grow up to 130-140 cm. But, as they mature, they bend over and collapse with only the panicles standing upright. Harvesting takes place by end-October. The organically-grown Pokkali is famed for



its peculiar taste and its high protein content. Farmers claim that the rice its grains are extra large which has several medicinal properties.

## **ii. BRRI dhan29**

BRRI dhan29 is developed by Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh in 1994. It is originated from BR 802-118-4-2. It is 95 cm tall with strong culm has anti lodging capacity. It is very popular variety in boro season in Bangladeshi farmer. Due to its high yielding capacity it required more fertilizer. It is tolerance to leaf blight and sheath blight disease. Average yield is 7.50 t ha<sup>-1</sup>. Rice grain is medium size fine grain white in color. Life cycle is 160 days. Due to its high yielding capability it is also called mega variety.

### **3.4.4 Experimental design**

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The total number of pots were used in this study was 108 (12 × 3 × 3).

### **3.4.5 Treatments under investigation**

The experiment comprised of two factors; Factor A: 12 rice genotypes viz., V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potrericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant)and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive) and Factor B: 3 salinity levels viz., S<sub>1</sub>= 0 mM NaCl (Control) , S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl.

### **3.4.6 Procedure of crop cultivation**

#### **i) Seed treatment and raising of seedling for crop cultivation**

As described in experiment 1.

#### **ii) Fertilizer application**

As described in experiment 1.

### **iii) Transplanting of seedling**

Seedlings of 10 day old were transplanted into the experimental pots. One seedling was transplanted in the puddle soil of each pot.

### **iv. Imposition of salinity treatments**

The commercial salt (NaCl) was used for developing salinity. For S<sub>1</sub>, S<sub>2</sub>, and S<sub>3</sub> treatments 0.0 g, 43.8 g and 87.6 g of salts were added, respectively in concerned pots. These amounts of salts were dissolved in 1000 ml of distilled water and the solutions were then poured uniformly into the pots. The saline treatments were given at maximum tillering stage *i.e.*, 75 DAT. The salinity levels of pots soils were monitored at 15 days interval from the imposition of salinity up to the completion of the investigation. Sometimes salinity levels were found to be dropped below the treatment standards because of high rainfall and then salinity levels were corrected by pouring appropriate salt solution in the respective treatments pots.

### **3.4.7 Intercultural operations**

As described in experiment 1.

### **3.4.8 Collection of data**

Data collection on the following parameters from the experiment on different growth stages was done:

- Plant height (cm)
- Leaves plant<sup>-1</sup> (no.)
- Nodes plant<sup>-1</sup> (no.)
- Days to 1<sup>st</sup> flowering (days)
- Growth duration (days)
- Normal leaf length (cm)
- Normal leaf breadth (cm)
- Normal leaf length breadth ratio
- Normal leaf area (cm<sup>2</sup>)
- Flag leaf length (cm)
- Flag leaf breadth (cm)

- Flag leaf length breadth ratio
- Flag leaf area (cm<sup>2</sup>)
- Root length (cm)
- Shoot dry weight hill<sup>-1</sup> (g)
- Root dry weight hill<sup>-1</sup> (g)
- Total dry weight hill<sup>-1</sup> (g)
- Tillers hill<sup>-1</sup> (No.)
- Effective tillers hill<sup>-1</sup> (no.)
- Non-effective tillers hill<sup>-1</sup> (no.)
- Panicle length (cm)
- Grains panicle<sup>-1</sup> (no.)
- Filled grains panicle<sup>-1</sup> (no.)
- Unfilled grains panicle<sup>-1</sup> (no.)
- Thousand grain weight (g)
- Grain yield hill<sup>-1</sup> (g)
- Biological yield hill<sup>-1</sup> (g)
- Harvest index (%)
- Chl a content on leaf (mg g<sup>-1</sup> FW)
- Chl b content on leaf (mg g<sup>-1</sup> FW)
- Carotenoid content (mg g<sup>-1</sup> FW)
- Proline content on leaf (μmol g<sup>-1</sup> FW)
- Relative water content (%)
- Water saturation deficit (%)
- Water retention capacity
- Water uptake capacity
- Plant survival rate (%)
- Phenotypic acceptability (PAcp)

### **Estimation of proline**

Proline content of the leaves during the anthesis stage in wild rice was estimated. Leaves from each replication of each species was collected and immediately kept in the ice-bag and was brought to the laboratory of Crop Physiology and Ecology Department, Hajee Mohammad Danesh Science and Technology University for proline estimation. One gram fresh weight of the leaf was taken for proline

estimation. Subsequently proline was estimated as Troll and Lindsley (1955) as follows.

At first, ninhydrin reagent was prepared in such a way so that it was utilized for proline estimation within two hours of preparation. For preparing ninhydrin reagent, addition of 30 ml glacial acetic acid and 30 ml 6 M orthophosphoric acid were mixed with 1.25 g of ninhydrin. It was subsequently heated and stirred gently to dissolve but the temperature was not allowed to exceed 70°C. Proline standards were prepared for 0, 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20 ppm with distilled water.

The fresh samples were crushed in mortar and pestle and homogenized the material in 10 ml 3% sulphosalicylic acid until no large segments of plant material remained. Homogenate was filtered through Whatman No. 2 filter paper and washed with 3% sulphosalicylic acid and the volume was set to 25 ml. Two ml of the filtrate and each standard proline solutions were then reacted with 2 ml of ninhydrin reagent and 2 ml of glacial acetic acid in a pyrex test tube and boil for one hour at 100°C in water bath covering the tube with aluminium foil to prevent excess evaporation. Subsequently, it was cooled in ice bath and 4 ml of toluene was added to each tube using a dispenser. Each tube was then shaken vigorously for 15 to 20 seconds in an electrical shaker and was allowed the layer to separate for 30 minutes. The absorbance of layer was measured through spectrophotometer at 520 nm with pure toluene as a blank. Proline content was expressed on a fresh weight basis from the standard curve, using standard L-proline according to the method developed by Troll and Lindsley (1955).



A



B

**Plate 3.4.1 A. Collection of leaf samples for chlorophyll determination and Water relation behavior B. Color developed during measuring of chlorophyll and carotenoids of rice genotypes**



**Plate 3.4.2 Determination of chlorophyll and carotenoids with a spectrophotometer**

### **Phenotypic acceptability (PAcp)**

Standard Evaluation System (SES) scoring is one of the indicators of measuring salinity tolerance in maximum tillering stage of rice plant. Salinity scoring was done to identify the tolerant and sensitive plants based on visual symptoms by scoring each



genotype from 1 to 9 following Modified Standard Evaluation System of IRRI (IRRI, 1996).

Where,

| <u>Scale</u> | <u>Remark</u> |
|--------------|---------------|
| 1            | Excellent     |
| 3            | Good          |
| 5            | Fair          |
| 7            | Poor          |
| 9            | Unacceptable  |

### 3.4.9 Statistical analysis

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program MSTAT-C and then mean difference were adjusted by Least Significance difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).



**Plate 3.4.3 Experimental view of screening of wild relatives of rice conferring to salinity stress**

### 3.5 Experiment 5: Allelic diversity analysis of wild rice accession for salinity tolerance

**Location:** The experiment was carried out at Laboratory, Biotechnology Division, Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh-2202.

**Objective:** To detect the genetic diversity of wild rice genotypes

#### 3.5.1 Plant materials

Twelve rice genotypes were used for this study as shown in Table 3.5.1 below:

**Table 3.5.1 Name of wild rice (*Oryza* sp.) genotypes**

| Sl.No. | Name the wild rice genotypes |
|--------|------------------------------|
| 1      | <i>O. rufipogon</i>          |
| 2      | <i>O. alta</i>               |
| 3      | <i>O. longistaminata</i>     |
| 4      | <i>O. barthii</i>            |
| 5      | <i>O. latifolia</i>          |
| 6      | <i>O. officinalis</i>        |
| 7      | <i>O. nivara</i>             |
| 8      | <i>O. punctata</i>           |
| 9      | <i>O. glaberima</i>          |
| 10     | <i>Porteresia coarctata</i>  |
| 11     | <i>Pokkali</i>               |
| 12     | <i>Nonabokra</i>             |

#### 3.5.2 Collection of leaf sample for DNA extraction

Leaves of 21 day old young, juvenile and vigorous plants were cut apart with sterilized scissors and washed in 70% ethanol and distilled water. The collected leaf samples were then kept in polythene bags with labeling. The bags were placed in an icebox to carry them in the laboratory for avoiding any damage to the leaf tissues. The samples were then stored in a 80°C freezer.

#### 3.5.3 Genomic DNA isolation

##### Reagent used

1. Extraction buffer: TEN buffer (100 mM Tris, 10 mM EDTA and 250 mM NaCl, pH = 8) + 1% SDS

2. Proteinase K: Diluted to 10 mg/ml using deionized water.
3. Phenol: Chloroform: Isoamyl alcohol = 25: 24: 1, equilibrated to pH near 8.0 with TEN buffer (pH = 8.0)
4. Chloroform: Isoamyl alcohol = 25: 1
5. TE buffer: 10 mM Tris, 1mM EDTA, pH = 8.0
6. Isopropanol
7. Ethanol: 100% and 70%. 8. Sodium acetate (3 M), pH = 5.2

Genomic DNA was extracted from the leaves using proteinase-K digestion, phenol–chloroform–isoamyl alcohol purification method (Bala *et al.*, 2017). The leaves were taken out from ethanol and dried on tissue paper. For each sample, approximately 30 mg of leaf sample was cut into slight pieces with the help of scissor and forceps and taken in 1.5 ml micro- centrifuge tube. Initially 225 µl of extraction buffer was added and the sample was ground with tissue homogenizer. Additional 225 µl of extraction buffer and 20 µl proteinase –K enzyme were added. The homogenate was incubated overnight at 37°C hot water bath (JP Selecta) for digestion. For purification, the tissue lysate was extracted with equal volume of phenol: chloroform: isoamyl alcohol (25:24:1) and mixed by vortexing for 30 sec. Then the solution was centrifuged for 10 min at 13,000 rpm to allow precipitation of cell debris. The organic layer portion and the extraction were mixed once with equal volume (450 µl) of chloroform: isoamyl alcohol (24:1) followed by vortexing for 20 sec. After centrifuge at 13,000 rpm for 10 min, the solution showed two distinct layers: upper layer contained DNA solution and lower layer had protein debris. The upper layer was transferred to a new tube and DNA was precipitate first using 0.6 volumes (240 µl) of isopropanol in the presence of 0.3 M sodium acetate (20 µl). After mixing with gentle shaking, genetic DNA was observed as a cotton-like structure. Then the tubes with tread like DNA were kept into the Freeze at - 20°C for 39 min. After then, DNA was pelleted by centrifugation at 13,000 rpm for 15 min. After removing the liquid completely, the pelleted DNA was washed with 0.5 ml of 70% ethanol and centrifuged at 13,000 rpm for 10 min. The ethanol was discarded and the pellet air-dried and suspended in 100 µl TE Buffer. Finally, the tubes with DNA samples were stored in freezer at -20°C.



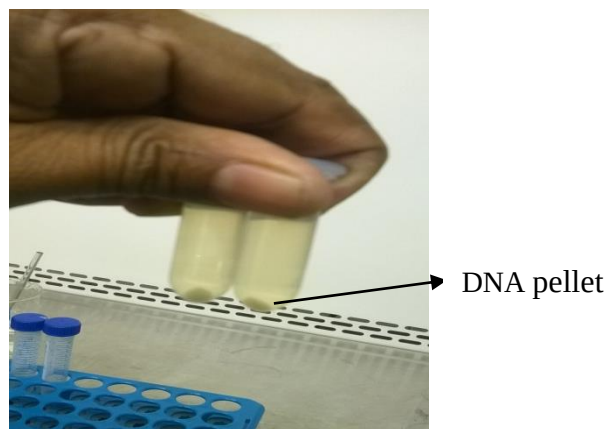


**Plate 3.5.1 DNA pellet of some representative wild rice genotype samples**

#### **3.5.4 Confirmation of DNA sample**

All DNA samples were tested qualitatively (presence of RNA or degradation of DNA) on 1% agarose gel. The extracted DNA often contains a large amount of RNA and pigments that can usually cause over estimation of DNA concentration. The quality of the DNA was estimated quantitatively by the Nanodrop Calibri, (TITERTEK BERTHOLD ) Germany.

#### **3.5.5 Preparation of 1% agarose gel**

For preparing 1% agarose gel, 1g agarose was taken in a 500ml conical flask containing 100ml electrophoretic buffer (1x TAE buffer). The top of the flask was covered with aluminium foil paper to avoid excessive evaporation and cooked in a microwave- oven with occasional swirling until complete disappearance of agarose particles. Then the flask was kept in room temperature to cool down. When the flask was cooled enough to hold with bare hand, the gel was poured on a gel bed placed on a level bench and the appropriate comb was inserted and air bubbles if any was removed carefully. The gel was kept at least 1 hour at room temperature to cool down completely and when it is done and solidified, the comb was removed gently to avoid disruption of the wells and placed in the electrophoration chamber containing 1x TAE buffer.

#### **3.5.6 Preparation of DNA samples for agarose gel electrophoresis (AGE)**

For each sample, 2  $\mu$ l of deionized distilled water was placed on a sterile polythene paper and 1  $\mu$ l of loading dye was added to it. Loading dye was used to monitor the

loading and progress of electrophoresis and to increase the weight of the samples so that it stayed in the well. Then 3  $\mu$ l of DNA was added to it and mixed well using micropipette. The samples were loaded carefully on the gel. A molecular weight marker DNA was loaded on either side of the gel. Electrophoresis was performed at 100V for 90 min using the power supply. The electrophoresis was stopped after the bromophenol blue dye had reached three-fourth of the gel length.

### 3.5.7 Documentation of DNA sample

For documentation, the gel was removed from the electrophoresis chamber, stained with ethidium bromide (1 $\mu$ g/ml) and placed on the high performance ultraviolet trans- illuminator of a gel documentation system (BioDoc-It<sup>TM</sup> Imaging system) to observe the quality of the genomic DNA. Then the gel image was viewed on the monitor and saved in computer hard drive. The electrophoresis of genomic DNA sample is shown in Plate 3.5.2.

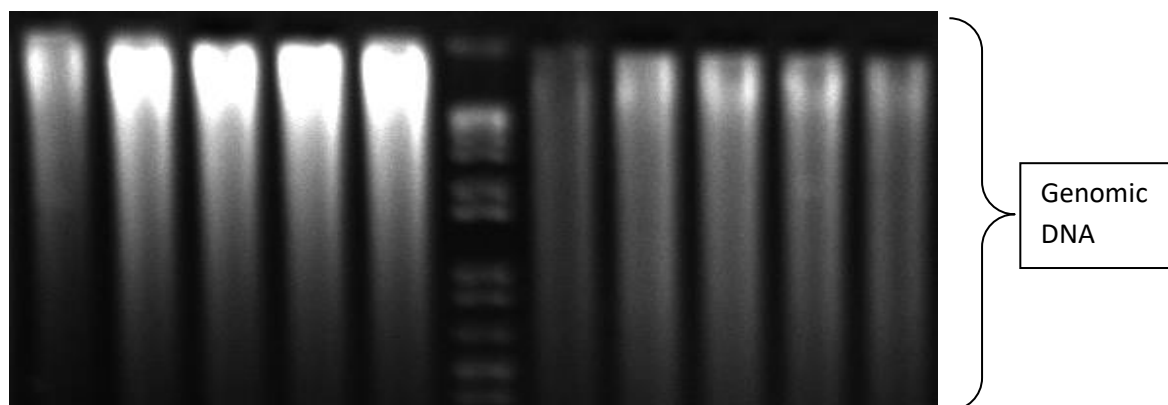


**Plate 3.5.2 Confirmation of genomic DNA sample**

### 3.5.8 Quantification of DNA concentration

In the beginning of the DNA quantification, the nanodrop quantifier was neutralized by using One microliter of TE buffer. The concentration of TE buffer was constant of the DNA isolation TE buffer. 1 ng/  $\mu$ l TE buffer place into the quantifier and make the result zero. After that 1 $\mu$ l DNA sample was placed into the machine and press measure, thus the concentration of DNA sample was measured as shown in Table 3.5.2

**Table 3.5.2 DNA concentration by nanodrop calibri (TITERTEK BERTHOLD)**

| Sl. No | Sample Name                 | Nucleic Acid Conc. (ng/μl) | A260/A280 (ng/μl) | Sample Type | Factor |
|--------|-----------------------------|----------------------------|-------------------|-------------|--------|
| 1      | <i>O. rufipogon</i>         | 1338.25                    | 1.77              | DNA         | 50     |
| 2      | <i>O. alta</i>              | 13.5033                    | 1.71              | DNA         | 50     |
| 3      | <i>O. longistaminata</i>    | 851.60                     | 1.64              | DNA         | 50     |
| 4      | <i>O. barthii</i>           | 429.74                     | 1.82              | DNA         | 50     |
| 5      | <i>O. latifolia</i>         | 805.71                     | 1.71              | DNA         | 50     |
| 6      | <i>O. officinalis</i>       | 1156.83                    | 1.98              | DNA         | 50     |
| 7      | <i>O. nivara</i>            | 1363.41                    | 1.77              | DNA         | 50     |
| 8      | <i>O. punctata</i>          | 1090.41                    | 1.89              | DNA         | 50     |
| 9      | <i>O. glaberima</i>         | 1357.25                    | 1.88              | DNA         | 50     |
| 10     | <i>Porteresia coarctata</i> | 1239.48                    | 1.80              | DNA         | 50     |
| 11     | <i>Pokkali</i>              | 1151.39                    | 1.88              | DNA         | 50     |
| 12     | <i>Nonabokra</i>            | 1369.82                    | 1.91              | DNA         | 50     |

**3.5.9 Preparation of working solution of DNA samples**

Before PCR amplification of DNA, the DNA concentrations were adjusted to 50 ng/μl using the formula:  $S_1V_1=S_2V_2$

Where,

$S_1$  = Initial strength (ng/ μl)

$S_2$  = Final strength (ng/ μl)

$V_1$  = Initial volume (μl)

$V_2$  = Final volume (μl)

In the laboratory, concentrated DNA was used as  $S_1$ , desired volume  $V_2=100$  μl, desired concentration  $S_2=50$ ng/μl. The initial volume  $V_1$  had to measure by the upper formula. Then, distilled water was mixed significantly with calculated  $V_1$  to make 100ng volume and the diluted DNA was used for the PCR process.

**3.5.10 Polymerase chain reaction (PCR)**

Polymerase Chain Reaction has become an obligatory tool of biological as well as molecular research for DNA amplification. It has been well known with its short mane as PCR. The amplification of DNA was performed following the method described by Bala *et al.* (2017) with some modifications.

### 3.5.11 Principle of the amplification of microsatellite marker

A microsatellite locus is characterized by a specific DNA sequence. To perform amplification of microsatellite marker, two oligonucleotide primers (Forward and Reverse) complementary to the flanking sequence on either side of the repeat unit array of known sequence are mixed with genomic DNA in presence of a thermostable Taq DNA polymerase, dNTPs and a suitable buffer. At the optimized temperature cycling conditions, the PCR was performed. During the thermal cycle, each primer binds to the each strand of the genomic DNA complementary to the primer at an optimal annealing temperature, the target sequence is amplified and a series of DNA segments is produced. Bands representing alleles at a given locus are identified through variation in the number of repeats at particular SSR (Simple Sequence Repeat) locus by their relative electrophoresis migration, by comparison with a ladder of known size (Jarne and Lagoda, 1996).

### 3.5.12 Parental survey and primer selection

Primers were evaluated based on intensity of bands, consistency within individual, presence of smearing and potentiality for population discrimination. In this experiment six random primers viz., RM11, RM25, RM171, RM5 and RM489 were used for parental surveys and selected. The sequences of the primers that are used for identification of salt tolerant wild rice genotypes are given below at Table 3.5.3.

**Table 3.5.3 List of primers for PCR (finger printing) analysis of wild rice genotypes**

| Sl. No. | Primer | Primer Sequences   | Product Size (bp) | No. of Base | Conc. | Anneal. Tem(°C) |
|---------|--------|--------------------|-------------------|-------------|-------|-----------------|
| 1       | RM11F  | TCTCCTCTTCCCCCGATC | 121-143           | 18          | 100n  | 54              |
|         | RM11R  | ATAGCGGGCGAGGCTTAG |                   | 18          | 100n  |                 |
| 2       | RM25   | GGAAAGAATGATCTTTTC | 129-147           | 22          | 100n  | 54              |
|         | RM25   | CTACCATCAAAACCAATG |                   | 21          | 100n  |                 |
| 3       | RM171  | AACGCGAGGACACGTACT | 324-344           | 21          | 100n  | 54              |
|         | RM171  | ACGAGATACGTACGCCTT |                   | 20          | 100n  |                 |
| 4       | RM5F   | TGCAACTTCTAGCTGCTC | 104-130           | 20          | 100n  | 54              |
|         | RM5R   | GCATCCGATCTTGATGGG |                   | 18          | 100n  |                 |
| 5       | RM234  | ACAGTATCCAAGGCCCTG | 133-164           | 19          | 100n  | 54              |
|         | RM234  | CACGTGAGACAAAGACG  |                   | 20          | 100n  |                 |
| 6       | RM489  | ACTTGAGACGATCGGACA | 235-271           | 20          | 100n  | 54              |
|         | RM489  | TCACCCATGGATGTTGTC |                   | 20          | 100n  |                 |

### 3.5.13 Genotyping of SSR markers

The DNA extraction was done from the leaf tissues of 21 day old seedlings and six salt tolerant SSR markers were taken. These six salt tolerant microsatellite primers covering six chromosomes were considered suitable (based on polymorphism) for Polymerase chain reaction (PCR) amplification and analysis. Detailed information of selected primers is given in table 3.5.3. PCR were done using, G-STROM, GSI, England, Thermo cycler. The PCR cocktail volume was 10 µl which contained, template DNA (diluted)- 3 µl, Mg<sup>2+</sup> free PCR buffer (10X)- 1.00 µl, *Taq* DNA polymerase- 0.10 µl, dNTPs (10mM)- 0.20 µl, Mg<sup>2+</sup> ions-1.30µL, forward primer and reverse primer- 0.50 µL of each and ddH<sub>2</sub>O- 3.40 µl. The PCR profile used an initial denaturation step for 5 min at 94<sup>0</sup> C followed by, three cyclic steps (35 cycles) - 1 minute denaturation at 94<sup>0</sup>C, 1 minute annealing at 54<sup>0</sup>C and 2 minute primer elongation at 72<sup>0</sup>C followed by single cycle of final elongation at 72<sup>0</sup>C for 5 minute and then stored at -20<sup>0</sup>C. In order to separate the amplified products electrophoreses were done at 70V for 1.5-2 hours in 1X Tris-borate-ethylenediaminetetraacetic acid (TBE) buffer using Polyacrylamide gels 10% (w/v). After staining gels in ethidium bromide (25-30 min in dark), it was visualized in an UVPRO (Uvipro platinum, EU) gel documentation unit.

### 3.5.14 Data analysis of SSR markers

Molecular weight of each unambiguous band was determined by comparing their migration distance with the 100 base pair DNA ladder using Alpha-Ease FC 5.0 software (Alpha Innotech, USA). The band profiles for each SSR primer were scored for distinct and reproducible bands as present (1) or absent (0). The summary statistics including the number of alleles per locus, major allele frequency, gene diversity and Polymorphism Information Content (PIC) values were determined using POWER MARKER version 3.23 (Liu and Muse, 2005), a genetic analysis software. Molecular weights for microsatellite products, in base-pairs, were estimated with Alpha Ease 4C software. The individual fragments were assigned as alleles of the appropriate microsatellite loci. Allele molecular weight data also used to determine the genetic distance for phylogeny reconstruction based on neighbor-joining method as implemented in POWER MARKER with the tree viewed using TREEVIEW. Polymorphism Information Content (PIC) or Expected heterozygosity for each SSR

marker was calculated based on the formula  $H_n = 1 - \sum P_i^2$ , where  $P_i$  is the allele frequency for the  $i^{\text{th}}$  allele (Nei *et al.*, 1983). The 12 genotypes were clustered based on the matrix of genetic similarities using the Un-weighted Pair Group Method with Arithmetic Averages (UPGMA). The cluster analysis and dendrogram construction were performed with NTSYS-PC (version 2.10e).

Genetic distance values (D) Nei's (1983) were calculated as:

$$D = -\ln J_{xy} / \sum J_x J_y$$

Where,

$$J_x = \sum X_i^2 / r \text{ in population X.}$$

$$J_y = \sum Y_i^2 / r \text{ in population Y.}$$

$$J_{xy} = \sum X_i Y_i, X_i \text{ and } Y_i \text{ are the frequency of the } i^{\text{th}} \text{ allele of a given locus.}$$

## CHAPTER IV

### RESULTS AND DISCUSSION

The study was carried out to screening the wild rice genotypes assessing their morpho-physiological characteristics conferring salinity and drought tolerance. The results have been presented and discussed with the help of tables and possible interpretations given under the following headings

#### 4.1 Experiment 1: Morphological characterization of wild species of rice

##### 4.1.1 Morphological description



A



B



C



D



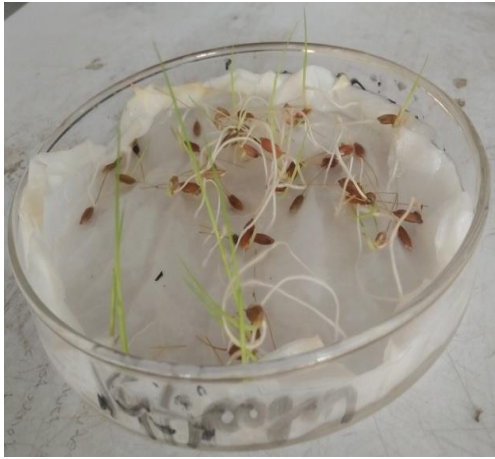
E

**Plate 4.1.1 Different growth stages of *Oryza punctata*; A. Germination of seeds, B. Primary tillering stage, C. Maximum tillering stage, D. Maturity stage and E. Grain of *Oryza punctata* with long awn**

### ***Oryza punctata***

*O. punctata* is an erect or spreading, robust annual grass type wild relatives of rice. It produce 128.50 cm tall plant with on an average 6.53 nodes. There were 7.53 leaves was observed plant<sup>-1</sup>. The bright to dark green leaves are 22.59 cm long, 1.80 cm width and length breadth ratio 12.62. Average leaf area was 36.83 cm<sup>2</sup>. It produced 16.57 cm long flag leaf, 1.74 cm breadth and 9.50 length breadth ratio with 22.54 cm<sup>2</sup> flag leaf area. It produced 20-23 cm long fibrous root. It is a photosensitive species and it needed 204 days for 1<sup>st</sup> flowering. It produced 65.33 tillers hill<sup>-1</sup> among which 41.00 tillers were functional. It attained 25.13 cm long panicle with 163.00 grain among which 106.00 were filled grain and 57.00 were unfilled. The small brownish red color seeds were less than 5 mm in size with long 2.4 cm long awn. Thousand grain weight was 8.86 gm. It required 230 days to complete its life cycle.





A



B



C



D



E



F

**Plate 4.1.2 Different growth stages of *Oryza rufipogon*; A. Germination of seeds, B. Primary tillering stage, C. Maximum tillering stage, D. Reproductive stage and E. Branching of tiller and F. Grain of *Oryza rufipogon* medium to long awn**

### ***Oryza rufipogon***

*O. rufipogon* is an erect, perennial tufted grass locally found in Louisiana, Arkansas and California states of USA. It produced 131.40 cm tall plant with 7.40 nodes and 8.80 leaves. The length of leaf was 30.78, 1.17 cm breadth, length breadth ratio 26.51, leaf area 35.79 cm. The linear leaf blade about was 16.57 cm long with 11.7 mm width, leaf sheaths loose, cylindrical, glabrous with distinct auricles at the junction with the blade. It also produced 17.22 cm long flag leaf with 1.23 cm breadth, length breadth ratio 13.97 and 21.24 cm<sup>2</sup> leaf area. It produced 27 cm long fibrous root. It is a photosensitive species and required 232.00 days 1<sup>st</sup> flower initiation. It attained 76.67 tillers hill<sup>-1</sup> among them 51.67 are effective. It has special character of branching nature of tiller. It produced 22.23 cm long panicle having 147.30 grain; among them 102.30 were filled and the rest 45 were empty. Grains are shattering in nature and were shattered as soon as they are mature. The narrow red-brown grains having long awn are enclosed by a stiff lemma and palea. Weight of thousand grain was 24.32 g. It required 265 days to complete its life cycle, so is a long duration wild relatives of rice.





A



B



C



D

**Plate 4.1.3** Different growth stages of *Oryza alta*; A. Seedling stage, B. Primary tillering stage, C. Maximum tillering stage and D. Dark color grain of *Oryza alta*

### ***Oryza alta***

*O. alta* is an erect or spreading, robust annual or perennial grass originated from *Officinalis* complex. It stands 171.20 cm tall plant with 3.33 nodes and 5.53 broad type leaves. Leaf length was 31.28 cm, breadth 2.24 cm, length breadth ratio 14.01 and leaf area 54.11 cm<sup>2</sup>. The flag leaf of *O. alta* was 14.05 cm long, 3.70 cm width, with 3.80 length breadth ratio and 31.63 cm<sup>2</sup> flag leaf area. Leaf sheaths are pale-green to brownish, glabrous, with 15-mm-long auricles at the junction with the blade. The dark-green leaf blades were 10.75 cm long, 3 cm with an indistinct mid-rib. The fibrous roots were fibrous. It is a photo in-sensitive species and required 110 days for 1<sup>st</sup> flowering. It produced 35.00 tillers hill<sup>-1</sup> with 21.00 effective one. It attained 35.23 cm long loose panicle with 280.30 grains, among them 124.70 was filled and the rest 155.70 was unfilled. It beard narrowly oblonghairy 7.60 mm long grain. Weight of thousand grain was only 8.14 g. It required only 145 days completing its life cycle. So we may address *O. alta* as short durated wild relatives of rice.



A



B



C



D



E



F

**Plate 4.1.4 Different growth stages of *Oryza nivara*; A. Germination of seeds, B. Primary tillering stage, C. Flowering stage, D. Maturity stage and E. Branching of tiller and F. Grain of *Oryza nivara* with awn**



### ***Oryza nivara***

*O. nivara* is an erect short to intermediate height, usually annual grass sometimes perennial form distributed in South and Southeast Asia. It was 109.70 cm tall producing 5.87 nodes and 7.53 leaves. Leaves were 22.62 cm long, 1.40 cm width, 16.16 length width ratio and 31.68 cm<sup>2</sup> leaf area. Leaf sheaths are pale-green with auricles at the junction with the blade. Flag leaves were 13.06 cm long, 1.40 cm width and 9.35 length breadth ratio and 17.27 cm<sup>2</sup> area. It produced 18 cm long fibrous root. It is photosensitive species and required 230 days for 1<sup>st</sup> flowering. It produced 93.00 tillers hill<sup>-1</sup> among them 72.00 were effective and 21 were non-effective. It has peculiar branching tiller production characteristic. It produced 20.17 cm long less branched panicle containing 72.00 grains, 65.67 filled and 6.33 unfilled grains. Grains were large sized golden brown color with thick strong medium to long awn. It has strong seed dormancy. Weight of thousand seed was 26.66 g. It required 260 days completing its life cycle which is long duration.



A



B



C

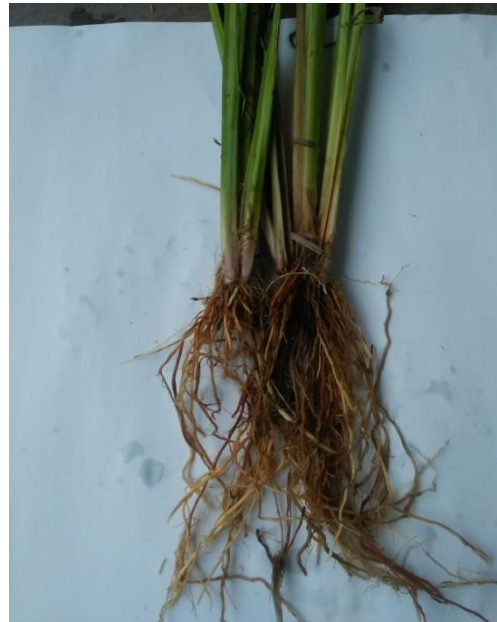


D

**Plate 4.1.5 Different growth stages of *Oryza longistaminata*; A. Germination of seeds, B. Primary tillering stage, C. Maximum tillering stage and D. Reproductive stage**



A



B



C

**Plate 4.1.6 Morphology of *Oryza longistaminata* with special features A. Branching of tiller, B. Rhizomatous root system and C. Seeds of *Oryza longistaminata* with/without medium to short awn**



### ***Oryza longistaminata***

*O. longistaminata* is a wild species member of the '*O. sativa*' complex of rice originated in middle Africa with erect with develops rhizomes and vigorously proliferation. It stands 139.90 cm tall with 6.40 nodes and 7.73 leaves. Leaf length was 24.18 cm, leaf breadth 1.56 cm with 15.48 length breadth ratio and 46.45 cm<sup>2</sup> leaf area. Flag leaf was 14.28 cm long, 2.51 cm width with 5.69 length breadth ratio and 23.11cm<sup>2</sup> leaf area. Leaf sheaths were pale-green, glabrous and nearly as long as the internodes. It produced 32.8 cm long fibrous root length with develops rhizomes underground and exhibited a typical rice growth pattern at ground level. It is also a photosensitive species and required 197.70 days for 1<sup>st</sup> flowering. It produced 55.00 tillers hill<sup>-1</sup> among which 32.33 were effective and the rest 22.33 were non effective. It has branching nature of tillers. It attained 27.20 cm long panicle with a tuft of hairs at the base of branches bearing 299.00 grains among which 161.70 were filled and the rest were unfilled (137.30). Narrowly oblong small size grain was brown in color with/without medium to short awned. Thousand grain weight 8.94 g. It required 230 days completing its life cycle.



A



B



C



D



E

**Plate 4.1.7 Different growth stages of *Oryza officinalis*; A. Primary tillering stage, B. Maximum tillering stage, C. Panicle initiation and D. Maturity stage and E. Dark color small size seeds of *Oryza officinalis***

### ***Oryza officinalis***

*O. officinalis* is a perennial grass type wild relative of rice with 130.50 cm long plant bearing 6.47 nodes and 7.73 leaves. Leaves were 20.06 cm long, 1.72 cm width with 11.76 length breadth ratio and 33.02 cm<sup>2</sup> area. Leaf sheaths were pale-green, tight, lower ones slightly inflated, with 15 mm long auricles at the junction with the blade. Leaf blade was linear, 15.80 cm long, 1-2 cm wide, glabrous or hairy. Flag leaf was 16.83 cm long, 1.71 cm width with 9.85 length width ratio and 22.21 cm<sup>2</sup> area. It produced 57.33 tillers hill<sup>-1</sup> among which 30.00 was effective tillers and the rest 27.33 was non-effective. It is light sensitive species and required 198.30 days for 1<sup>st</sup> flowering. It produced 26.27 cm long panicle bearing 213.3 grains, 95.33 filled grains and 118.00 unfilled grains. Grains were dark color small in size. Thousand grain weight was 8.15 g. From seed germination to maturity it required 230 days.





A



B



C



D



E



F

**Plate 4.1.8 Different growth stages of *Oryza barthii*; A. Germination of seeds, B. Seedling stage, C. Tillering stage and D. Flowering stage E. Grain filling stage F. Seed of *Oryza barthii* with gigantic awn**

### ***Oryza barthii***

*O. barthii* is annual aquatic grass type wild relative of rice native to Africa. It produced 131.90 cm tall erect plant with 7.40 nodes and 9.27 leaves. It had 23.12 cm long, 1.30 cm wide leaf with 17.84 length breadth ratio and 30.01 cm<sup>2</sup> leaf area. Flag leaf was 13.10 cm long, 1.40 cm width with 9.37 length breadth ratio and 17.40 cm<sup>2</sup> area. *O. barthii* is also a photosensitive species. It required 202.00 days for 1<sup>st</sup> flowering. It produced 65.00 tillers hill<sup>-1</sup>, 55.67 effective tillers and the rest was non-effective. It produced 28.63 cm long panicle bearing 42.00 grains, 31.67 filled and 10.33 unfilled grains. Small size grains are straw color with gigantic awn. At the initial stage the awn was purple color which was very attractive. Weight of thousand grain was 7.22 g. It required 235 days for completing its life cycle.





A



B



C



D

**Plate 4.1.9 Different growth stages of *Oryza latifolia*; A. Germination of seeds, B. Seedling stage, C. Primary tillering stage and D. Maximum tillering stage**



A



B



C



D

**Plate 4.1.10** Growth stage of *Oryza latifolia* with special character; A. Maturity stage, B. Branching of tiller, C. Leaf comparison between *O. latifolia* and BRRI dhan29 and D. Seeds of *Oryza latifolia*



### ***Oryza latifolia***

*O. latifolia* is a perennial grass closely related to *O. alta* and *O. grandiglumis*. It produced the tallest plant 198.50 cm with 6.47 nodes and 6.73 broad leaves. Leaf length was 54.40 cm, leaf breadth 2.93 cm with 18.58 length breadth ratio and 123.10 cm<sup>2</sup> leaf area. It produced the large size plant and leaf than any other tested genotypes. Flag leaf was 46.10 cm long, 3.05 cm width with 15.09 length breadth ratio and 98.90 cm<sup>2</sup> flag leaf area. Leaf sheaths were pale-green, glabrous and with 15 mm long auricles at the junction with the blade. It produced 50 cm long fibrous roots vigorous. It is also a photo in-sensitive species and required 107.00 days for 1<sup>st</sup> flowering. It produced only 29.67 tillers hill<sup>-1</sup> among which 19.33 were effective and the rest were non effective. It has branching of tiller character. It produced longest loose panicle 48.73 cm which is comprised of a few spreading branches with a tuft of hairs at the base bearing 350.70 grains among which only 55.67 were filled and the rest were unfilled (295.00). So it produced maximum number of sterile grains than any other tested genotypes. The brown seeds are medium, 5 mm long without bearing awn. Thousand grain weight 11.41 g. It required only 146 days completing its life cycle. So, *O. latifolia* could be resourceful producing short durated rice in the future hybridization program. Besides this it has long plant, broad leaf and gigantic panicle production capacity which could also be useful.





A



B



C



D

**Plate 4.1.11** Growth stage of *Porteresia coarctata*; A. Primary tillering stage, B. Maximum tillering stage, C. Flowering stage and D. Rhizome root system

***Porteresia coarctata***

*Porteresia coarctata* is an erect, short perennial grass with 106.30 cm long plant bearing 7.00 nodes and 7.13 leaves. Leaves were short narrow with 12.93 cm long, 0.76 cm width with 17.04 length breadth ratio and only 7.77 cm<sup>2</sup> area. Leaves are waxy unlike those of tested rice, and the surfaces display alternate ridges and furrows. Small flag leaf with 8.43 cm length, 0.70 cm width with 12.08 length width ratio and only 3.45 cm<sup>2</sup> area. It has a highly differentiated underground rhizome system from the nodes of which a number of leafy shoots arise to make a complex association. Rhizoid-like thin rootlets arise from the rhizome serving the purpose of absorption and anchorage. It produced 73.00 tillers hill<sup>-1</sup> among which 27.33 was effective tillers and the rest was non-effective. It is photosensitive species and required 107.00 days for 1<sup>st</sup> flowering. It secured 17.27 cm long panicle bearing 61.67 grains, 52.00 filled grains and 9.67 unfilled grains. Thousand grain weight was 13.55 g. From seed germination to maturity it required only 150 days.



A



B



C



D



E

**Plate 4.1.12 Growth stage of *Oryza glaberrima*; A. Germination of seeds, B. Tillering stage, C. Flowering stage, D. Maturity stage E. Seeds of *Oryza glaberrima***

### ***Oryza glaberrima***

*O. glaberrima* is called African rice is the main and the only cultivated rice among the whole African rice species. It is an annual and preferentially grass type wild rice species. It produced 127.10 cm tall plant bearing 5.53 nodes and 8.17 leaves. Leaves alternate 29.49 cm long, 1.47 cm width, length width ratio was 20.13 and leaf area was 37.50 cm<sup>2</sup>. Flag leaf was 13.57 cm long, 1.74 cm width with 7.78 length breadth ratio and 19.52 cm<sup>2</sup> area. The rooting system is fibrous. It is a photosensitive species and required 221.70 days for 1<sup>st</sup> flowering. It produced 67.67 tillers hill<sup>-1</sup> and 54.33 effective tillers hill<sup>-1</sup>. It attained 20.43 cm long panicle with 79.00 grains, 63.67 filled grains and 15.33 unfilled grains. Grain is a laterally compressed caryopsis up to 9 mm long and 3 mm wide, often reddish, tightly enveloped by lemma (glume inferior) and palea (glume superior) which is usually without apical awn and can be colored. Thousand grain weight was 20.27 g. It required 265 days completing life cycle. So it's a long duration wild rice species.



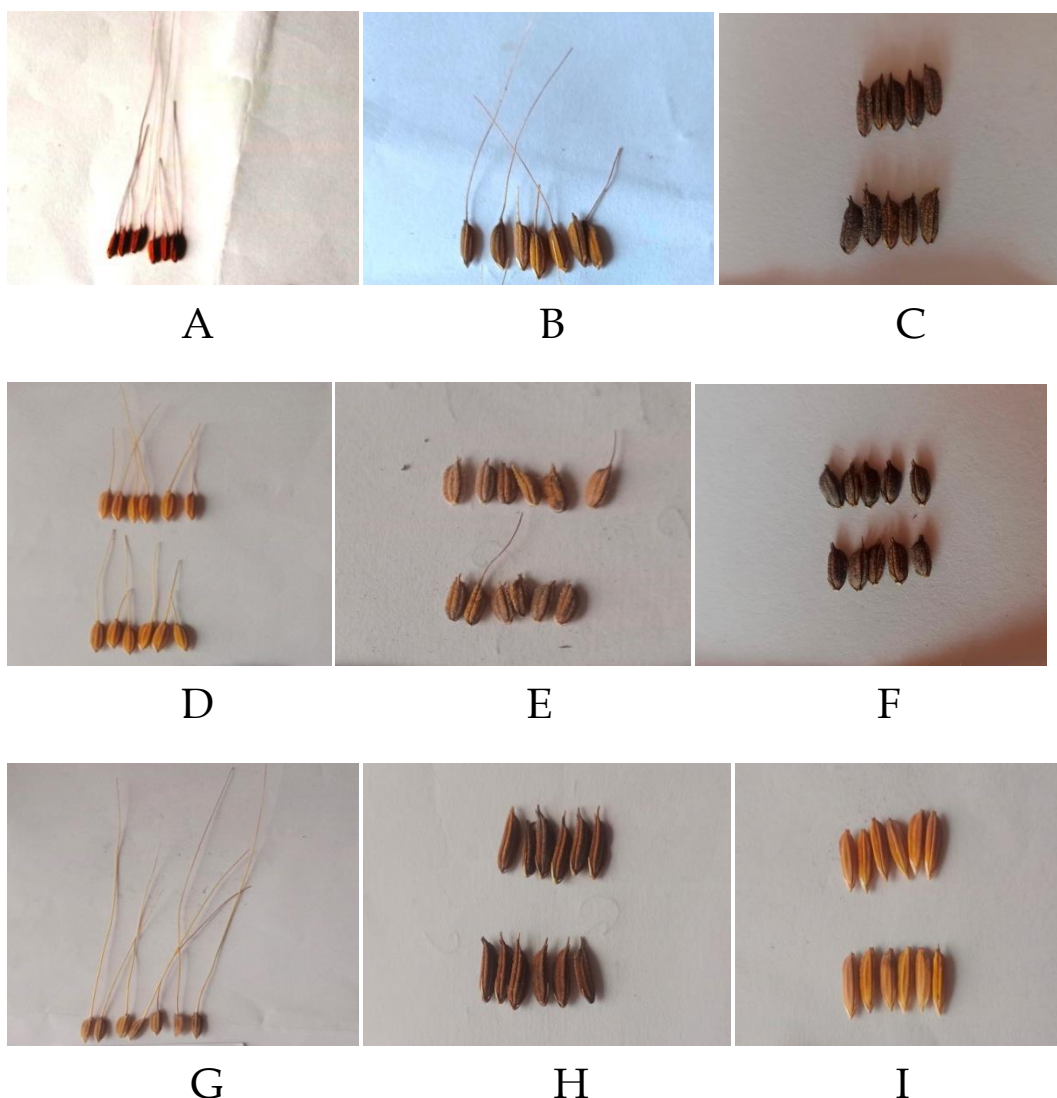


**Plate 4.1.13** Seeds of different wild rice genotypes; A. Seeds of *Oryza punctata*, B. Seeds of *Oryza rufipogon*, C. Seeds of *Oryza alta*, D. Seeds of *Oryza nivara*, E. Seeds of *Oryza longistaminata*, F. Seeds of *Oryza officinalis*, G. Seeds of *Oryza barthii* H. Seeds of *Oryza latifolia* and I. Seeds of *Oryza glaberrima*

#### 4.1.2 Plant height

Plant height is an important morphological character that acts as a potent indicator of availability of growth resources in its vicinity. Plant height of wild rice varied significantly during the growth period under the current investigations (Table 4.1.1). The longest plant (194.00 cm) was recorded from wild rice genotype *O. latifolia* ACC. No.2 (V<sub>5</sub>) which was statistically similar with V<sub>21</sub>, V<sub>24</sub> and V<sub>2</sub>. On the other hand, the shortest plant (103.00 cm) was recorded from wild rice genotype *Potericia coractata* ACC. No.3 (V<sub>33</sub>) which was statistically similar with V<sub>31</sub>, V<sub>9</sub> and V<sub>27</sub>. The rest of the species gave the intermediate height. Plant height is an important growth

parameter for any crop since it defines or alters yield contributing traits, which in turn gives grain production (Reddy and Redd, 1997). It is a complicated trait that is the result of various genetically controlled elements, most of which are ruled by the genotypes' genetic make-up, which is based on the number of internodes and length of internodes (Parashivamurthy *et al.*, 2012; Rahman *et al.*, 2018). Chouhan *et al.* (2014b) reported that high variability was found in plant height which ranged from 128.72 to 210.82 cm among the tested varieties. Shrestha *et al.* (2021) showed that plant height varied from IR73008-136-2-2-3 (86.50 cm) to Bange masino (173.5 cm). Dangi *et al.* (2017) reported that variety Kalanamak resulted in significantly tallest plant (106.54 cm) over rest of the tested varieties. The results of our experiment similar to the results of Kumar *et al.* (2017); Gewaily *et al.* (2018); Jahan *et al.* (2020); Shrestha *et al.* (2021) who observed plant height differed significantly among the varieties.

#### **4.1.3 Leaves hill<sup>-1</sup>**

The different genotypes of wild rice showed significant variation for leaves hill<sup>-1</sup> (Table 4.1.1). The result of the investigation showed that, the maximum leaves hill<sup>-1</sup> (10.07) was scored by wild rice genotype *O. rufipogon* ACC. No.2 (V<sub>4</sub>) which was statistically similar with V<sub>25</sub>. On the other hand, the minimum leaves hill<sup>-1</sup> (5.53) was scored by wild rice genotype *O. alta* ACC. No.3 (V<sub>38</sub>) which was statistically similar with V<sub>12</sub>, V<sub>14</sub>, V<sub>5</sub>, V<sub>21</sub> and V<sub>2</sub>. Dangi *et al.* (2017) revealed that at harvest stage the varieties IR- 64, BPT-5204 and IET 24780 produced significantly highest leaves hill<sup>-1</sup> over rest of the varieties. The differences in growth characters due to genotypes may be attributed to their inherent characteristics. The findings of our current investigation are corroborated with those of Siddiq *et al.* (2011); Thomas and Lal (2012); Dangi *et al.* (2017).

#### **4.1.4 Nodes plant<sup>-1</sup>**

Statistically significant variation was recorded for nodes plant<sup>-1</sup> of wild rice for different species variation (Table 4.1.1). The result of the investigation revealed that the maximum nodes plant<sup>-1</sup> (10.00) was found from wild rice genotype *O. rufipogon* ACC. No.2 (V<sub>4</sub>) which was statistically at par with V<sub>25</sub> where as the minimum nodes plant<sup>-1</sup> (3.47) was found from wild rice genotypes *O. alta* ACC. No.1 (V<sub>12</sub>), *O. alta*

ACC. No.2 (V<sub>14</sub>) and *O. alta* ACC. No.3 (V<sub>38</sub>) which were statistically at par with V<sub>39</sub>.

#### 4.1.5 Chlorophyll content on leaves

Different species of wild rice showed significant variation for chlorophyll (Chl) content on leaves (Table 4.1.1). The results revealed that, the highest Chl content on leaves (42.28%) was recorded from *O. latifolia* ACC. No.2 (V<sub>5</sub>) which was statistically similar with V<sub>40</sub>, V<sub>20</sub>, V<sub>12</sub>, V<sub>13</sub>, V<sub>9</sub>, V<sub>8</sub>, V<sub>14</sub>, V<sub>23</sub>, V<sub>36</sub> and V<sub>2</sub> on the other hand the lowest Chl content on leaves (29.28%) was recorded from *O. nivara* ACC. No.2 (V<sub>6</sub>) which was statistically similar with V<sub>16</sub>, V<sub>17</sub>, V<sub>11</sub>, V<sub>25</sub>, V<sub>30</sub>, V<sub>34</sub>, V<sub>39</sub> and V<sub>35</sub>. The rest of the treatment gave the intermediate results. Kiran *et al.* (2013) reported that the total Chl content was highest in DRRH-3, followed by PA-6444 and *O. glaberrima*, Accession (ACC.) No. IR 104033. The lowest Chl content was found in *O. glaberrima*, ACC. No. IR 101800. Genotypes maintaining higher leaf Chl (both Chl a and b) during the growth period may be considered as potential donors for their ability to produce higher biomass and photosynthetic capacity (Hassan *et al.* 2009). Significant variations in SPAD values (Chl content) among different *Oryza* species have been reported by Zhao *et al.* (2010). The higher Chl content was also reported for wild rice species by Yeo *et al.* (1994). Zhao *et al.* (2010) reported that among 17 *Oryza* species, *O. rufipogon* and *O. australiensis* exhibited the highest Chl content and photosynthesis ability, and they suggested that *O. rufipogon* was the best wild resource species for improving rice photosynthesis.

#### 4.1.6 Length of normal leaf

Different species of wild rice exerted significant variation for length of normal leaf (Table 4.1.2). Data showed that the longest normal leaf (56.01 cm) was recorded from *O. latifolia* ACC. No.3 (V<sub>21</sub>) which showed statistically similarity with V<sub>5</sub> treatment and the shortest one (11.93 cm) was recorded from *Potericia coractata* ACC. No.2 (V<sub>31</sub>) which showed statistically similarity with V<sub>34</sub>, V<sub>30</sub>, V<sub>33</sub>, V<sub>9</sub> and V<sub>11</sub>. Chouhan *et al.* (2014b) reported that leaf length varied from 52.61 to 78.90 cm in respect of different tested rice varieties. Our findings are consistent with those of Patra and Dhua (2003); Chouhan *et al.* (2014b) who concluded that the leaf length varied with different rice varieties.

**Table 4.1.1 Plant height, leaves hill<sup>-1</sup>, nodes plant<sup>-1</sup> and chlorophyll content of leaves of wild species of rice**

| Treatments                  | Plant height<br>(cm) | Leaves hill <sup>-1</sup><br>(No.) | Nodes plant <sup>-1</sup><br>(No.) | Chlorophyll content<br>of leaves (%) |
|-----------------------------|----------------------|------------------------------------|------------------------------------|--------------------------------------|
| V <sub>1</sub>              | 136.40 ef            | 8.80 cd                            | 6.73 d-g                           | 38.13 b-g                            |
| V <sub>2</sub>              | 183.90 ab            | 6.27 l-n                           | 5.83 h-n                           | 39.57 a-d                            |
| V <sub>3</sub>              | 127.40 f-i           | 8.13 c-h                           | 5.40 l-p                           | 33.31 i-n                            |
| V <sub>4</sub>              | 164.90 cd            | 10.07 a                            | 10.00 a                            | 33.51 i-n                            |
| V <sub>5</sub>              | 194.00 a             | 6.13 m-n                           | 5.53 k-p                           | 42.28 a                              |
| V <sub>6</sub>              | 127.50 f-i           | 8.07 c-i                           | 5.27 m-q                           | 29.28 o                              |
| V <sub>7</sub>              | 117.50 i-m           | 8.00 c-i                           | 6.07 g-m                           | 36.47 c-i                            |
| V <sub>8</sub>              | 125.50 f-jk          | 7.67 e-k                           | 6.73 d-g                           | 39.58 a-d                            |
| V <sub>9</sub>              | 111.10 l-n           | 7.07 i-m                           | 7.00 c-f                           | 39.83 a-d                            |
| V <sub>10</sub>             | 129.50 f-h           | 8.47 c-g                           | 5.07 n-q                           | 36.23 d-i                            |
| V <sub>11</sub>             | 115.10 j-m           | 8.53 c-f                           | 8.07 b                             | 30.52 m-o                            |
| V <sub>12</sub>             | 162.70 d             | 5.60 n                             | 3.47 s                             | 39.87 a-d                            |
| V <sub>13</sub>             | 126.50 f-j           | 7.60 f-k                           | 6.60 d-h                           | 38.92 a-e                            |
| V <sub>14</sub>             | 161.20 d             | 5.73 n                             | 3.47 s                             | 38.71 a-f                            |
| V <sub>15</sub>             | 127.80 f-i           | 7.97 c-i                           | 6.53 d-i                           | 34.03 h-m                            |
| V <sub>16</sub>             | 122.90 g-l           | 8.67 c-e                           | 5.53 k-p                           | 30.00 no                             |
| V <sub>17</sub>             | 126.90 f-j           | 7.60 f-k                           | 4.73 pq                            | 31.09 m-o                            |
| V <sub>18</sub>             | 129.40 f-h           | 8.53 c-f                           | 7.33 b-d                           | 33.36 i-n                            |
| V <sub>19</sub>             | 125.50 f-k           | 7.27 h-l                           | 6.70 d-g                           | 36.52 c-i                            |
| V <sub>20</sub>             | 142.00 e             | 7.67 e-k                           | 6.47 e-j                           | 40.14 abc                            |
| V <sub>21</sub>             | 191.90 a             | 6.20 mn                            | 5.70 j-o                           | 36.40 c-i                            |
| V <sub>22</sub>             | 124.90 f-k           | 8.00 c-i                           | 5.13 n-q                           | 34.04 h-m                            |
| V <sub>23</sub>             | 126.60 f-j           | 7.80 d-k                           | 6.00 g-m                           | 38.52 a-f                            |
| V <sub>24</sub>             | 184.30 ab            | 6.87 j-m                           | 6.50 e-j                           | 35.02 f-l                            |
| V <sub>25</sub>             | 157.20 d             | 9.87 ab                            | 9.27 a                             | 32.33 j-o                            |
| V <sub>26</sub>             | 133.40 e-g           | 8.93 bc                            | 7.27 b-e                           | 36.09 d-j                            |
| V <sub>27</sub>             | 114.60 k-n           | 8.60 c-f                           | 6.20 f-l                           | 35.59 e-k                            |
| V <sub>28</sub>             | 133.50 efg           | 8.20 c-h                           | 5.73 i-o                           | 35.56 e-k                            |
| V <sub>29</sub>             | 123.20 g-k           | 7.67 e-k                           | 4.47 qr                            | 34.37 g-m                            |
| V <sub>30</sub>             | 118.30 h-m           | 8.67 c-e                           | 6.67 d-g                           | 31.33 l-o                            |
| V <sub>31</sub>             | 108.30 mn            | 6.80 k-m                           | 6.27 f-k                           | 37.60 b-h                            |
| V <sub>32</sub>             | 123.90 g-k           | 7.47 g-k                           | 6.60 d-h                           | 35.04 f-l                            |
| V <sub>33</sub>             | 103.00 n             | 6.80 k-m                           | 6.30 f-k                           | 36.20 d-i                            |
| V <sub>34</sub>             | 125.10 f-k           | 8.10 c-h                           | 6.93 c-f                           | 30.05 no                             |
| V <sub>35</sub>             | 123.60 g-k           | 7.47 g-k                           | 4.93 o-q                           | 31.75 k-o                            |
| V <sub>36</sub>             | 127.60 f-i           | 7.40 h-k                           | 6.40 f-j                           | 38.80 a-f                            |
| V <sub>37</sub>             | 129.50 f-h           | 7.87 d-j                           | 5.40 l-p                           | 36.11 d-j                            |
| V <sub>38</sub>             | 175.40 bc            | 5.53 n                             | 3.47 s                             | 37.64 b-h                            |
| V <sub>39</sub>             | 127.40 f-i           | 6.80 k-m                           | 3.67 rs                            | 31.31 l-o                            |
| V <sub>40</sub>             | 128.30 f-i           | 8.13 c-h                           | 7.60 bc                            | 40.56 ab                             |
| <b>LSD<sub>(0.05)</sub></b> | <b>11.89</b>         | <b>1.01</b>                        | <b>0.83</b>                        | <b>3.86</b>                          |
| <b>CV (%)</b>               | <b>5.38</b>          | <b>8.11</b>                        | <b>8.37</b>                        | <b>6.67</b>                          |

V<sub>1</sub>= *Oryza rufipogon* Accession (ACC.) No.1, V<sub>2</sub>= *O. latifolia* ACC. No.1, V<sub>3</sub>= *O. nivara* ACC. No.1, V<sub>4</sub>= *O. rufipogon* ACC. No.2, V<sub>5</sub>= *O. latifolia* ACC. No.2, V<sub>6</sub>= *O. nivara* ACC. No.2, V<sub>7</sub>= *O. officinalis* ACC. No.1, V<sub>8</sub>= *O. longistaminata* ACC. No.1, V<sub>9</sub>= *Potericia coaractata* ACC. No.1, V<sub>10</sub>= *O. nivara* ACC. No.3, V<sub>11</sub>= *O. rufipogon* ACC. No.3, V<sub>12</sub>= *O. alta* ACC. No.1, V<sub>13</sub>= *O. longistaminata*



ACC. No.2, V<sub>14</sub>= *O. alta* ACC. No.2, V<sub>15</sub>= *O. punctata* ACC. No.1, V<sub>16</sub>= *O. barthii* ACC. No.1, V<sub>17</sub>= *O. nivara* ACC. No.4, V<sub>18</sub>= *O. barthii* ACC. No.6, V<sub>19</sub>= *O. punctata* ACC. No.2, V<sub>20</sub>= *O. longistaminata* ACC. No.3, V<sub>21</sub>= *O. latifolia* ACC. No.3, V<sub>22</sub>= *O. nivara* (ACC.) No.5, V<sub>23</sub>= *O. officinalis* ACC. No.2, V<sub>24</sub>= *O. latifolia* ACC. No.4, V<sub>25</sub>= *O. rufipogon* ACC. No.4, V<sub>26</sub>= *O. rufipogon* ACC. No.5, V<sub>27</sub>= *O. latifolia* ACC. No.3, V<sub>28</sub>= *O. nivara* ACC. No.6, V<sub>29</sub>= *O. glaberrima* ACC. No.1, V<sub>30</sub>= *O. rufipogon* ACC. No.6, V<sub>31</sub>= *Potericia coractata* ACC. No.2, V<sub>32</sub>= *O. longistaminata* ACC. No.4, V<sub>33</sub>= *Potericia coractata* ACC. No.3, V<sub>34</sub>= *O. rufipogon* ACC. No.7, V<sub>35</sub>= *O. glaberrima* ACC. No.2, V<sub>36</sub>= *O. punctata* ACC. No.3, V<sub>37</sub>= *O. glaberrima* ACC. No.3, V<sub>38</sub>= *O. alta* ACC. No.3, V<sub>39</sub>= *O. glaberrima* ACC. No.4 and V<sub>40</sub>= *O. punctata* ACC. No.4.

#### 4.1.7 Breadth of normal leaf

Breadth of normal leaf varied significantly for different species of wild rice (Table 4.1.2). The widest normal leaf (3.00 cm) was observed from *O. latifolia* ACC. No.4 (V<sub>24</sub>) which was statistically similar with V<sub>21</sub>, V<sub>5</sub> and V<sub>2</sub> whereas the narrowest normal leaf (0.75 cm) was observed from both *Potericia coractata* ACC. No.2 (V<sub>31</sub>) and *P. coractata* ACC. No.3 (V<sub>33</sub>) which were statistically similar with V<sub>9</sub>. Chouhan *et al.* (2014b) concluded that leaf breadth varied from 1.04 to 1.80 cm with their investigated rice varieties. Patra and Dhua (2003) reported similar findings for leaf breadth.

#### 4.1.8 Length breadth ratio of normal leaf

Length breadth ratio of normal leaf showed significant difference for different species variation of wild rice (Table 4.1.2). The maximum length breadth ratio of normal leaf (27.90) was recorded from *O. rufipogon* ACC. No.5 (V<sub>26</sub>) which was statistically similar with V<sub>1</sub> and the minimum length breadth ratio of normal leaf (7.98) was recorded from *O. alta* ACC. No.1 (V<sub>12</sub>) which was statistically similar with V<sub>38</sub>, V<sub>30</sub> and V<sub>14</sub>.

#### 4.1.9 Normal leaf area

Normal leaf area showed significant variation for different genotypes of wild rice (Table 4.1.2). The maximum normal leaf area (123.10 cm<sup>2</sup>) was distinctly recorded from *O. latifolia* ACC. No.2 (V<sub>5</sub>) and the minimum normal leaf area (7.44 cm<sup>2</sup>) was recorded from *P. coractata* ACC. No.3 (V<sub>33</sub>) which was statistically similar with V<sub>31</sub> and V<sub>9</sub> treatments. The leaf area of plant is one of the major determinants of its growth. It is the ratio of leaf area to its ground area (Radford, 1967) and it is the functional size of the standing crop on unit land area (Hunt, 1978). It depends on the growth, number of leaves plant<sup>-1</sup>, population density and leaf senescence (Khan,

1981). Our results are in harmony with those obtained by Islam *et al.* (2013); Sarker *et al.* (2013); Sokoto and Muhammad (2014) who reported that leaf area differed with species variation due to different genetic make-up.

**Table 4.1.2 Normal leaf characteristics of wild species of rice**

| Treatments                  | Length of normal leaf (cm) | Breadth of normal leaf (cm) | Length breadth ratio of normal leaf | Normal leaf area (cm <sup>2</sup> ) |
|-----------------------------|----------------------------|-----------------------------|-------------------------------------|-------------------------------------|
| V <sub>1</sub>              | 30.78 d-g                  | 1.17 o-q                    | 26.50 a                             | 35.79 l-q                           |
| V <sub>2</sub>              | 51.69 b                    | 2.83 a                      | 17.46 c-f                           | 109.2 c                             |
| V <sub>3</sub>              | 23.54 jk                   | 1.30 m-p                    | 18.13 b-d                           | 30.57 r-t                           |
| V <sub>4</sub>              | 18.55 op                   | 1.22 n-q                    | 15.19 g-k                           | 22.70 u                             |
| V <sub>5</sub>              | 54.40 ab                   | 2.93 a                      | 18.35 b-d                           | 123.1 a                             |
| V <sub>6</sub>              | 20.59 k-p                  | 1.48 j-m                    | 14.08 i-m                           | 30.42 st                            |
| V <sub>7</sub>              | 20.06 n-p                  | 1.72 e-h                    | 11.52 no                            | 33.02 o-t                           |
| V <sub>8</sub>              | 24.18 ij                   | 1.56 h-l                    | 15.80 e-j                           | 46.45 e-g                           |
| V <sub>9</sub>              | 13.27 q                    | 0.77 r                      | 15.07 h-k                           | 7.77 w                              |
| V <sub>10</sub>             | 22.62 j-n                  | 1.40 k-n                    | 17.16 c-h                           | 31.68 p-t                           |
| V <sub>11</sub>             | 14.53 q                    | 1.12 pq                     | 13.04 k-n                           | 16.24 v                             |
| V <sub>12</sub>             | 18.11 op                   | 2.05 bc                     | 7.98 q                              | 49.78 d-f                           |
| V <sub>13</sub>             | 24.17 ij                   | 1.56 h-k                    | 15.80 e-j                           | 45.85 f-h                           |
| V <sub>14</sub>             | 20.28 l-p                  | 2.24 b                      | 9.04 pq                             | 50.61 de                            |
| V <sub>15</sub>             | 23.35 jk                   | 1.95 cd                     | 14.44 i-m                           | 38.31 k-n                           |
| V <sub>16</sub>             | 32.03 c-e                  | 1.23 n-q                    | 13.22 k-n                           | 40.05 i-l                           |
| V <sub>17</sub>             | 23.12 j-m                  | 1.31 m-p                    | 17.58 b-e                           | 30.01 t                             |
| V <sub>18</sub>             | 33.36 cd                   | 1.52 i-l                    | 13.22 k-n                           | 44.21 g-i                           |
| V <sub>19</sub>             | 19.72 n-p                  | 1.81 d-g                    | 12.66 l-n                           | 37.07 k-o                           |
| V <sub>20</sub>             | 34.17 c                    | 1.73 e-h                    | 15.80 e-j                           | 48.52 e-g                           |
| V <sub>21</sub>             | 56.01 a                    | 2.94 a                      | 18.71 bc                            | 115.9 b                             |
| V <sub>22</sub>             | 26.96 hi                   | 1.37 l-n                    | 19.80 b                             | 31.80 p-t                           |
| V <sub>23</sub>             | 21.13 k-o                  | 1.75 e-h                    | 11.36 no                            | 35.14 m-r                           |
| V <sub>24</sub>             | 52.36 b                    | 3.00 a                      | 17.33 c-g                           | 116.1 b                             |
| V <sub>25</sub>             | 17.86 p                    | 1.24 n-q                    | 14.73 i-l                           | 21.91 u                             |
| V <sub>26</sub>             | 31.10 d-f                  | 1.13 o-q                    | 27.90 a                             | 34.83 m-s                           |
| V <sub>27</sub>             | 20.23 m-p                  | 1.79 d-g                    | 11.33 no                            | 34.49 n-t                           |
| V <sub>28</sub>             | 22.74 j-n                  | 1.32 m-o                    | 17.40 c-g                           | 31.34 q-t                           |
| V <sub>29</sub>             | 27.76 gh                   | 1.68 f-i                    | 16.30 d-i                           | 39.34 j-m                           |
| V <sub>30</sub>             | 12.37 q                    | 1.26 n-q                    | 9.737 o-q                           | 15.53 v                             |
| V <sub>31</sub>             | 11.93 q                    | 0.75 r                      | 15.07 h-k                           | 7.633 w                             |
| V <sub>32</sub>             | 33.02 cd                   | 1.71 e-i                    | 19.09 bc                            | 43.95 g-j                           |
| V <sub>33</sub>             | 12.82 q                    | 0.75 r                      | 15.23 f-k                           | 7.44 w                              |
| V <sub>34</sub>             | 12.34 q                    | 1.11 q                      | 11.11 n-p                           | 13.71 v                             |
| V <sub>35</sub>             | 28.61 f-h                  | 1.40 k-n                    | 16.21 d-i                           | 36.28 l-p                           |
| V <sub>36</sub>             | 21.07 k-o                  | 1.87 c-f                    | 12.79 l-n                           | 38.54 k-n                           |
| V <sub>37</sub>             | 32.60 cd                   | 1.63 g-j                    | 13.87 j-m                           | 41.60 h-k                           |
| V <sub>38</sub>             | 31.28 c-f                  | 2.24 b                      | 9.04 pq                             | 54.11 d                             |
| V <sub>39</sub>             | 29.49 e-h                  | 1.47 j-m                    | 15.05 h-k                           | 37.50 k-o                           |
| V <sub>40</sub>             | 23.26 j-l                  | 1.90 c-e                    | 12.34 mn                            | 36.50 l-o                           |
| <b>LSD<sub>(0.05)</sub></b> | <b>3.03</b>                | <b>0.19</b>                 | <b>2.23</b>                         | <b>4.63</b>                         |
| <b>CV (%)</b>               | <b>7.11</b>                | <b>7.23</b>                 | <b>9.04</b>                         | <b>6.84</b>                         |

V<sub>1</sub>= *Oryza rufipogon* Accession (ACC.) No.1, V<sub>2</sub>= *O. latifolia* ACC. No.1, V<sub>3</sub>= *O. nivara* ACC. No.1, V<sub>4</sub>= *O. rufipogon* ACC. No.2, V<sub>5</sub>= *O. latifolia* ACC. No.2, V<sub>6</sub>= *O. nivara* ACC. No.2, V<sub>7</sub>= *O. officinalis* ACC. No.1, V<sub>8</sub>= *O. longistaminata* ACC. No.1, V<sub>9</sub>= *Potericia coaractata* ACC. No.1, V<sub>10</sub>= *O. nivara* ACC. No.3, V<sub>11</sub>= *O. rufipogon* ACC. No.3, V<sub>12</sub>= *O. alta* ACC. No.1, V<sub>13</sub>= *O. longistaminata* ACC. No.2, V<sub>14</sub>= *O. alta* ACC. No.2, V<sub>15</sub>= *O. punctata* ACC. No.1, V<sub>16</sub>= *O. barthii* ACC. No.1, V<sub>17</sub>= *O. nivara* ACC. No.4, V<sub>18</sub>= *O. barthii* ACC. No.6, V<sub>19</sub>= *O. punctata* ACC. No.2, V<sub>20</sub>= *O. longistaminata* ACC. No.3, V<sub>21</sub>= *O. latifolia* ACC. No.3, V<sub>22</sub>= *O. nivara* (ACC.) No.5, V<sub>23</sub>= *O. officinalis* ACC. No.2, V<sub>24</sub>= *O. latifolia* ACC. No.4, V<sub>25</sub>= *O. rufipogon* ACC. No.4, V<sub>26</sub>= *O. rufipogon* ACC. No.5, V<sub>27</sub>= *O. latifolia* ACC. No.3, V<sub>28</sub>= *O. nivara* ACC. No.6, V<sub>29</sub>= *O. glaberrima* ACC. No.1, V<sub>30</sub>= *O. rufipogon* ACC. No.6, V<sub>31</sub>= *Potericia coractata* ACC. No.2, V<sub>32</sub>= *O. longistaminata* ACC. No.4, V<sub>33</sub>= *Potericia coractata* ACC. No.3, V<sub>34</sub>= *O. rufipogon* ACC. No.7, V<sub>35</sub>= *O. glaberrima* ACC. No.2, V<sub>36</sub>= *O. punctata* ACC. No.3, V<sub>37</sub>= *O. glaberrima* ACC. No.3, V<sub>38</sub>= *O. alta* ACC. No.3, V<sub>39</sub>= *O. glaberrima* ACC. No.4 and V<sub>40</sub>= *O. punctata* ACC. No. 4.

#### 4.1.10 Length of flag leaf

Different varieties of wild rice exerted significant variation for length of flag leaf (Table 4.1.3). Data showed that the longest flag leaf (46.10 cm) was recorded from *O. latifolia* ACC. No.2 (V<sub>5</sub>) and the shortest flag leaf (8.43 cm) was recorded from *P. coaractata* ACC. No.1 (V<sub>9</sub>) which showed statistically similarity with V<sub>31</sub>, V<sub>33</sub>, V<sub>32</sub>, V<sub>3</sub> and V<sub>6</sub>. Our results are supported by Singh *et al.* (2013a); Chouhan *et al.* (2014b) who also showed that length of flag leaf varied with different rice varieties.

#### 4.1.11 Breadth of flag leaf

Breadth of flag leaf varied significantly for different varieties of wild rice (Table 4.1.3). The widest flag leaf (3.70 cm) was observed from *O. glaberrima* ACC. No.4 (V<sub>38</sub>) which was statistically similar with V<sub>14</sub> whereas the narrowest flag leaf (0.69 cm) was observed from both *P. coractata* ACC. No.2 (V<sub>31</sub>) and *P. coractata* ACC. No.3 (V<sub>33</sub>) which were statistically similar with V<sub>9</sub>. Our findings are close confirmation with the findings of Singh *et al.* (2013a); Chouhan *et al.* (2014b) who opinioned that breadth of flag leaf differ with different rice genotypes.

#### 4.1.12 Length breadth ratio of flag leaf

Length breadth ratio of flag leaf showed significant variation for different wild rice genotypes (Table 4.1.3). The maximum length breadth ratio of flag leaf (14.49) was observed from *O. latifolia* ACC. No.2 (V<sub>5</sub>) which was statistically similar with V<sub>1</sub>, V<sub>26</sub>, V<sub>33</sub> and V<sub>31</sub> and the minimum length breadth ratio of flag leaf (3.94) was observed from *O. alta* ACC. No.2 (V<sub>14</sub>) which was statistically similar with V<sub>38</sub>, V<sub>12</sub> and V<sub>32</sub>.

#### 4.1.13 Flag leaf area

Flag leaf area showed significant variation for different genotypic variation of wild rice (Table 4.1.3). The maximum flag leaf area (98.90 cm<sup>2</sup>) was distinctly recorded from *O. latifolia* ACC. No.2 (V<sub>5</sub>) and the minimum flag leaf area (3.45 cm<sup>2</sup>) was recorded from V<sub>9</sub> treatment which was statistically similar with *P. coractata* ACC. No.2 (V<sub>31</sub>) and *P. coractata* ACC. No.3 (V<sub>33</sub>).

#### 4.1.14 Root length

Statistically significant variation was recorded for root length for different varieties of wild rice (Table 4.1.4). The result of the experiment revealed that the longest root (45.00 cm) was recorded from *O. latifolia* ACC. No.2 (V<sub>5</sub>) which was statistically similar with V<sub>24</sub> and V<sub>2</sub> and the shortest root (9.83 cm) was recorded from *O. glaberrima* ACC. No.1 (V<sub>29</sub>) which was statistically similar with V<sub>35</sub>, V<sub>39</sub>, V<sub>17</sub> and V<sub>22</sub>.

#### 4.1.15 Root dry weight hill<sup>-1</sup>

Root dry weight hill<sup>-1</sup> showed statistically significant variation for different wild species of rice (Table 4.1.4). Result showed that, the maximum root dry weight hill<sup>-1</sup> (190.90 g) was found from *O. glaberrima* ACC. No.3 (V<sub>37</sub>) which was statistically at par with V<sub>38</sub>, V<sub>40</sub>, V<sub>8</sub>, V<sub>3</sub>, V<sub>4</sub>, V<sub>5</sub>, V<sub>6</sub>, V<sub>20</sub>, V<sub>28</sub>, V<sub>35</sub> and V<sub>39</sub> and the minimum root dry weight hill<sup>-1</sup> (24.92 g) was found from *P. coractata* ACC. No.2 (V<sub>31</sub>) which was statistically at par with V<sub>18</sub>, V<sub>16</sub>, V<sub>9</sub> and V<sub>33</sub>.

#### 4.1.16 Shoot dry weight hill<sup>-1</sup>

Statistically significant variation was recorded in case of shoot dry weight hill<sup>-1</sup> for different species variation of wild rice (Table 4.1.4). The maximum shoot dry weight hill<sup>-1</sup> (211.70 g) was scored by *O. rufipogon* ACC. No.6 (V<sub>30</sub>) which was statistically similar with V<sub>2</sub> and the minimum shoot dry weight hill<sup>-1</sup> (39.92 g) was scored by *P. coractata* ACC. No.2 (V<sub>31</sub>) which was statistically similar with V<sub>33</sub>, V<sub>9</sub>, V<sub>16</sub> and V<sub>18</sub>.

**Table 4.1.3 Flag leaf characteristics of wild species of rice**

| Treatments        | Length of flag leaf (cm) | Breadth of flag leaf (cm) | Length breadth ratio of flag leaf | Flag leaf area (cm <sup>2</sup> ) |
|-------------------|--------------------------|---------------------------|-----------------------------------|-----------------------------------|
| V <sub>1</sub>    | 17.22 d                  | 1.23 j-l                  | 14.07 a                           | 21.24 jk                          |
| V <sub>2</sub>    | 38.10 b                  | 3.40 b                    | 12.30 b-d                         | 89.93 b                           |
| V <sub>3</sub>    | 10.03 p-s                | 1.44 h-j                  | 7.02 m-o                          | 14.49 o                           |
| V <sub>4</sub>    | 10.63 n-r                | 1.03 l                    | 10.46 e-h                         | 10.88 p                           |
| V <sub>5</sub>    | 46.10 a                  | 3.05 c                    | 14.49 a                           | 98.90 a                           |
| V <sub>6</sub>    | 10.08 p-s                | 1.44 h-j                  | 7.02 m-o                          | 14.55 o                           |
| V <sub>7</sub>    | 16.83 d                  | 1.71 fg                   | 9.04 h-k                          | 22.21 ij                          |
| V <sub>8</sub>    | 14.28 g-j                | 2.51 d                    | 5.83 o-q                          | 23.11 h-j                         |
| V <sub>9</sub>    | 8.43 s                   | 0.70 m                    | 11.84 c-e                         | 3.45 q                            |
| V <sub>10</sub>   | 13.06 h-m                | 1.40 i-k                  | 9.35 g-j                          | 17.27 l-n                         |
| V <sub>11</sub>   | 12.79 h-m                | 1.17 kl                   | 10.67 e-g                         | 15.03 no                          |
| V <sub>12</sub>   | 11.73 m-q                | 2.73 d                    | 4.36 qr                           | 24.67 g-i                         |
| V <sub>13</sub>   | 14.61 e-i                | 2.52 d                    | 5.98 n-p                          | 26.69 fg                          |
| V <sub>14</sub>   | 12.32 j-o                | 3.50 ab                   | 3.94 r                            | 30.29 de                          |
| V <sub>15</sub>   | 16.61 de                 | 1.88 f                    | 9.14 h-k                          | 23.19 h-j                         |
| V <sub>16</sub>   | 11.74 m-q                | 1.66 f-h                  | 7.12 m-o                          | 15.84 m-o                         |
| V <sub>17</sub>   | 13.10 h-m                | 1.40 i-k                  | 9.37 g-j                          | 17.40 l-n                         |
| V <sub>18</sub>   | 11.83 l-p                | 1.67 f-h                  | 7.17 m-o                          | 16.15 m-o                         |
| V <sub>19</sub>   | 13.84 g-l                | 1.84 f                    | 5.84 op                           | 24.87 gh                          |
| V <sub>20</sub>   | 14.48 f-i                | 2.63 d                    | 9.03 h-k                          | 27.80 ef                          |
| V <sub>21</sub>   | 34.59 c                  | 3.28 bc                   | 11.50 d-f                         | 82.62 c                           |
| V <sub>22</sub>   | 13.01 h-m                | 1.26 jkl                  | 10.29 f-h                         | 16.46 m-o                         |
| V <sub>23</sub>   | 15.46 d-g                | 1.71 fg                   | 8.78 i-l                          | 25.96 fg                          |
| V <sub>24</sub>   | 34.79 c                  | 3.16 c                    | 11.90 c-e                         | 82.62 c                           |
| V <sub>25</sub>   | 10.69 n-r                | 1.03 l                    | 10.69 e-g                         | 10.88 p                           |
| V <sub>26</sub>   | 16.54 d-f                | 1.17 kl                   | 14.19 a                           | 19.29 kl                          |
| V <sub>27</sub>   | 16.83 d                  | 1.72 fg                   | 9.04 h-k                          | 24.28 g-i                         |
| V <sub>28</sub>   | 11.99 k-p                | 1.50 g-i                  | 8.00 j-m                          | 17.97 lm                          |
| V <sub>29</sub>   | 12.63 i-n                | 1.73 fg                   | 7.39 l-n                          | 18.20 lm                          |
| V <sub>30</sub>   | 12.81 h-m                | 1.18 kl                   | 10.91 d-f                         | 15.04 no                          |
| V <sub>31</sub>   | 9.09 rs                  | 0.69 m                    | 13.28 a-c                         | 3.52 q                            |
| V <sub>32</sub>   | 10.41 o-s                | 2.18 e                    | 4.90 p-r                          | 22.97 h-j                         |
| V <sub>33</sub>   | 9.73 q-s                 | 0.69 m                    | 13.66 ab                          | 3.58 q                            |
| V <sub>34</sub>   | 12.82 h-m                | 1.17 kl                   | 10.93 d-f                         | 15.03 no                          |
| V <sub>35</sub>   | 16.91 d                  | 1.80 f                    | 10.13 f-i                         | 17.58 l-n                         |
| V <sub>36</sub>   | 14.76 e-h                | 1.73 fg                   | 7.77 k-m                          | 21.35 jk                          |
| V <sub>37</sub>   | 13.90 g-l                | 1.66 f-h                  | 8.38 j-m                          | 19.25 kl                          |
| V <sub>38</sub>   | 14.05 g-k                | 3.70 a                    | 4.01 r                            | 31.63 d                           |
| V <sub>39</sub>   | 13.57 g-m                | 1.74 f                    | 7.84 k-m                          | 19.52 kl                          |
| V <sub>40</sub>   | 16.57 de                 | 1.74 f                    | 7.84 k-m                          | 22.54 h-j                         |
| <b>LSD (0.05)</b> | <b>2.07</b>              | <b>0.24</b>               | <b>1.47</b>                       | <b>2.63</b>                       |
| <b>CV (%)</b>     | <b>8.10</b>              | <b>7.88</b>               | <b>9.90</b>                       | <b>6.30</b>                       |

V<sub>1</sub>= *Oryza rufipogon* Accession (ACC.) No.1, V<sub>2</sub>= *O. latifolia* ACC. No.1, V<sub>3</sub>= *O. nivara* ACC. No.1, V<sub>4</sub>= *O. rufipogon* ACC. No.2, V<sub>5</sub>= *O. latifolia* ACC. No.2, V<sub>6</sub>= *O. nivara* ACC. No.2, V<sub>7</sub>= *O. officinalis* ACC. No.1, V<sub>8</sub>= *O. longistaminata* ACC. No.1, V<sub>9</sub>= *Potericia coaractata* ACC. No.1, V<sub>10</sub>= *O. nivara* ACC. No.3, V<sub>11</sub>= *O. rufipogon* ACC. No.3, V<sub>12</sub>= *O. alta* ACC. No.1, V<sub>13</sub>= *O. longistaminata* ACC. No.2, V<sub>14</sub>= *O. alta* ACC. No.2, V<sub>15</sub>= *O. punctata* ACC. No.1, V<sub>16</sub>= *O. barthii* ACC. No.1, V<sub>17</sub>=

*O. nivara* ACC. No.4, V<sub>18</sub>= *O. barthii* ACC. No.6, V<sub>19</sub>= *O. punctata* ACC. No.2, V<sub>20</sub>= *O. longistaminata* ACC. No.3, V<sub>21</sub>= *O. latifolia* ACC. No.3, V<sub>22</sub>= *O. nivara* (ACC.) No.5, V<sub>23</sub>= *O. officinalis* ACC. No.2, V<sub>24</sub>= *O. latifolia* ACC. No.4, V<sub>25</sub>= *O. rufipogon* ACC. No.4, V<sub>26</sub>= *O. rufipogon* ACC. No.5, V<sub>27</sub>= *O. latifolia* ACC. No.3, V<sub>28</sub>= *O. nivara* ACC. No.6, V<sub>29</sub>= *O. glaberrima* ACC. No.1, V<sub>30</sub>= *O. rufipogon* ACC. No.6, V<sub>31</sub>= *Potericia coractata* ACC. No.2, V<sub>32</sub>= *O. longistaminata* ACC. No.4, V<sub>33</sub>= *Potericia coractata* ACC. No.3, V<sub>34</sub>= *O. rufipogon* ACC. No.7, V<sub>35</sub>= *O. glaberrima* ACC. No.2, V<sub>36</sub>= *O. punctata* ACC. No.3, V<sub>37</sub>= *O. glaberrima* ACC. No.3, V<sub>38</sub>= *O. alta* ACC. No.3, V<sub>39</sub>= *O. glaberrima* ACC. No.4 and V<sub>40</sub>= *O. punctata* ACC. No. 4.

#### 4.1.17 Total dry weight hill<sup>-1</sup>

Statistically significant variation was exerted in case of total dry weight hill<sup>-1</sup> for different species differences of wild rice (Table 4.1.4). The maximum total dry weight hill<sup>-1</sup> (377.8 g) was scored by *O. latifolia* ACC. No.2 (V<sub>5</sub>) which was statistically similar with V<sub>2</sub>, V<sub>27</sub>, V<sub>21</sub>, V<sub>28</sub>, V<sub>3</sub>, V<sub>1</sub> and V<sub>6</sub> on the other hand the minimum total dry weight hill<sup>-1</sup> (58.53 g) was scored by *O. officinalis* ACC. No.1 (V<sub>7</sub>) which was statistically similar with V<sub>9</sub>, V<sub>31</sub> and V<sub>33</sub>. Chamely *et al.* (2015) reported that variety BRRI dna28 produced the highest dry matter than other tested varieties. Roy *et al.* (2014a) revealed that the variety BRRI dhan48 was superior in relation to total dry matter weight hill<sup>-1</sup> and the lowest total dry matter weight hill<sup>-1</sup> was observed in BRRI dhan42. The significant variation in total dry matter weight hill<sup>-1</sup> among the varieties was also reported by Ahmed (2006); Amin *et al.* (2006).

#### 4.1.18 Days to 1<sup>st</sup> flowering

Days to 1<sup>st</sup> flowering significantly varied due to different species of wild rice (Table 4.1.5). Result showed that, the delayed 1<sup>st</sup> flowering (233.70 days) was observed from both *O. rufipogon* ACC. No.4 (V<sub>25</sub>) and *O. rufipogon* ACC. No.5 (V<sub>26</sub>) which were statistically similar with V<sub>30</sub>, V<sub>11</sub>, V<sub>4</sub> and V<sub>1</sub> where as the earliest 1<sup>st</sup> flowering (106.30 days) was observed from *O. latifolia* ACC. No.3 (V<sub>21</sub>) which were statistically similar with V<sub>24</sub>, V<sub>2</sub> and V<sub>5</sub>. There is a thumb rule that the rice variety which 1<sup>st</sup> flower comes after 20 October is treated as photosensitive variety. Following the thumb rule, in our investigation V<sub>2</sub>, V<sub>5</sub>, V<sub>9</sub>, V<sub>21</sub>, V<sub>24</sub>, V<sub>31</sub> and V<sub>33</sub> are photo insensitive genotypes; V<sub>7</sub>, V<sub>8</sub>, V<sub>12</sub>, V<sub>13</sub>, V<sub>14</sub>, V<sub>15</sub>, V<sub>16</sub>, V<sub>18</sub>, V<sub>19</sub>, V<sub>20</sub>, V<sub>23</sub>, V<sub>27</sub>, V<sub>34</sub>, V<sub>36</sub>, V<sub>38</sub> and V<sub>40</sub> are moderately photosensitive genotypes and V<sub>1</sub>, V<sub>4</sub>, V<sub>6</sub>, V<sub>10</sub>, V<sub>11</sub>, V<sub>22</sub>, V<sub>25</sub>, V<sub>26</sub>, V<sub>28</sub>, V<sub>29</sub>, V<sub>30</sub>, V<sub>35</sub>, V<sub>37</sub> and V<sub>39</sub> genotypes are highly photosensitive. The results of present investigation for days to 1<sup>st</sup> flowering are conformity with the findings of Singh *et al.* (2013a); Chouhan *et al.* (2014a,b) who

reported that days to 1<sup>st</sup> flowering had significant difference with species variation and this might be due to the different in life span of varieties.

**Table 4.1.4 Length of root, root dry weight, shoot dry weight and total dry weight of wild species of rice**

| Treatments                  | Length of root<br>(cm) | Root dry weight<br>hill <sup>-1</sup> (gm) | Shoot dry weight<br>hill <sup>-1</sup> (gm) | Total dry weight<br>hill <sup>-1</sup> (gm) |
|-----------------------------|------------------------|--------------------------------------------|---------------------------------------------|---------------------------------------------|
| V <sub>1</sub>              | 19.73 i-n              | 174.20 c-h                                 | 179.20 de                                   | 356.90 a-d                                  |
| V <sub>2</sub>              | 42.60 a-c              | 173.40 c-h                                 | 200.50 ab                                   | 374.60 a                                    |
| V <sub>3</sub>              | 14.67 qr               | 187.20 a-c                                 | 179.70 de                                   | 367.70 abc                                  |
| V <sub>4</sub>              | 26.00 fg               | 187.20 a-c                                 | 159.90 hi                                   | 347.10 c-e                                  |
| V <sub>5</sub>              | 45.00 a                | 183.10 a-d                                 | 194.40 bc                                   | 377.80 a                                    |
| V <sub>6</sub>              | 15.17 p-r              | 182.10 a-d                                 | 182.20 c-e                                  | 365.20 a-c                                  |
| V <sub>7</sub>              | 26.00 fg               | 144.00 l                                   | 153.00 h-j                                  | 58.53 p                                     |
| V <sub>8</sub>              | 27.87 f                | 189.90 ab                                  | 157.70 h-j                                  | 335.10 d-f                                  |
| V <sub>9</sub>              | 19.00 k-n              | 34.01 p                                    | 46.68 p                                     | 78.09 p                                     |
| V <sub>10</sub>             | 17.37 n-q              | 127.30 m                                   | 177.60 d-f                                  | 305.50 h-j                                  |
| V <sub>11</sub>             | 22.33 h-j              | 156.60 i-l                                 | 188.20 b-d                                  | 337.00 d-f                                  |
| V <sub>12</sub>             | 37.57 de               | 127.10 m                                   | 164.90 gh                                   | 292.60 jk                                   |
| V <sub>13</sub>             | 22.53 hi               | 161.20 h-k                                 | 182.60 c-e                                  | 336.50 d-f                                  |
| V <sub>14</sub>             | 36.20 e                | 121.80 mn                                  | 165.50 f-h                                  | 287.50 j-l                                  |
| V <sub>15</sub>             | 22.67 hi               | 162.00 g-k                                 | 147.00 j                                    | 308.80 g-j                                  |
| V <sub>16</sub>             | 19.17 j-n              | 30.25 p                                    | 51.15 p                                     | 118.00 o                                    |
| V <sub>17</sub>             | 12.97 r-t              | 116.50 mn                                  | 162.20 g-i                                  | 289.00 j-l                                  |
| V <sub>18</sub>             | 21.33 h-m              | 27.90 p                                    | 52.40 p                                     | 120.40 o                                    |
| V <sub>19</sub>             | 21.67 h-l              | 165.80 f-j                                 | 121.70 kl                                   | 287.50 j-l                                  |
| V <sub>20</sub>             | 29.00 f                | 181.90 a-d                                 | 184.80 c-e                                  | 338.70 d-f                                  |
| V <sub>21</sub>             | 40.10 cd               | 176.50 b-f                                 | 193.60 bc                                   | 370.90 ab                                   |
| V <sub>22</sub>             | 12.83 r-t              | 111.20 n                                   | 154.40 hij                                  | 265.90 lm                                   |
| V <sub>23</sub>             | 23.27 gh               | 143.90 l                                   | 151.10 ij                                   | 263.40 m                                    |
| V <sub>24</sub>             | 43.33 ab               | 73.41 o                                    | 94.96 o                                     | 168.40 n                                    |
| V <sub>25</sub>             | 27.67 f                | 175.60 b-g                                 | 155.00 h-j                                  | 330.90 e-g                                  |
| V <sub>26</sub>             | 18.73 l-o              | 151.40 kl                                  | 173.70 e-g                                  | 326.10 e-h                                  |
| V <sub>27</sub>             | 22.00 h-k              | 116.40 mn                                  | 103.00 no                                   | 371.80 ab                                   |
| V <sub>28</sub>             | 15.78 o-r              | 181.10 a-e                                 | 186.40 cd                                   | 368.30 a-c                                  |
| V <sub>29</sub>             | 9.83 t                 | 170.00 d-i                                 | 147.00 j                                    | 317.50 f-i                                  |
| V <sub>30</sub>             | 22.33 h-j              | 125.70 m                                   | 211.70 a                                    | 336.50 d-f                                  |
| V <sub>31</sub>             | 18.83 k-o              | 24.92 p                                    | 39.92 p                                     | 72.350 p                                    |
| V <sub>32</sub>             | 23.67 gh               | 160.70 h-k                                 | 128.70 k                                    | 289.30 j-l                                  |
| V <sub>33</sub>             | 18.17 m-p              | 30.76 p                                    | 42.09 p                                     | 73.53 p                                     |
| V <sub>34</sub>             | 23.83 gh               | 153.40 j-l                                 | 183.30 c-e                                  | 337.40 d-f                                  |
| V <sub>35</sub>             | 9.933 t                | 188.70 ab                                  | 160.10 hi                                   | 348.60 b-e                                  |
| V <sub>36</sub>             | 20.73 h-m              | 167.40 e-j                                 | 108.80 mn                                   | 276.20 k-m                                  |
| V <sub>37</sub>             | 14.07 rs               | 190.90 a                                   | 159.10 h-j                                  | 349.80 b-e                                  |
| V <sub>38</sub>             | 40.23 b-d              | 189.60 ab                                  | 173.00 e-g                                  | 296.20 i-k                                  |
| V <sub>39</sub>             | 11.33 st               | 182.40 a-d                                 | 158.40 h-j                                  | 341.40 de                                   |
| V <sub>40</sub>             | 23.67 gh               | 187.40 a-c                                 | 115.80 lm                                   | 300.90 ij                                   |
| <b>LSD<sub>(0.05)</sub></b> | <b>3.17</b>            | <b>14.33</b>                               | <b>12.58</b>                                | <b>23.75</b>                                |
| <b>CV (%)</b>               | <b>8.31</b>            | <b>6.15</b>                                | <b>5.25</b>                                 | <b>5.09</b>                                 |

V<sub>1</sub>= *Oryza rufipogon* Accession (ACC.) No.1, V<sub>2</sub>= *O. latifolia* ACC. No.1, V<sub>3</sub>= *O. nivara* ACC. No.1, V<sub>4</sub>= *O. rufipogon* ACC. No.2, V<sub>5</sub>= *O. latifolia* ACC. No.2, V<sub>6</sub>= *O. nivara* ACC. No.2, V<sub>7</sub>= *O. officinalis* ACC. No.1, V<sub>8</sub>= *O. longistaminata* ACC. No.1, V<sub>9</sub>= *Potericia coaractata* ACC. No.1, V<sub>10</sub>= *O. nivara* ACC. No.3, V<sub>11</sub>= *O. rufipogon* ACC. No.3, V<sub>12</sub>= *O. alta* ACC. No.1, V<sub>13</sub>= *O. longistaminata* ACC. No.2, V<sub>14</sub>= *O. alta* ACC. No.2, V<sub>15</sub>= *O. punctata* ACC. No.1, V<sub>16</sub>= *O. barthii* ACC. No.1, V<sub>17</sub>= *O. nivara* ACC. No.4, V<sub>18</sub>= *O. barthii* ACC. No.6, V<sub>19</sub>= *O. punctata* ACC. No.2, V<sub>20</sub>= *O. longistaminata* ACC. No.3, V<sub>21</sub>= *O. latifolia* ACC. No.3, V<sub>22</sub>= *O. nivara* (ACC.) No.5, V<sub>23</sub>= *O. officinalis* ACC. No.2, V<sub>24</sub>= *O. latifolia* ACC. No.4, V<sub>25</sub>= *O. rufipogon* ACC. No.4, V<sub>26</sub>= *O. rufipogon* ACC. No.5, V<sub>27</sub>= *O. latifolia* ACC. No.3, V<sub>28</sub>= *O. nivara* ACC. No.6, V<sub>29</sub>= *O. glaberrima* ACC. No.1, V<sub>30</sub>= *O. rufipogon* ACC. No.6, V<sub>31</sub>= *Potericia coractata* ACC. No.2, V<sub>32</sub>= *O. longistaminata* ACC. No.4, V<sub>33</sub>= *Potericia coractata* ACC. No.3, V<sub>34</sub>= *O. rufipogon* ACC. No.7, V<sub>35</sub>= *O. glaberrima* ACC. No.2, V<sub>36</sub>= *O. punctata* ACC. No.3, V<sub>37</sub>= *O. glaberrima* ACC. No.3, V<sub>38</sub>= *O. alta* ACC. No.3, V<sub>39</sub>= *O. glaberrima* ACC. No.4 and V<sub>40</sub>= *O. punctata* ACC. No.4.

#### 4.1.19 Growth duration

There was a marked difference among the different rice species on the growth duration of wild rice (Table 4.1.5). Result showed that, the longest growth duration (270.00 days) was found in *O. rufipogon* ACC. No.2 (V<sub>4</sub>), *O. rufipogon* ACC. No.4 (V<sub>25</sub>), *O. rufipogon* ACC. No.6 (V<sub>30</sub>) and *O. rufipogon* ACC. No.7 (V<sub>34</sub>) where as the shortest growth duration (145.00 days) was found in *O. latifolia* ACC. No.1 (V<sub>2</sub>), *O. latifolia* ACC. No.2 (V<sub>5</sub>), *O. alta* ACC. No.1 (V<sub>12</sub>), *O. alta* ACC. No.2 (V<sub>14</sub>), *O. latifolia* ACC. No.3 (V<sub>21</sub>), *O. latifolia* ACC. No.4 (V<sub>24</sub>) and *O. alta* ACC. No.3 (V<sub>38</sub>). The rest of the treatments showed the intermediate growth duration. This might be due to different genetic potentiality of varieties. Our results obtained in this experiment are in agreement with those of Subudhi *et al.* (2011); Chouhan *et al.* (2014a,b).

#### 4.1.20 Tillers hill<sup>-1</sup>

Tillers hill<sup>-1</sup> showed statistically significant difference for different species of wild rice (Table 4.1.6). The result of the study showed that, the maximum tillers hill<sup>-1</sup> (135.00) was achieved from *O. rufipogon* ACC. No.7 (V<sub>34</sub>) and the minimum tillers hill<sup>-1</sup> (24.00) was achieved from *O. latifolia* ACC. No. (V<sub>21</sub>) which was statistically similar with V<sub>24</sub> and V<sub>2</sub>. This might be due to the diversity of genetic make-up of varieties and ability to accumulate the photosynthates in the vegetative plant parts. Debnath (2010) reported that BRRI dhan29 produced maximum number of tillers hill<sup>-1</sup> compared to BRRI hybrid dhan2. Shrestha *et al.* (2021) reported that the number of tillers plant<sup>-1</sup> varied from NR 11410-B-B-9 (6) to Sunaulo sugandha (15). Chamely *et al.* (2015) also reported that the highest number of total tillers hill<sup>-1</sup> (12.71) was recorded in the variety BRRI dhan29 which was statistically similar with the variety



**Table 4.1.5 Days to 1<sup>st</sup> flowering and growth duration of wild species of rice**

| Treatments      | Days to 1 <sup>st</sup><br>flowering | Growth duration<br>(days) |
|-----------------|--------------------------------------|---------------------------|
| V <sub>1</sub>  | 232.30 a                             | 265.00 b                  |
| V <sub>2</sub>  | 107.30 n                             | 145.00 g                  |
| V <sub>3</sub>  | 226.30 b                             | 260.00 c                  |
| V <sub>4</sub>  | 232.70 a                             | 270.00 a                  |
| V <sub>5</sub>  | 108.00 n                             | 145.00 g                  |
| V <sub>6</sub>  | 226.70 b                             | 260.00 c                  |
| V <sub>7</sub>  | 197.70 i-l                           | 230.00 e                  |
| V <sub>8</sub>  | 198.00 i-k                           | 230.00 e                  |
| V <sub>9</sub>  | 117.00 m                             | 150.00 f                  |
| V <sub>10</sub> | 226.70 b                             | 260.00 c                  |
| V <sub>11</sub> | 233.00 a                             | 270.00 a                  |
| V <sub>12</sub> | 199.30 hi                            | 145.00 g                  |
| V <sub>13</sub> | 196.00 l                             | 230.00 e                  |
| V <sub>14</sub> | 200.00 gh                            | 145.00 g                  |
| V <sub>15</sub> | 201.70 fg                            | 230.00 e                  |
| V <sub>16</sub> | 202.70 f                             | 235.00 d                  |
| V <sub>17</sub> | 227.30 b                             | 260.00 c                  |
| V <sub>18</sub> | 203.30 f                             | 235.00 d                  |
| V <sub>19</sub> | 203.00 f                             | 230.00 e                  |
| V <sub>20</sub> | 196.30 kl                            | 230.00 e                  |
| V <sub>21</sub> | 106.30 n                             | 145.00 g                  |
| V <sub>22</sub> | 225.70 bc                            | 260.00 c                  |
| V <sub>23</sub> | 197.30 j-l                           | 230.00 e                  |
| V <sub>24</sub> | 106.70 n                             | 145.00 g                  |
| V <sub>25</sub> | 233.70 a                             | 270.00 a                  |
| V <sub>26</sub> | 233.70 a                             | 265.00 b                  |
| V <sub>27</sub> | 196.70 kl                            | 230.00 e                  |
| V <sub>28</sub> | 227.00 b                             | 260.00 c                  |
| V <sub>29</sub> | 224.30 cd                            | 265.00 b                  |
| V <sub>30</sub> | 233.30 a                             | 270.00 a                  |
| V <sub>31</sub> | 116.70 m                             | 150.00 f                  |
| V <sub>32</sub> | 198.70 h-j                           | 230.00 e                  |
| V <sub>33</sub> | 116.70 m                             | 150.00 f                  |
| V <sub>34</sub> | 213.30 e                             | 270.00 a                  |
| V <sub>35</sub> | 223.30 d                             | 265.00 b                  |
| V <sub>36</sub> | 203.30 f                             | 230.00 e                  |
| V <sub>37</sub> | 223.00 d                             | 265.00 b                  |
| V <sub>38</sub> | 200.00 gh                            | 145.00 g                  |
| V <sub>39</sub> | 222.70 d                             | 265.00 b                  |
| V <sub>40</sub> | 201.70 fg                            | 230.00 e                  |
| LSD (0.05)      | 1.92                                 | 0.02                      |
| CV (%)          | 0.60                                 | 0.00                      |

V<sub>1</sub>= *Oryza rufipogon* Accession (ACC.) No.1, V<sub>2</sub>= *O. latifolia* ACC. No.1, V<sub>3</sub>= *O. nivara* ACC. No.1, V<sub>4</sub>= *O. rufipogon* ACC. No.2, V<sub>5</sub>= *O. latifolia* ACC. No.2, V<sub>6</sub>= *O. nivara* ACC. No.2, V<sub>7</sub>= *O. officinalis* ACC. No.1, V<sub>8</sub>= *O. longistaminata* ACC. No.1, V<sub>9</sub>= *Potericia coaractata* ACC. No.1, V<sub>10</sub>= *O. nivara* ACC. No.3, V<sub>11</sub>= *O. rufipogon* ACC. No.3, V<sub>12</sub>= *O. alta* ACC. No.1, V<sub>13</sub>= *O. longistaminata* ACC. No.2, V<sub>14</sub>= *O. alta* ACC. No.2, V<sub>15</sub>= *O. punctata* ACC. No.1, V<sub>16</sub>= *O. barthii* ACC. No.1, V<sub>17</sub>=

*O. nivara* ACC. No.4, V<sub>18</sub>= *O. barthii* ACC. No.6, V<sub>19</sub>= *O. punctata* ACC. No.2, V<sub>20</sub>= *O. longistaminata* ACC. No.3, V<sub>21</sub>= *O. latifolia* ACC. No.3, V<sub>22</sub>= *O. nivara* (ACC.) No.5, V<sub>23</sub>= *O. officinalis* ACC. No.2, V<sub>24</sub>= *O. latifolia* ACC. No.4, V<sub>25</sub>= *O. rufipogon* ACC. No.4, V<sub>26</sub>= *O. rufipogon* ACC. No.5, V<sub>27</sub>= *O. latifolia* ACC. No.3, V<sub>28</sub>= *O. nivara* ACC. No.6, V<sub>29</sub>= *O. glaberrima* ACC. No.1, V<sub>30</sub>= *O. rufipogon* ACC. No.6, V<sub>31</sub>= *Potericia coractata* ACC. No.2, V<sub>32</sub>= *O. longistaminata* ACC. No.4, V<sub>33</sub>= *Potericia coractata* ACC. No.3, V<sub>34</sub>= *O. rufipogon* ACC. No.7, V<sub>35</sub>= *O. glaberrima* ACC. No.2, V<sub>36</sub>= *O. punctata* ACC. No.3, V<sub>37</sub>= *O. glaberrima* ACC. No.3, V<sub>38</sub>= *O. alta* ACC. No.3, V<sub>39</sub>= *O. glaberrima* ACC. No.4 and V<sub>40</sub>= *O. punctata* ACC. No.4.

BRRI dhan28 and the lowest number of total tillers hill<sup>-1</sup> was observed in BRRI dhan45. Our present findings are similar to those of Roy *et al.* (2014a); Dangi *et al.* (2017); Kumar *et al.* (2017) who concluded that species variation affected the tillers hill<sup>-1</sup> of rice.

#### 4.1.21 Effective tillers hill<sup>-1</sup>

Effective tillers hill<sup>-1</sup> showed significant variation for different species of wild rice (Table 4.1.6). The result of the investigation exerted that, the highest effective tillers hill<sup>-1</sup> (81.33) was recorded from *O. rufipogon* ACC. No.7 (V<sub>34</sub>) which was statistically similar with V<sub>28</sub> and V<sub>30</sub> and the lowest effective tillers hill<sup>-1</sup> (12.67) was recorded from both *O. latifolia* ACC. No.3 (V<sub>21</sub>) and *O. latifolia* ACC. No.4 (V<sub>24</sub>) which were statistically similar with V<sub>2</sub> and V<sub>14</sub>. The diversity in the genetic make-up of the species is the cause of the variability in the number of effective tillers plant<sup>-1</sup>. Kumar *et al.* (2017) added that the higher number of effective tillers might be attributed to higher affinity of these varieties to produce more number of tillers m<sup>-2</sup> in early growing period followed by differential ability of cultivars to utilize the fertilizer nutrients as well as partitioning of photoassimilates. Rice grain yield is heavily influenced by effective tillering ability. Too few tillers result in fewer panicles, whereas too many tillers result in high tiller mortality, undersized panicles, poor grain filling, and reduced grain yield (Peng *et al.*, 1994). Effective tillers are one of the most important yield components, as the final yield is mostly determined by the number of panicles bearing tillers per unit area (Roy *et al.*, 2014a). Kumar *et al.* (2017) reviewed that rice species PAC-837 recorded significantly higher effective tillers m<sup>-2</sup> (264.00), which was statistically at par with DRRH-3. Chamely *et al.* (2015) also reported that the highest number of effective tillers hill<sup>-1</sup> (11.07) was observed in the variety BRRI dhan29 and the lowest one was observed in BRRI dhan45. Chouhan *et al.* (2014b) showed that number of effective tillers plant<sup>-1</sup> varied from 3.50 to 10.15 with mean of 7.19 and 65.71 % accessions had more than 6 tillers

plant<sup>-1</sup>. The findings of our research are collaborate with those reported by Roy *et al.* (2014a); Chamely *et al.* (2015); Shrestha *et al.* (2021) who stated that number of effective tillers hill<sup>-1</sup> was varied with varieties.

#### **4.1.22 Non-effective tillers hill<sup>-1</sup>**

Non-effective tillers hill<sup>-1</sup> showed significant variation for different genotypes of wild rice (Table 4.1.6). The result of the investigation exerted that, the highest non-effective tillers hill<sup>-1</sup> (53.67) was recorded from *O. rufipogon* ACC. No.7 (V<sub>34</sub>) and the lowest non-effective tillers hill<sup>-1</sup> (10.33) was recorded from *O. barthii* ACC. No.6 (V<sub>18</sub>) which was statistically similar with V<sub>29</sub>, V<sub>21</sub>, V<sub>16</sub>, V<sub>2</sub>, V<sub>24</sub>, V<sub>35</sub>, V<sub>37</sub> and V<sub>39</sub>. The results of our experiment are not similar with the findings of Ashrafuzzaman (2006); Debnath (2010). While the similar findings are also reported by Chouhan *et al.* (2014b); Shiyam *et al.* (2014); Roy *et al.* (2014a) who found significant variation among varieties in respect of number of non-effective tillers hill<sup>-1</sup>.

#### **4.1.23 Panicle length**

Significant variation was recorded in panicle length for different species of wild rice (Table 4.1.7). The result showed that, the longest panicle (49.50 cm) was achieved from *O. latifolia* ACC. No.2 (V<sub>5</sub>) which was statistically similar with V<sub>2</sub>, V<sub>24</sub> and V<sub>22</sub> and the shortest panicle (14.87 cm) was achieved from *O. rufipogon* ACC. No.7 (V<sub>34</sub>) treatment which was statistically similar with V<sub>30</sub>, V<sub>33</sub> and V<sub>11</sub>. The variation in panicle length as assessed might be due to genetic characters of the varieties primarily influenced by the heredity. Chouhan *et al.* (2014b) presented that panicle length varied from 17.72 to 28.50 cm with mean of 23.09 cm and 68.57% accessions had intermediate type. Shrestha *et al.* (2021) reported that the panicle length ranged from NR 11182-B-21 (21 cm) to NR 11196- B-3-3 (30.9 cm). Chamely *et al.* (2015) presented that the longest panicle (23.19 cm) was found in the variety BRRI dhan29 and the smallest one was found in BRRI dhan45. Dangi *et al.* (2017) showed that the variety IR-64 produced maximum panicle length (23.55 cm) while variety Kalanamak attained minimum the value. Our present investigation findings are close conformity with the findings of Gangashetty *et al.* (2013); Singh and Kumar (2014); Tiwari *et al.* (2015) who observed that varieties differed significantly in respect of panicle length.

**Table 4.1.6 Tillering of wild species of rice**

| Treatments        | Tillers hill <sup>-1</sup> (no.) | Effective tillers hill <sup>-1</sup> (no.) | Non-effective tillers hill <sup>-1</sup> (no.) |
|-------------------|----------------------------------|--------------------------------------------|------------------------------------------------|
| V <sub>1</sub>    | 76.00 gh                         | 52.00 fg                                   | 24.00 f-i                                      |
| V <sub>2</sub>    | 30.00 r-t                        | 16.67 op                                   | 13.33 m-o                                      |
| V <sub>3</sub>    | 86.67 f                          | 71.00 c                                    | 15.67 lm                                       |
| V <sub>4</sub>    | 67.33 i-k                        | 40.67 j-l                                  | 26.67 fg                                       |
| V <sub>5</sub>    | 34.33 r                          | 18.67 o                                    | 15.67 lm                                       |
| V <sub>6</sub>    | 96.33 de                         | 70.00 c                                    | 26.33 fg                                       |
| V <sub>7</sub>    | 52.33 n-p                        | 31.67 n                                    | 20.67 i-k                                      |
| V <sub>8</sub>    | 44.33 q                          | 28.33 n                                    | 16.00 lm                                       |
| V <sub>9</sub>    | 77.67 g                          | 46.33 hi                                   | 31.33 de                                       |
| V <sub>10</sub>   | 93.67 ef                         | 74.33 bc                                   | 19.33 kl                                       |
| V <sub>11</sub>   | 103.0 cd                         | 63.67 d                                    | 39.33 c                                        |
| V <sub>12</sub>   | 35.00 r                          | 19.00 o                                    | 16.00 lm                                       |
| V <sub>13</sub>   | 47.00 pq                         | 28.00 n                                    | 19.00 kl                                       |
| V <sub>14</sub>   | 31.67 rs                         | 17.33 op                                   | 14.33 mn                                       |
| V <sub>15</sub>   | 61.00 k-m                        | 37.33 lm                                   | 23.67 g-j                                      |
| V <sub>16</sub>   | 58.33 l-n                        | 47.33 gh                                   | 11.00 no                                       |
| V <sub>17</sub>   | 78.33 g                          | 57.33 ef                                   | 21.00 i-k                                      |
| V <sub>18</sub>   | 64.00 j-l                        | 53.67 ef                                   | 10.33 o                                        |
| V <sub>19</sub>   | 66.67 i-k                        | 39.00 kl                                   | 27.67 ef                                       |
| V <sub>20</sub>   | 54.67 m-o                        | 32.33 mn                                   | 22.33 h-k                                      |
| V <sub>21</sub>   | 24.00 t                          | 12.67 p                                    | 11.33 no                                       |
| V <sub>22</sub>   | 76.00 gh                         | 57.33 ef                                   | 18.67 kl                                       |
| V <sub>23</sub>   | 53.33 n-p                        | 32.00 mn                                   | 21.33 i-k                                      |
| V <sub>24</sub>   | 26.00 st                         | 12.67 p                                    | 13.33 m-o                                      |
| V <sub>25</sub>   | 66.67 i-k                        | 42.67 h-l                                  | 24.00 f-i                                      |
| V <sub>26</sub>   | 69.67 h-j                        | 47.33 gh                                   | 22.33 h-k                                      |
| V <sub>27</sub>   | 48.00 o-q                        | 28.00 n                                    | 20.00 jk                                       |
| V <sub>28</sub>   | 105.3 c                          | 81.00 a                                    | 24.33 f-i                                      |
| V <sub>29</sub>   | 54.67 m-o                        | 43.33 h-k                                  | 11.33 no                                       |
| V <sub>30</sub>   | 123.3 b                          | 79.33 ab                                   | 44.00 b                                        |
| V <sub>31</sub>   | 73.33 g-i                        | 41.33 i-l                                  | 32.00 d                                        |
| V <sub>32</sub>   | 49.33 o-q                        | 28.00 n                                    | 21.33 ijk                                      |
| V <sub>33</sub>   | 76.33 gh                         | 41.33 i-l                                  | 35.00 d                                        |
| V <sub>34</sub>   | 135.0 a                          | 81.33 a                                    | 53.67 a                                        |
| V <sub>35</sub>   | 57.67 l-n                        | 45.33 h-j                                  | 12.33 m-o                                      |
| V <sub>36</sub>   | 68.33 ij                         | 42.67 h-l                                  | 25.67 f-h                                      |
| V <sub>37</sub>   | 71.33 g-i                        | 58.67 de                                   | 12.67 m-o                                      |
| V <sub>38</sub>   | 36.33 r                          | 21.67 o                                    | 14.67 mn                                       |
| V <sub>39</sub>   | 70.33 h-j                        | 57.67 e                                    | 12.67 m-o                                      |
| V <sub>40</sub>   | 71.33 g-i                        | 45.33 h-j                                  | 26.00 f-h                                      |
| <b>LSD (0.05)</b> | <b>7.31</b>                      | <b>5.61</b>                                | <b>3.93</b>                                    |
| <b>CV (%)</b>     | <b>6.88</b>                      | <b>7.92</b>                                | <b>11.12</b>                                   |

V<sub>1</sub>= *Oryza rufipogon* Accession (ACC.) No.1, V<sub>2</sub>= *O. latifolia* ACC. No.1, V<sub>3</sub>= *O. nivara* ACC. No.1, V<sub>4</sub>= *O. rufipogon* ACC. No.2, V<sub>5</sub>= *O. latifolia* ACC. No.2, V<sub>6</sub>= *O. nivara* ACC. No.2, V<sub>7</sub>= *O. officinalis* ACC. No.1, V<sub>8</sub>= *O. longistaminata* ACC. No.1, V<sub>9</sub>= *Potericia coaractata* ACC. No.1, V<sub>10</sub>= *O. nivara* ACC. No.3, V<sub>11</sub>= *O. rufipogon* ACC. No.3, V<sub>12</sub>= *O. alta* ACC. No.1, V<sub>13</sub>= *O. longistaminata* ACC. No.2, V<sub>14</sub>= *O. alta* ACC. No.2, V<sub>15</sub>= *O. punctata* ACC. No.1, V<sub>16</sub>= *O. barthii*

ACC. No.1, V<sub>17</sub>= *O. nivara* ACC. No.4, V<sub>18</sub>= *O. barthii* ACC. No.6, V<sub>19</sub>= *O. punctata* ACC. No.2, V<sub>20</sub>= *O. longistaminata* ACC. No.3, V<sub>21</sub>= *O. latifolia* ACC. No.3, V<sub>22</sub>= *O. nivara* (ACC.) No.5, V<sub>23</sub>= *O. officinalis* ACC. No.2, V<sub>24</sub>= *O. latifolia* ACC. No.4, V<sub>25</sub>= *O. rufipogon* ACC. No.4, V<sub>26</sub>= *O. rufipogon* ACC. No.5, V<sub>27</sub>= *O. latifolia* ACC. No.3, V<sub>28</sub>= *O. nivara* ACC. No.6, V<sub>29</sub>= *O. glaberrima* ACC. No.1, V<sub>30</sub>= *O. rufipogon* ACC. No.6, V<sub>31</sub>= *Potericia coractata* ACC. No.2, V<sub>32</sub>= *O. longistaminata* ACC. No.4, V<sub>33</sub>= *Potericia coractata* ACC. No.3, V<sub>34</sub>= *O. rufipogon* ACC. No.7, V<sub>35</sub>= *O. glaberrima* ACC. No.2, V<sub>36</sub>= *O. punctata* ACC. No.3, V<sub>37</sub>= *O. glaberrima* ACC. No.3, V<sub>38</sub>= *O. alta* ACC. No.3, V<sub>39</sub>= *O. glaberrima* ACC. No.4 and V<sub>40</sub>= *O. punctata* ACC. No.4.

#### 4.1.24 Grains panicle<sup>-1</sup>

Grains panicle<sup>-1</sup> significantly varied due to different species of wild rice (Table 4.1.7). Our results showed that, the maximum grains panicle<sup>-1</sup> (359.70) was observed from *O. latifolia* ACC. No.4 (V<sub>24</sub>) which was statistically similar with V<sub>5</sub> and the minimum one (35.00) was observed from *O. rufipogon* ACC. No.2 (V<sub>4</sub>) which was statistically similar with V<sub>16</sub> and V<sub>18</sub>. Species differences regarding the number of grains panicle<sup>-1</sup> was probably due to their genetic make-up and also due to the variation in photosynthetic assimilate accumulation especially after heading. Kumar *et al.* (2017) observed higher number of grains panicle<sup>-1</sup> in rice species DRRH-3 followed by PR-115 and lower number of grains panicle<sup>-1</sup> in PR-121. Chamely *et al.* (2015) confirmed that the highest number of grains panicle<sup>-1</sup> (159.55) was recorded in the variety BRRI dhan29 which was about double compare to the variety BBRI dhan45 and about 1.5 fold more than the variety BRRI dhan28. Chouhan *et al.* (2014b) noted that total number of grains panicle<sup>-1</sup> varied from 267.29 to 54.61 with mean of 107.32 among the tested rice varieties. Dangi *et al.* (2017) Variety IR- 64 produced maximum number of grains panicle<sup>-1</sup> (129.44) while variety Kalanamak attained the minimum value for number of grains panicle<sup>-1</sup>. Variation in number of grains panicle<sup>-1</sup> with rice varieties was also reported by Gohain (2014); Dangi *et al.* (2017); Kumar *et al.* (2017).

#### 4.1.25 Filled grains panicle<sup>-1</sup>

Filled grains panicle<sup>-1</sup> significantly varied due to different species of wild rice (Table 4.1.7). Results showed that, the maximum filled grains panicle<sup>-1</sup> (165.00) was observed from *O. longistaminata* ACC. No.3 (V<sub>20</sub>) which was statistically similar with V<sub>13</sub> and V<sub>32</sub> and the minimum one (10.67) was observed from *O. rufipogon* ACC. No.2 (V<sub>4</sub>) which was statistically similar with V<sub>25</sub>. *O. longistaminata* ACC. No.3 produced 1446.39% more filled grains panicle<sup>-1</sup> than *O. rufipogon* ACC. No.2 wild rice. Shrestha *et al.* (2021) stated that the number of filled grains panicle<sup>-1</sup> is one of

the most critical yields determining features. Gravois and McNew (1993) found that filled grains panicle<sup>-1</sup> had a beneficial direct effect on rice yield. The higher number of filled grains panicle<sup>-1</sup> might be attributed to genetic make-up, higher affinity of these varieties to produce more photosynthates and differential ability of cultivars to partitioning of these photosynthates from source to sink (Yesuf and Balcha, 2014; Jahan *et al.*, 2020). Chouhan *et al.* (2014b) observed that the filled grains panicle<sup>-1</sup> varied from 19.12 to 231.90 with mean of 69.65. Dangi *et al.* (2017) reported that the variety IR- 64 produced maximum number of filled grains panicle<sup>-1</sup> (116.22) and while variety Kalanamak attained minimum value for filled grains panicle<sup>-1</sup>. The present investigation results are conformity with the finding of Dangi *et al.* (2017); Jahan *et al.* (2020); Shrestha *et al.* (2021).

#### **4.1.26 Unfilled grains panicle<sup>-1</sup>**

Unfilled grains panicle<sup>-1</sup> significantly varied due to different species of wild rice (Table 4.1.7). Result revealed that, the maximum unfilled grains panicle<sup>-1</sup> (325.30) was observed from *O. latifolia* ACC. No.4 (V<sub>24</sub>) and the minimum one (5.00) was observed from *O. nivara* ACC. No.3 (V<sub>10</sub>) which was statistically similar with V<sub>3</sub>, V<sub>6</sub>, V<sub>28</sub>, V<sub>17</sub>, V<sub>16</sub>, V<sub>9</sub>, V<sub>18</sub>, V<sub>22</sub>, V<sub>31</sub> and V<sub>33</sub>. The reasons for differences in producing unfilled grains panicle<sup>-1</sup> might be due to the variation in genetic make-up of the variety that might be influenced by heredity. Dangi *et al.* (2017) found that the number of unfilled grains panicle<sup>-1</sup> was significantly lowest (13.58 and 14.61) in IR- 64 and BPT-5204 varieties, respectively over other varieties. These results are in agreement with the findings of Singh and Kumar (2014); Tiwari *et al.*, (2015); Jahan *et al.* (2020) who observed the that the production of unfilled grains panicle<sup>-1</sup> differed

#### **4.1.27 Thousand grain weight**

Thousand grain weight of wild rice varied significantly due to different species variation (Table 4.1.8). The highest thousand grain weight (33.61g) was recorded from *O. barthii* ACC. No.6 (V<sub>18</sub>) which was statistically similar with V<sub>16</sub> where as the lowest thousand grain weight (8.06 g) was recorded from *O. officinalis* ACC. No.1 (V<sub>7</sub>) which was statistically similar with V<sub>12</sub>, V<sub>14</sub>, V<sub>15</sub>, V<sub>13</sub>, V<sub>8</sub>, V<sub>20</sub>, V<sub>19</sub>, V<sub>23</sub>, V<sub>27</sub>, V<sub>32</sub>, V<sub>36</sub>, V<sub>38</sub> and V<sub>40</sub>. *O. barthii* ACC. No.6 produced 317% more thousand grain weight than *O. officinalis* ACC. No.1. These results might be due to ability of this cultivar to partition more dry matter from source to sink. Similarly, Kastura and

**Table 4.1.7 Panicle length, grains panicle<sup>-1</sup>, filled grains panicle<sup>-1</sup> and unfilled grains panicle<sup>-1</sup> of wild species of rice**

| Treatments      | Panicle length<br>(cm) | Grains panicle <sup>-1</sup><br>(no.) | Filled grains<br>panicle <sup>-1</sup> (no.) | Unfilled grains<br>panicle <sup>-1</sup> (no.) |
|-----------------|------------------------|---------------------------------------|----------------------------------------------|------------------------------------------------|
| V <sub>1</sub>  | 21.80 i-k              | 144.70 hi                             | 98.00 ef                                     | 46.67 lm                                       |
| V <sub>2</sub>  | 49.33 a                | 326.70 b                              | 47.00 no                                     | 279.70 c                                       |
| V <sub>3</sub>  | 23.60 h-j              | 57.00 n-p                             | 50.00 k-o                                    | 7.00 st                                        |
| V <sub>4</sub>  | 18.73 lm               | 35.00 r                               | 10.67 s                                      | 24.33 no                                       |
| V <sub>5</sub>  | 49.50 a                | 345.70 a                              | 53.33 j-n                                    | 292.30 b                                       |
| V <sub>6</sub>  | 21.33 jk               | 73.00 m                               | 66.00 hi                                     | 7.00 st                                        |
| V <sub>7</sub>  | 27.27 fg               | 212.30 f                              | 87.67 g                                      | 124.7 hi                                       |
| V <sub>8</sub>  | 30.00 c-e              | 296.00 d                              | 156.70 b                                     | 139.3 fg                                       |
| V <sub>9</sub>  | 17.47 mn               | 62.67 m-o                             | 53.00 j-n                                    | 9.67 q-t                                       |
| V <sub>10</sub> | 23.80 hi               | 62.67 m-o                             | 57.67 jk                                     | 5.00 t                                         |
| V <sub>11</sub> | 15.27 n-p              | 90.67 kl                              | 38.67 pq                                     | 52.00 kl                                       |
| V <sub>12</sub> | 31.07 cd               | 301.30 cd                             | 123.00 c                                     | 178.30 d                                       |
| V <sub>13</sub> | 30.53 c-e              | 300.30 cd                             | 160.30 ab                                    | 140.00 f                                       |
| V <sub>14</sub> | 32.23 bc               | 293.70 de                             | 112.30 d                                     | 181.30 d                                       |
| V <sub>15</sub> | 29.47 d-f              | 157.30 gh                             | 100.70 ef                                    | 56.67 jk                                       |
| V <sub>16</sub> | 28.33 ef               | 39.33 qr                              | 29.670 r                                     | 9.67 q-t                                       |
| V <sub>17</sub> | 21.60 i-k              | 65.67 mn                              | 57.33 j-l                                    | 8.33 rst                                       |
| V <sub>18</sub> | 28.63 d-f              | 44.33 p-r                             | 34.00 qr                                     | 10.33 q-t                                      |
| V <sub>19</sub> | 28.20 ef               | 154.70 gh                             | 98.67 ef                                     | 56.00 jk                                       |
| V <sub>20</sub> | 29.40 d-f              | 298.00 d                              | 165.00 a                                     | 133.00 f-h                                     |
| V <sub>21</sub> | 48.77 a                | 313.00 bc                             | 38.67 pq                                     | 274.30 c                                       |
| V <sub>22</sub> | 21.60 i-k              | 51.00 o-q                             | 42.00 o-q                                    | 9.00 rst                                       |
| V <sub>23</sub> | 30.53 c-e              | 214.00 f                              | 96.00 f                                      | 118.00 i                                       |
| V <sub>24</sub> | 49.10 a                | 359.70 a                              | 34.33 qr                                     | 325.30 a                                       |
| V <sub>25</sub> | 17.33 m-o              | 37.67 qr                              | 12.00 s                                      | 25.67 n                                        |
| V <sub>26</sub> | 20.70 kl               | 138.00 i                              | 96.67 f                                      | 41.33 m                                        |
| V <sub>27</sub> | 28.53 ef               | 220.70 f                              | 94.67 fg                                     | 126.00 hi                                      |
| V <sub>28</sub> | 22.33 i-k              | 73.00 m                               | 66.00 hi                                     | 7.00 st                                        |
| V <sub>29</sub> | 21.60 i-k              | 76.33 lm                              | 60.33 ij                                     | 16.00 o-r                                      |
| V <sub>30</sub> | 15.00 op               | 106.30 j                              | 45.33 n-p                                    | 61.00 j                                        |
| V <sub>31</sub> | 16.67 m-p              | 58.33 n-p                             | 48.33 m-o                                    | 10.00 q-t                                      |
| V <sub>32</sub> | 28.13 ef               | 288.00 de                             | 157.30 ab                                    | 130.70 gh                                      |
| V <sub>33</sub> | 15.73 n-p              | 56.67 n-p                             | 47.33 no                                     | 9.33 q-t                                       |
| V <sub>34</sub> | 14.87 p                | 103.70 jk                             | 44.00 op                                     | 59.67 jk                                       |
| V <sub>35</sub> | 20.80 kl               | 70.67 mn                              | 55.67 j-m                                    | 15.00 p-s                                      |
| V <sub>36</sub> | 25.13 gh               | 155.70 gh                             | 97.33 ef                                     | 58.33 jk                                       |
| V <sub>37</sub> | 23.27 h-j              | 90.33 kl                              | 71.00 h                                      | 19.33 n-p                                      |
| V <sub>38</sub> | 33.67 b                | 281.00 e                              | 123.70 c                                     | 157.30 e                                       |
| V <sub>39</sub> | 20.13 kl               | 67.33 mn                              | 49.33 l-o                                    | 18.00 n-q                                      |
| V <sub>40</sub> | 30.07 c-e              | 162.30 g                              | 105.00 de                                    | 57.33 jk                                       |
| LSD (0.05)      | 2.44                   | 14.48                                 | 8.15                                         | 8.92                                           |
| CV (%)          | 5.66                   | 5.67                                  | 6.72                                         | 6.65                                           |

V<sub>1</sub>= *Oryza rufipogon* Accession (ACC.) No.1, V<sub>2</sub>= *O. latifolia* ACC. No.1, V<sub>3</sub>= *O. nivara* ACC. No.1, V<sub>4</sub>= *O. rufipogon* ACC. No.2, V<sub>5</sub>= *O. latifolia* ACC. No.2, V<sub>6</sub>= *O. nivara* ACC. No.2, V<sub>7</sub>= *O. officinalis* ACC. No.1, V<sub>8</sub>= *O. longistaminata* ACC. No.1, V<sub>9</sub>= *Potericia coaractata* ACC. No.1, V<sub>10</sub>= *O. nivara* ACC. No.3, V<sub>11</sub>= *O. rufipogon* ACC. No.3, V<sub>12</sub>= *O. alta* ACC. No.1, V<sub>13</sub>= *O. longistaminata*

ACC. No.2, V<sub>14</sub>= *O. alta* ACC. No.2, V<sub>15</sub>= *O. punctata* ACC. No.1, V<sub>16</sub>= *O. barthii* ACC. No.1, V<sub>17</sub>= *O. nivara* ACC. No.4, V<sub>18</sub>= *O. barthii* ACC. No.6, V<sub>19</sub>= *O. punctata* ACC. No.2, V<sub>20</sub>= *O. longistaminata* ACC. No.3, V<sub>21</sub>= *O. latifolia* ACC. No.3, V<sub>22</sub>= *O. nivara* (ACC.) No.5, V<sub>23</sub>= *O. officinalis* ACC. No.2, V<sub>24</sub>= *O. latifolia* ACC. No.4, V<sub>25</sub>= *O. rufipogon* ACC. No.4, V<sub>26</sub>= *O. rufipogon* ACC. No.5, V<sub>27</sub>= *O. latifolia* ACC. No.3, V<sub>28</sub>= *O. nivara* ACC. No.6, V<sub>29</sub>= *O. glaberrima* ACC. No.1, V<sub>30</sub>= *O. rufipogon* ACC. No.6, V<sub>31</sub>= *Potericia coractata* ACC. No.2, V<sub>32</sub>= *O. longistaminata* ACC. No.4, V<sub>33</sub>= *Potericia coractata* ACC. No.3, V<sub>34</sub>= *O. rufipogon* ACC. No.7, V<sub>35</sub>= *O. glaberrima* ACC. No.2, V<sub>36</sub>= *O. punctata* ACC. No.3, V<sub>37</sub>= *O. glaberrima* ACC. No.3, V<sub>38</sub>= *O. alta* ACC. No.3, V<sub>39</sub>= *O. glaberrima* ACC. No.4 and V<sub>40</sub>= *O. punctata* ACC. No.4.

Nakaide (2011) concluded that the rice varieties with greater sink capacity and source activity plant<sup>-1</sup> could produce more thousand grain weight under aerobic conditions. with variety. Chouhan *et al.* (2014b) reported that thousand grain weight is the key characters for high yield and it varied from 14.10 to 33.50 g with mean of 23.53 g, and showed the presence of high variability among the tested varieties. Dangi *et al.* (2017) recorded highest thousand grain weight (23.39 g) in variety IR64 compare to that Kalanamak which produced lowest thousand grain weight. The result of our present findings also supported by the findings of Gangashetty *et al.* (2013); Chouhan *et al.* (2014a); Tiwari *et al.* (2015); Kumar *et al.* (2017) who concluded that the thousand grains weight depends on species genetic potentiality.

#### 4.1.28 Grain yield hill<sup>-1</sup>

Statistically significant variation was recorded in the grain yield hill<sup>-1</sup> for different species of wild rice (Table 4.1.8). The result of the investigation revealed that, the highest grain yield hill<sup>-1</sup> (101.60 g) was distinctly recorded from *O. nivara* ACC. No.6 (V<sub>28</sub>) and the lowest grain yield hill<sup>-1</sup> (3.52 g) was recorded from *O. latifolia* ACC. No.4 (V<sub>24</sub>) which was statistically similar with V<sub>21</sub>, V<sub>25</sub>, V<sub>4</sub>, V<sub>2</sub> and V<sub>5</sub> treatments. *O. nivara* ACC. No.6 produced 2786.36% more grain hill<sup>-1</sup> than *O. latifolia* ACC. No.4. The highest yield of grain might be attributed to maximum yield contributing characters of rice genotypes. Tripathi *et al.* (2013) opined that for maintaining the high productivity levels, genetic diversity is essential. There was also a lot of variation in grain production across the twelve coarse rice genotypes (Zahid *et al.*, 2005). Chouhan *et al.* (2014b) reported that grain yield plant<sup>-1</sup> varied from 7.89 to 36.98 g with mean of 23.04 g showed high variability in grain yield plant<sup>-1</sup>. Shrestha *et al.* (2021) reported that that grain yield ranged from 2.45 t ha<sup>-1</sup> (Sunaulo Sugandha) to 5.65 t ha<sup>-1</sup> (NR10676-B-3-3-3). Rice genotypes NR 10676-B-1-3-3-3 (5.65 t ha<sup>-1</sup>) produced the highest yield, followed by NR10410-89-3-2-1-1 (5.54 t ha<sup>-1</sup>). Dangi *et al.* (2017) found that the variety IR 64 being at par with BPT-5204 resulted in



significantly highest grain yield ( $42.98 \text{ q ha}^{-1}$ ) which was 9.07, 11.68, 15.01 and 16.49% higher than that produced by BPT-5204, IET 24780, IET 23824 and Sahbhaghi, respectively. Roy *et al.* (2014a) recorded highest grain yield ( $3.97 \text{ t ha}^{-1}$ ) from variety BRRI dhan48 and the lowest one ( $2.58 \text{ t ha}^{-1}$ ) was observed in BRRI dhan42. The results of our investigation are conformity with the earlier reports of Chamely *et al.* (2015); Kumar *et al.* (2017); Shrestha *et al.* (2021) who concluded that the grain yield of rice varied with species variation.

#### **4.1.29 Biological yield hill<sup>-1</sup>**

Different species of wild rice exerted significant variation on biological yield hill<sup>-1</sup> (Table 4.1.8). The maximum biological yield hill<sup>-1</sup> (288.00 g) was distinctly found from *O. nivara* ACC. No.6 (V<sub>28</sub>) and the minimum biological yield hill<sup>-1</sup> (63.20 g) was found from *Potericia coractata* ACC. No.2 (V<sub>31</sub>) which was statistically similar with V<sub>33</sub> and V<sub>9</sub>. Our results are in harmony with those obtained by Chouhan *et al.* (2014b); Tiwari *et al.* (2015); Dangi *et al.* (2017) who reported variable in biological yield among the varieties.

#### **4.1.30 Harvest index**

Harvest index for different species of wild rice showed significant differences (Table 4.1.8). The maximum harvest index (40.59 %) was distinctly recorded from *O. barthii* ACC. No.6 (V<sub>18</sub>) and the minimum harvest index (2.61 %) was recorded from *O. latifolia* ACC. No.3 (V<sub>21</sub>) which was statistically similar with V<sub>4</sub>, V<sub>2</sub>, V<sub>5</sub>, V<sub>24</sub> and V<sub>25</sub>. Ndaeyo *et al.* (2008); Mahajan *et al.* (2012) reported differential ability of partitioning of dry matter and utilization of available nutrients by various varieties of rice which confirm the variations in harvest index. Kumar *et al.* (2017) revealed that the rice variety PAC-837 attained significantly higher harvest index which was statistically at par with DRRH-3. Dangi *et al.* (2017) showed that the variety Chittimuthyalu gave the maximum harvest index (33.80%) followed by Anjali (33.61%), while minimum value (28.94%) observed from IR-64. The results of our present investigation are in agreement with the findings of Chamely *et al.* (2015); Tiwari *et al.*, (2015); Dangi *et al.* (2017) who reported that harvest index varied due to species variations.

**Table 4.1.8 Thousand grain weight and yield of wild species of rice**

| Treatments                  | Thousand grain weight (g) | Grain yield hill <sup>-1</sup> (g) | Biological yield hill <sup>-1</sup> (g) | Harvest index (%) |
|-----------------------------|---------------------------|------------------------------------|-----------------------------------------|-------------------|
| V <sub>1</sub>              | 24.22 c                   | 77.30 c                            | 256.50 bc                               | 30.09 de          |
| V <sub>2</sub>              | 11.35 g                   | 7.58 s-u                           | 208.10 d-f                              | 3.64 rs           |
| V <sub>3</sub>              | 26.22 b                   | 69.00 d                            | 248.70 c                                | 27.74 ef          |
| V <sub>4</sub>              | 13.58 f                   | 5.29 tu                            | 165.20 k-m                              | 3.26 s            |
| V <sub>5</sub>              | 11.64 g                   | 8.83 s-u                           | 203.20 e-g                              | 4.36 rs           |
| V <sub>6</sub>              | 26.03 b                   | 87.93 b                            | 270.10 b                                | 32.56 cd          |
| V <sub>7</sub>              | 8.06 h                    | 17.47 o-q                          | 170.50 j-l                              | 10.27 op          |
| V <sub>8</sub>              | 8.87 h                    | 22.61 l-o                          | 180.30 i-k                              | 12.52 m-o         |
| V <sub>9</sub>              | 13.49 f                   | 24.13 k-m                          | 70.81 st                                | 34.02 c           |
| V <sub>10</sub>             | 26.46 b                   | 78.03 c                            | 255.70 bc                               | 30.44 de          |
| V <sub>11</sub>             | 17.08 e                   | 21.35 m-o                          | 209.60 d-f                              | 10.22 op          |
| V <sub>12</sub>             | 8.08 h                    | 13.14 q-s                          | 178.00 i-k                              | 7.38 q            |
| V <sub>13</sub>             | 8.90 h                    | 21.98 l-o                          | 204.50 d-f                              | 10.75 op          |
| V <sub>14</sub>             | 8.08 h                    | 10.95 r-t                          | 176.40 i-k                              | 6.18 qr           |
| V <sub>15</sub>             | 8.77 h                    | 20.42 m-p                          | 167.40 kl                               | 12.16 no          |
| V <sub>16</sub>             | 33.30 a                   | 30.54 h-j                          | 81.69 rs                                | 37.30 b           |
| V <sub>17</sub>             | 26.57 b                   | 52.50 e                            | 214.70 de                               | 24.46 gh          |
| V <sub>18</sub>             | 33.61 a                   | 35.78 gh                           | 88.18 qr                                | 40.59 a           |
| V <sub>19</sub>             | 8.67 h                    | 21.71 m-o                          | 143.40 no                               | 15.15 k-m         |
| V <sub>20</sub>             | 8.90 h                    | 27.37 j-l                          | 212.20 d-f                              | 12.89 m-o         |
| V <sub>21</sub>             | 11.47 g                   | 5.21 u                             | 198.80 f-h                              | 2.62 s            |
| V <sub>22</sub>             | 26.33 b                   | 57.39 e                            | 211.80 d-f                              | 27.09 fg          |
| V <sub>23</sub>             | 8.17 h                    | 17.94 n-q                          | 169.00 j-l                              | 10.62 op          |
| V <sub>24</sub>             | 11.58 g                   | 3.52 u                             | 98.49 q                                 | 3.68 rs           |
| V <sub>25</sub>             | 13.63 f                   | 5.93 tu                            | 160.90 lm                               | 3.69 rs           |
| V <sub>26</sub>             | 24.27 c                   | 69.26 d                            | 243.00 c                                | 28.57 ef          |
| V <sub>27</sub>             | 8.15 h                    | 14.75 qr                           | 117.70 p                                | 12.53 m-o         |
| V <sub>28</sub>             | 26.58 b                   | 101.60 a                           | 288.00 a                                | 35.32 bc          |
| V <sub>29</sub>             | 20.17 d                   | 29.89 ij                           | 176.90 i-k                              | 16.90 k           |
| V <sub>30</sub>             | 17.09 e                   | 34.49 g-i                          | 246.20 c                                | 14.01 l-n         |
| V <sub>31</sub>             | 13.34 f                   | 23.29 l-n                          | 63.20 t                                 | 37.03 b           |
| V <sub>32</sub>             | 8.71 h                    | 22.72 l-o                          | 151.40 mn                               | 14.98 k-m         |
| V <sub>33</sub>             | 13.36 f                   | 22.63 l-o                          | 64.72 t                                 | 34.95 bc          |
| V <sub>34</sub>             | 17.08 e                   | 36.72 g                            | 220.00 d                                | 16.63 kl          |
| V <sub>35</sub>             | 20.22 d                   | 32.68 g-j                          | 184.20 h-j                              | 17.74 jk          |
| V <sub>36</sub>             | 8.70 h                    | 22.77 l-o                          | 131.60 op                               | 17.27 jk          |
| V <sub>37</sub>             | 20.21 d                   | 44.08 f                            | 203.10 e-g                              | 21.68 hi          |
| V <sub>38</sub>             | 8.18 h                    | 15.20 p-r                          | 188.20 g-i                              | 8.07 pq           |
| V <sub>39</sub>             | 20.12 d                   | 42.45 f                            | 200.80 e-g                              | 21.08 i           |
| V <sub>40</sub>             | 8.80 h                    | 29.24 i-k                          | 145.00 no                               | 20.03 ij          |
| <b>LSD<sub>(0.05)</sub></b> | <b>1.53</b>               | <b>5.66</b>                        | <b>15.51</b>                            | <b>2.82</b>       |
| <b>CV (%)</b>               | <b>5.89</b>               | <b>10.84</b>                       | <b>5.32</b>                             | <b>9.49</b>       |

V<sub>1</sub>= *Oryza rufipogon* Accession (ACC.) No.1, V<sub>2</sub>= *O. latifolia* ACC. No.1, V<sub>3</sub>= *O. nivara* ACC. No.1, V<sub>4</sub>= *O. rufipogon* ACC. No.2, V<sub>5</sub>= *O. latifolia* ACC. No.2, V<sub>6</sub>= *O. nivara* ACC. No.2, V<sub>7</sub>= *O. officinalis* ACC. No.1, V<sub>8</sub>= *O. longistaminata* ACC. No.1, V<sub>9</sub>= *Potericia coaractata* ACC. No.1, V<sub>10</sub>= *O. nivara* ACC. No.3, V<sub>11</sub>= *O. rufipogon* ACC. No.3, V<sub>12</sub>= *O. alta* ACC. No.1, V<sub>13</sub>= *O. longistaminata* ACC. No.2, V<sub>14</sub>= *O. alta* ACC. No.2, V<sub>15</sub>= *O. punctata* ACC. No.1, V<sub>16</sub>= *O. barthii*

ACC. No.1, V<sub>17</sub>= *O. nivara* ACC. No.4, V<sub>18</sub>= *O. barthii* ACC. No.6, V<sub>19</sub>= *O. punctata* ACC. No.2, V<sub>20</sub>= *O. longistaminata* ACC. No.3, V<sub>21</sub>= *O. latifolia* ACC. No.3, V<sub>22</sub>= *O. nivara* (ACC.) No.5, V<sub>23</sub>= *O. officinalis* ACC. No.2, V<sub>24</sub>= *O. latifolia* ACC. No.4, V<sub>25</sub>= *O. rufipogon* ACC. No.4, V<sub>26</sub>= *O. rufipogon* ACC. No.5, V<sub>27</sub>= *O. latifolia* ACC. No.3, V<sub>28</sub>= *O. nivara* ACC. No.6, V<sub>29</sub>= *O. glaberrima* ACC. No.1, V<sub>30</sub>= *O. rufipogon* ACC. No.6, V<sub>31</sub>= *Potericia coractata* ACC. No.2, V<sub>32</sub>= *O. longistaminata* ACC. No.4, V<sub>33</sub>= *Potericia coractata* ACC. No.3, V<sub>34</sub>= *O. rufipogon* ACC. No.7, V<sub>35</sub>= *O. glaberrima* ACC. No.2, V<sub>36</sub>= *O. punctata* ACC. No.3, V<sub>37</sub>= *O. glaberrima* ACC. No.3, V<sub>38</sub>= *O. alta* ACC. No.3, V<sub>39</sub>= *O. glaberrima* ACC. No.4 and V<sub>40</sub>= *O. punctata* ACC. No.4.

#### **4.1.31 Multivariate analysis (D<sup>2</sup> Statistics)**

##### **4.1.31.1 Cluster mean for the characters**

This is a useful statistical procedure to obtain genotypes from various clusters having desirable traits. Forty wild rice genotypes were grouped into 5 clusters based on various traits (Table 4.1.9). The genotypes in cluster I showed the highest values of length breadth ratio (18.33), root dry weight (163.58 g), grain yield haill<sup>-1</sup>(61.85 g) biological yield (229.46 g) and growth duration (262.50 days). Cluster II had the maximum cluster mean values for the plant height (188.53 cm), leaf length (53.62) and leaf breadth (2.93), grain panicle<sup>-1</sup> (336.25) and minimum growth duration (145 d). Cluster III produced the highest cluster mean for the character of total tiller hill<sup>-1</sup> (99.07), effective tiller (61.53) and non-effective tiller (37.53), shoot dry weight (179.62 g), total dry weight (337.78 g) and maximum days to flowering (229.20). Cluster IV had showed the reasonable values highest filled grain panicle<sup>-1</sup> (119.88). Cluster V had the maximum mean values for the harvest index (36.78).

##### **4.1.31.2 Non-hierarchical clustering**

Based on non-hierarchical clustering, 40 wild rice genotypes used in the study were grouped into five different clusters using the covariance matrix. The distribution of genotypes into different clusters is presented in Table 4.1.10. Clusters IV included the maximum number of genotypes (17) followed by clusters III (11), cluster II (5), cluster V (4) and cluster I (3).

**Table 4.1.9 Cluster mean for twenty-nine characters in 40 rice genotypes**

| Characters                               | Cluster |        |        |        |        |
|------------------------------------------|---------|--------|--------|--------|--------|
|                                          | I       | II     | III    | IV     | V      |
| Plant height (cm)                        | 128.60  | 188.53 | 136.14 | 134.65 | 114.93 |
| Total Tillers hill <sup>-1</sup>         | 78.00   | 28.58  | 99.07  | 51.38  | 69.93  |
| Effective tillers hill <sup>-1</sup>     | 59.61   | 15.17  | 61.53  | 30.76  | 46.00  |
| Non-effective tillers hill <sup>-1</sup> | 18.39   | 13.42  | 37.53  | 20.62  | 23.93  |
| Leaves hill <sup>-1</sup>                | 8.00    | 6.37   | 9.05   | 7.32   | 7.57   |
| Length of leaf                           | 26.66   | 53.62  | 15.13  | 23.86  | 20.68  |
| Breadth of leaf                          | 1.38    | 2.93   | 1.19   | 1.85   | 1.00   |
| Length breadth ratio                     | 18.33   | 17.96  | 12.76  | 12.79  | 14.36  |
| Leaf area                                | 34.26   | 116.09 | 18.02  | 42.31  | 21.42  |
| Flag leaf length                         | 13.50   | 38.39  | 11.95  | 14.48  | 10.16  |
| Flag leaf breadth                        | 1.48    | 3.22   | 1.11   | 2.29   | 1.08   |
| Flag leaf ratio                          | 9.42    | 12.55  | 10.73  | 6.82   | 10.61  |
| Flag leaf area                           | 17.77   | 88.52  | 13.37  | 25.11  | 8.51   |
| Node number                              | 5.32    | 5.89   | 8.19   | 5.88   | 6.49   |
| Root length                              | 14.37   | 42.76  | 24.43  | 26.93  | 19.30  |
| Root dry weight                          | 163.58  | 151.62 | 159.67 | 158.50 | 29.57  |
| Shoot dry weight                         | 168.33  | 170.87 | 179.62 | 146.97 | 46.45  |
| Total Dry weight                         | 333.49  | 322.90 | 337.78 | 288.79 | 92.46  |
| Chlorophyll content on leaf              | 33.94   | 38.32  | 31.55  | 37.89  | 35.40  |
| Days to flowering                        | 226.58  | 107.08 | 229.20 | 199.26 | 151.27 |
| Panicle length                           | 21.88   | 49.18  | 16.24  | 29.59  | 21.37  |
| Grains panicle <sup>-1</sup>             | 80.81   | 336.25 | 74.67  | 238.24 | 52.27  |
| Filled grain panicle <sup>-1</sup>       | 64.17   | 43.33  | 30.13  | 119.88 | 42.47  |
| Unfilled grain panicle <sup>-1</sup>     | 16.64   | 292.92 | 44.53  | 118.36 | 9.80   |
| Thousand grain weight                    | 23.95   | 11.51  | 15.69  | 8.50   | 21.42  |
| Grain yield hill <sup>-1</sup>           | 61.85   | 6.29   | 20.75  | 19.88  | 27.27  |
| Biological yield hill <sup>-1</sup>      | 229.46  | 177.15 | 200.37 | 166.84 | 73.72  |
| Harvest index                            | 26.14   | 3.57   | 9.56   | 12.20  | 36.78  |
| Growth duration                          | 262.50  | 145.00 | 270.00 | 211.79 | 184.00 |

**Table 4.1.10 Distribution of 40 wild rice genotypes into five clusters based on non-hierarchical clustering**

| Cluster no | Total genotypes | Name of Genotypes                                                                                                                                                                                                                                                                                           |
|------------|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| I          | 3               | G <sub>12</sub> , G <sub>14</sub> , G <sub>38</sub>                                                                                                                                                                                                                                                         |
| II         | 5               | G <sub>9</sub> , G <sub>16</sub> , G <sub>18</sub> , G <sub>31</sub> , G <sub>33</sub>                                                                                                                                                                                                                      |
| III        | 11              | G <sub>7</sub> , G <sub>8</sub> , G <sub>13</sub> , G <sub>15</sub> , G <sub>19</sub> , G <sub>20</sub> , G <sub>23</sub> , G <sub>27</sub> , G <sub>32</sub> , G <sub>36</sub> , G <sub>40</sub>                                                                                                           |
| IV         | 17              | G <sub>1</sub> , G <sub>3</sub> , G <sub>4</sub> , G <sub>6</sub> , G <sub>10</sub> , G <sub>11</sub> , G <sub>17</sub> , G <sub>22</sub> , G <sub>25</sub> , G <sub>26</sub> , G <sub>28</sub> , G <sub>29</sub> , G <sub>30</sub> , G <sub>34</sub> , G <sub>35</sub> , G <sub>37</sub> , G <sub>39</sub> |
| V          | 4               | G <sub>2</sub> , G <sub>5</sub> , G <sub>21</sub> , G <sub>24</sub>                                                                                                                                                                                                                                         |

G<sub>1</sub>=*Oryza rufipogon* Accession (ACC.) No.1, G<sub>2</sub>=*O. latifolia* ACC. No.1, G<sub>3</sub>=*O. nivara* ACC. No.1, G<sub>4</sub>=*O. rufipogon* ACC. No.2, G<sub>5</sub>=*O. latifolia* ACC. No.2, G<sub>6</sub>=*O. nivara* ACC. No.2, G<sub>7</sub>=*O. officinalis* ACC. No.1, G<sub>8</sub>=*O. longistaminata* ACC. No.1, G<sub>9</sub>=*Potericia coaractata* ACC. No.1, G<sub>10</sub>=*O. nivara* ACC. No.3, G<sub>11</sub>=*O. rufipogon* ACC. No.3, G<sub>12</sub>=*O. alta* ACC. No.1, G<sub>13</sub>=*O. longistaminata* ACC. No.2, G<sub>14</sub>=*O. alta* ACC. No.2, G<sub>15</sub>=*O. punctata* ACC. No.1, G<sub>16</sub>=*O. barthii* ACC. No.1, G<sub>17</sub>=*O. nivara* ACC. No.4, G<sub>18</sub>=*O. barthii* ACC. No.2, G<sub>19</sub>=*O. punctata* ACC. No.2, G<sub>20</sub>=*O. longistaminata* ACC. No.3, G<sub>21</sub>=*O. latifolia* ACC. No.3, G<sub>22</sub>=*O. nivara* (ACC.) No.5, G<sub>23</sub>=*O. officinalis* ACC. No.2, G<sub>24</sub>=*O. latifolia* ACC. No.4, G<sub>25</sub>=*O. rufipogon* ACC. No.4, G<sub>26</sub>=*O. rufipogon* ACC. No.5, G<sub>27</sub>=*O. latifolia* ACC. No.5, G<sub>28</sub>=*O. nivara* ACC. No.6, G<sub>29</sub>=*O. glaberrima* ACC. No.1, G<sub>30</sub>=*O. rufipogon* ACC. No.6, G<sub>31</sub>=*Potericia coractata* ACC. No.2, G<sub>32</sub>=*O. longistaminata* ACC. No.4, G<sub>33</sub>=*Potericia coractata* ACC. No.3, G<sub>34</sub>=*O. rufipogon* ACC. No.7, G<sub>35</sub>=*O. glaberrima* ACC. No.2, G<sub>36</sub>=*O. punctata* ACC. No.3, G<sub>37</sub>=*O. glaberrima* ACC. No.3, G<sub>38</sub>=*O. alta* ACC. No.3, G<sub>39</sub>=*O. glaberrima* ACC. No.4, G<sub>40</sub>=*O. punctata* ACC. No.4

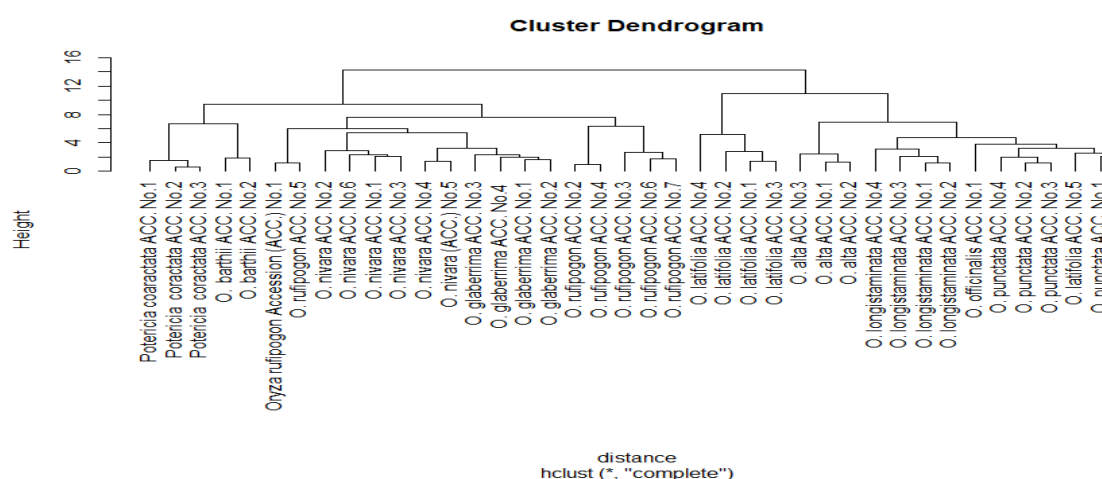


**Figure 4.1.1 Cluster dendrogram showing contribution of various traits in variability among the rice genotypes**

#### 4.1.31.3 Principal component analysis (PCA)

The principal component analysis (PCA) clearly and concisely explains the genetic diversity of wild rice genotypes. Mean data of 40 wild rice genotypes were calculated and PCA was applied to sum up momentous variation from collected mean data. Out of sixteen principal components, three principal components (PCs) depicted more than one Eigen value so these three components have been given due consideration for further explanation. In Table 4.1.11 shows that the first three principal components PC1, PC2 and PC3 explained 44.57%, 16.34% and 11.85% of variation, respectively with 72.75% cumulative variance among all attributes. The results showed that the first two principal components accounted for 60.91% of the total variation among 16 component axes of the total genotypes, whereas the Eigen values were found as 82.03% in the first four component axes. The attributes of worthy

importance in PC1 were total tiller hill<sup>-1</sup> (0.33), effective tillers (0.35), thousand grain weight (0.25) and grain yield hill<sup>-1</sup> (0.25).

#### **4.1.31.4 Canonical variate analysis (CVA)**

Intra-cluster and inter-cluster distances ( $D^2$ ) values for 40 wild rice genotypes grouped into 6 clusters are presented in Table 4.1.12. The more inter-cluster and intra-cluster distances, the more variability among the genotypes between and within clusters, respectively and vice versa. The results obtained from the present study indicated that the inter-cluster distances were larger than intra-cluster distances in all cases, suggesting wider genetic diversity among the genotypes of different groups. The maximum inter-cluster distance was observed between clusters II and V (602.11) followed by clusters I and II (588.51). The maximum inter-cluster distance indicated that the genotypes in these clusters were far diverse than those of other clusters. The minimum inter-cluster distance was observed between clusters III and IV (311.90), indicating a close relation distance among the genotypes of those clusters. The highest intra-cluster distance was found in cluster III (323.12) followed by cluster II (281.42). The lowest intra-cluster distance was noticed for cluster IV (148.68). These results revealed that the genotypes in cluster III were distantly related. On the other hand, the genotypes in cluster IV were closely related. Ten genotypes were selected from these two clusters (III and IV) to use next trials for obtaining a wide spectrum of variation among the segregates.

**Table 4.1.11 Eigen values, proportion of variability for sixteen principal component axes in 40 rice genotypes**

| Statistical variable           | PC1   | PC2   | PC3   | PC4   | PC5   | PC6   | PC7   | PC8   | PC9   | PC10  | PC11  | PC12  | PC13  | PC14  | PC15   | PC16   |
|--------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|--------|
| <b>Eigen values</b>            | 2.67  | 1.62  | 1.38  | 1.22  | 1.06  | 0.84  | 0.61  | 0.48  | 0.38  | 0.34  | 0.27  | 0.18  | 0.16  | 0.14  | 0.12   | 0.00   |
| <b>Total variance (%)</b>      | 44.57 | 16.34 | 11.85 | 9.28  | 7.09  | 4.42  | 2.31  | 1.46  | 0.91  | 0.72  | 0.46  | 0.21  | 0.17  | 0.13  | 0.09   | 0.00   |
| <b>Cumulative variance (%)</b> | 44.57 | 60.91 | 72.75 | 82.03 | 89.12 | 93.53 | 95.85 | 97.31 | 98.21 | 98.94 | 99.40 | 99.61 | 99.78 | 99.91 | 100.00 | 100.00 |
| <b>Traits</b>                  |       |       |       |       |       |       |       |       |       |       |       |       |       |       |        |        |
| <b>PH</b>                      | -0.25 | -0.18 | -0.14 | -0.46 | -0.21 | 0.09  | 0.06  | 0.48  | -0.37 | -0.21 | 0.03  | -0.05 | 0.35  | 0.12  | 0.27   | 0.00   |
| <b>TT</b>                      | 0.33  | 0.02  | 0.11  | 0.09  | -0.37 | 0.09  | -0.06 | -0.03 | 0.05  | -0.30 | -0.06 | 0.16  | 0.11  | 0.06  | -0.03  | -0.76  |
| <b>ET</b>                      | 0.35  | -0.04 | -0.08 | 0.08  | -0.24 | 0.13  | 0.02  | -0.11 | 0.11  | -0.38 | -0.13 | 0.46  | 0.24  | 0.00  | -0.03  | 0.58   |
| <b>NET</b>                     | 0.18  | 0.14  | 0.45  | 0.08  | -0.51 | -0.02 | -0.19 | 0.13  | -0.09 | -0.03 | 0.09  | -0.51 | -0.20 | 0.15  | -0.01  | 0.29   |
| <b>Leaves</b>                  | 0.28  | -0.04 | 0.21  | -0.31 | 0.35  | 0.22  | -0.13 | 0.09  | 0.20  | 0.08  | 0.46  | 0.08  | 0.14  | 0.51  | -0.22  | 0.00   |
| <b>NN</b>                      | 0.11  | 0.13  | 0.50  | -0.42 | 0.16  | 0.34  | -0.04 | -0.04 | -0.23 | 0.11  | -0.34 | 0.22  | -0.17 | -0.36 | 0.06   | 0.00   |
| <b>RDW</b>                     | -0.01 | -0.56 | 0.14  | -0.11 | -0.06 | -0.07 | 0.40  | -0.45 | -0.33 | -0.06 | -0.06 | -0.13 | -0.02 | 0.16  | -0.36  | 0.00   |
| <b>SDW</b>                     | 0.01  | -0.54 | 0.02  | -0.14 | -0.35 | -0.03 | -0.08 | 0.15  | 0.44  | 0.47  | -0.12 | 0.21  | -0.20 | 0.02  | 0.16   | 0.00   |
| <b>SPAD</b>                    | -0.26 | -0.03 | 0.17  | 0.24  | 0.03  | 0.56  | 0.51  | 0.22  | 0.39  | -0.16 | -0.06 | -0.18 | 0.01  | -0.03 | -0.04  | 0.00   |
| <b>DF</b>                      | 0.26  | -0.34 | 0.02  | 0.08  | 0.28  | -0.24 | -0.01 | 0.51  | -0.04 | -0.38 | 0.09  | 0.00  | -0.37 | -0.30 | -0.18  | 0.00   |
| <b>PL</b>                      | -0.32 | -0.10 | -0.16 | -0.23 | -0.01 | 0.23  | -0.34 | -0.34 | 0.14  | -0.47 | 0.11  | -0.02 | -0.49 | 0.10  | 0.17   | 0.00   |
| <b>Grain</b>                   | -0.33 | -0.18 | 0.12  | 0.04  | -0.06 | 0.08  | -0.51 | -0.01 | 0.11  | -0.03 | 0.04  | -0.07 | 0.41  | -0.37 | -0.49  | 0.00   |
| <b>FG</b>                      | -0.14 | -0.26 | 0.25  | 0.53  | 0.25  | 0.11  | -0.31 | 0.08  | -0.28 | 0.00  | -0.27 | 0.16  | 0.04  | 0.38  | 0.24   | 0.00   |
| <b>Weight</b>                  | 0.25  | 0.03  | -0.47 | -0.10 | 0.07  | 0.27  | -0.17 | 0.12  | 0.00  | 0.09  | -0.56 | -0.32 | -0.08 | 0.21  | -0.32  | 0.00   |
| <b>Yield</b>                   | 0.25  | -0.18 | -0.29 | 0.23  | -0.09 | 0.52  | -0.06 | -0.07 | -0.35 | 0.25  | 0.45  | -0.04 | -0.07 | -0.28 | 0.11   | 0.00   |
| <b>Duration</b>                | 0.31  | -0.25 | 0.07  | -0.07 | 0.26  | -0.06 | -0.07 | -0.23 | 0.24  | -0.12 | -0.09 | -0.47 | 0.35  | -0.20 | 0.49   | 0.00   |

**Notes:** *PH* Plant height, *TT* Total tiller hill<sup>-1</sup>, *ET* Effective tiller hill<sup>-1</sup>, *NET* Non-effective tiller hill<sup>-1</sup>, *NN* Node number hill<sup>-1</sup>, *RDW* Root dry weight, *SDW* Shoot dry weight, *DF* Days to flowering, *PL* Panicle length, *FG* Filled grain

**Table 4.1.12 Average intra-cluster and inter-cluster distances ( $D^2$ ) for 40 rice genotypes**

| Cluster no. | I             | II            | III           | IV            | V             |
|-------------|---------------|---------------|---------------|---------------|---------------|
| <b>I</b>    | <b>193.51</b> |               |               |               |               |
| <b>II</b>   | 588.90        | <b>281.42</b> |               |               |               |
| <b>III</b>  | 401.87        | 438.25        | <b>323.12</b> |               |               |
| <b>IV</b>   | 373.74        | 384.15        | 311.90        | <b>148.68</b> |               |
| <b>V</b>    | 468.32        | 602.11        | 403.66        | 492.98        | <b>149.39</b> |

**Notes:** Bold and diagonal values indicate intra-cluster distance



## **4.2 Experiment 2: Physiological characterization of wild species of rice**

### **4.2.1 Plant height**

The plant height of wild rice was significantly influenced by different species at different days after transplanting (DAT) (Table 4.2.1). The tallest plant (83.97, 106.50, 134.60, 186.60 and 198.50 cm at 25, 50, 75, 100 DAT and harvest, respectively) was recorded from *O. latifolia* (V<sub>4</sub>) which were statistically similar with V<sub>2</sub> at 25, 50 and 50 DAT. The shortest plant (41.17, 53.98, 71.69, 101.4 and 106.3 cm at 25, 50, 75, 100 DAT and harvest, respectively) was recorded from *P. coactata* (V<sub>5</sub>) which were statistically similar with V<sub>8</sub> at 50 and 75 DAT; with V<sub>3</sub> at 75 DAT and harvest. Plant height is an important growth parameter for any crop since it defines or alters yield contributing traits, which in turn gives seed production (Reddy and Redd, 1997). It is a complicated trait that is the result of various genetically controlled elements, most of which are ruled by the genotypes' genetic make-up, which is based on the number of internodes and length of internodes (Rahman *et al.*, 2018 and Parashivamurthy *et al.*, 2012). Chouhan *et al.* (2014b) reported that high variability was found in plant height which ranged from 128.72 to 210.82 cm among the tested varieties. Shrestha *et al.* (2021) showed that plant height varied from IR73008-136-2-2-3 (86.50 cm) to Bange masino (173.5 cm). Dangi *et al.* (2017) reported that species Kalanamak resulted in significantly tallest plant (106.54 cm) over rest of the varieties. The results of our experiment similar to the results of Kumar *et al.* (2017); Gewaily *et al.* (2018); Jahan *et al.* (2020); Shrestha *et al.* (2021) who observed plant height differed significantly among the varieties.

### **4.2.2 Normal leaf length**

Significant variation of normal leaf length of wild rice was found due to different varieties (Table 4.2.2). Result revealed that, wild rice genotype *O. latifolia* (V<sub>4</sub>) distinctly produced the longest normal leaf (54.40 cm) and wild rice genotype *P. coactata* (V<sub>5</sub>) distinctly produced the shortest normal leaf (12.93 cm). Rest of the varieties produced the intermediate length of normal leaf. Chouhan *et al.* (2014b) reported that leaf length varied from 52.61 to 78.90 cm in respect of different tested rice varieties. Our findings are consistent with those of Patra and Dhua (2003);

Chouhan *et al.* (2014b) who concluded that the leaf length varied with different rice varieties.

**Table 4.2.1 Plant height of wild species of rice**

| Treatments                  | Plant height (cm) at different days after transplanting (DATs) |              |             |              |              |
|-----------------------------|----------------------------------------------------------------|--------------|-------------|--------------|--------------|
|                             | 25                                                             | 50           | 75          | 100          | At Harvest   |
| V <sub>1</sub>              | 61.53 de                                                       | 79.07 b      | 101.0 bc    | 126.00 cd    | 131.40 c     |
| V <sub>2</sub>              | 78.07 ab                                                       | 100.10 a     | 131.3 a     | 164.10 b     | 171.20 b     |
| V <sub>3</sub>              | 58.70 ef                                                       | 66.20 c      | 82.13 d     | 105.70 e     | 109.70 d     |
| V <sub>4</sub>              | 83.97 a                                                        | 106.50 a     | 134.6 a     | 186.60 a     | 198.50 a     |
| V <sub>5</sub>              | 41.17 g                                                        | 53.98 d      | 71.69 e     | 101.40 e     | 106.30 d     |
| V <sub>6</sub>              | 73.17 bc                                                       | 83.47 b      | 96.53 c     | 123.00 d     | 127.10 c     |
| V <sub>7</sub>              | 67.33 cd                                                       | 84.07 b      | 106.2 b     | 135.80 c     | 139.90 c     |
| V <sub>8</sub>              | 53.30 f                                                        | 63.27 cd     | 79.67 de    | 125.90 cd    | 130.50 c     |
| V <sub>9</sub>              | 75.40 b                                                        | 83.67 b      | 97.07 bc    | 124.10 cd    | 128.50 c     |
| V <sub>10</sub>             | 67.40 cd                                                       | 79.40 b      | 99.73 bc    | 124.20 cd    | 131.90 c     |
| <b>LSD<sub>(0.05)</sub></b> | <b>7.44</b>                                                    | <b>10.45</b> | <b>9.42</b> | <b>11.89</b> | <b>13.72</b> |
| <b>CV (%)</b>               | <b>6.57</b>                                                    | <b>7.62</b>  | <b>5.49</b> | <b>5.26</b>  | <b>5.82</b>  |

V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

#### 4.2.3 Normal leaf breadth

Significant difference of normal leaf breadth of wild rice was found due to species variation (Table 4.2.2). Result showed that, wild rice genotype *O. latifolia* (V<sub>4</sub>) distinctly scored the widest normal leaf (2.93 cm) and wild rice genotype *P. coactata* (V<sub>5</sub>) distinctly scored the narrowest normal leaf (0.76 cm). Rest of the varieties scored the intermediate breadth of normal leaf. Chouhan *et al.* (2014b) concluded that leaf breadth varied from 1.04 to 1.80 cm with investigated rice varieties. Patra and Dhua (2003) reported similar findings for leaf breadth.

#### 4.2.4 Normal leaf length breadth ratio

The normal leaf length breadth ratio of wild rice was significantly influenced by different rice genotypes (Table 4.2.2). The maximum normal leaf length breadth ratio (26.51) was scored by *O. rufipogon* (V<sub>1</sub>) and the minimum normal leaf length breadth ratio (11.76) was scored by *O. officinalis* (V<sub>8</sub>) which was statistically similar with V<sub>9</sub> and V<sub>2</sub>.

#### 4.2.5 Normal leaf area

The normal leaf area of wild rice was significantly differed by different species (Table 4.2.2). The highest normal leaf area (123.10 cm<sup>2</sup>) was distinctly observed in *O. latifolia* (V<sub>4</sub>) and the lowest normal leaf area (7.77 cm<sup>2</sup>) was distinctly observed in *P. coactata* (V<sub>5</sub>).

**Table 4.2.2 Leaf characteristics of wild species of rice**

| Treatments                  | Normal leaf length (cm) | Normal leaf breadth (cm) | Normal leaf length breadth ratio | Normal leaf area (cm <sup>2</sup> ) |
|-----------------------------|-------------------------|--------------------------|----------------------------------|-------------------------------------|
| V <sub>1</sub>              | 30.78 b                 | 1.17 g                   | 26.51 a                          | 35.79 d-f                           |
| V <sub>2</sub>              | 31.28 b                 | 2.27 b                   | 14.01 ef                         | 54.11 b                             |
| V <sub>3</sub>              | 22.62 cd                | 1.40 ef                  | 16.16 c-e                        | 31.68 fg                            |
| V <sub>4</sub>              | 54.40 a                 | 2.93 a                   | 18.58 bc                         | 123.1 a                             |
| V <sub>5</sub>              | 12.93 e                 | 0.76 h                   | 17.04 cd                         | 7.77 h                              |
| V <sub>6</sub>              | 29.49 b                 | 1.47 ef                  | 20.13 b                          | 37.50 d                             |
| V <sub>7</sub>              | 24.18 c                 | 1.56 de                  | 15.48 de                         | 46.45 c                             |
| V <sub>8</sub>              | 20.06 d                 | 1.72 cd                  | 11.76 f                          | 33.02 e-g                           |
| V <sub>9</sub>              | 22.59 cd                | 1.80 c                   | 12.62 f                          | 36.83 de                            |
| V <sub>10</sub>             | 23.12 cd                | 1.31 fg                  | 17.84 b-d                        | 30.01 g                             |
| <b>LSD<sub>(0.05)</sub></b> | <b>3.43</b>             | <b>0.20</b>              | <b>2.44</b>                      | <b>4.14</b>                         |
| <b>CV (%)</b>               | <b>7.37</b>             | <b>6.95</b>              | <b>8.35</b>                      | <b>5.53</b>                         |

V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

#### 4.2.6 Flag leaf length

Significant difference of flag leaf length of wild rice was observed due to different varieties (Table 4.2.3). Result showed that, *O. latifolia* (V<sub>4</sub>) distinctly produced the longest flag leaf (46.10 cm) and *P. coactata* (V<sub>5</sub>) distinctly produced the shortest flag leaf (8.43 cm). Rest of the varieties produced the intermediate length of flag leaf. Our results are supported by Singh *et al.* (2013a); Chouhan *et al.* (2014b) who also explained that length of flag leaf varied with different rice varieties.

#### 4.2.7 Flag leaf breadth

Significant variation of flag leaf breadth of wild rice was found due to species variation (Table 4.2.3). Result revealed that, *O. alta* (V<sub>2</sub>) distinctly scored the widest

flag leaf (3.70 cm) where as *P. coactata* (V<sub>5</sub>) distinctly scored the narrowest flag leaf (0.70 cm). Rest of the varieties scored the intermediate breadth of flag leaf. Our findings are close confirmation with the findings of Singh *et al.* (2013a); Chouhan *et al.* (2014b) who opinioned that breadth of flag leaf differ with different rice genotypes.

#### 4.2.8 Flag leaf length breadth ratio

The flag leaf length breadth ratio of wild rice was significantly varied by species variation (Table 4.2.3). The maximum flag leaf length breadth ratio (15.09) was produced by *O. latifolia* (V<sub>4</sub>) which was statistically similar with V<sub>1</sub> treatment and the minimum flag leaf length breadth ratio (3.80) was distinctly produced by *O. alta* (V<sub>2</sub>).

#### 4.2.9 Flag leaf area

The flag leaf area of wild rice was significantly differed by different species (Table 4.2.3). The highest flag leaf area (98.90 cm<sup>2</sup>) was vaguely produced by *O. latifolia* (V<sub>4</sub>) and the lowest flag leaf area (3.45 cm<sup>2</sup>) was vaguely produced by *P. coactata* (V<sub>5</sub>).

**Table 4.2.3 Flag leaf characteristics of wild species of rice**

| Treatments                  | Flag leaf length (cm) | Flag leaf breadth (cm) | Flag leaf length breadth ratio | Flag leaf area (cm <sup>2</sup> ) |
|-----------------------------|-----------------------|------------------------|--------------------------------|-----------------------------------|
| V <sub>1</sub>              | 17.22 b               | 1.23 e                 | 13.97 a                        | 21.24 cd                          |
| V <sub>2</sub>              | 14.05 d               | 3.70 a                 | 3.80 f                         | 31.63 b                           |
| V <sub>3</sub>              | 13.06 d               | 1.40 e                 | 9.35 c                         | 17.27 e                           |
| V <sub>4</sub>              | 46.10 a               | 3.05 b                 | 15.09 a                        | 98.90 a                           |
| V <sub>5</sub>              | 8.43 e                | 0.70 f                 | 12.08 b                        | 3.45 f                            |
| V <sub>6</sub>              | 13.57 d               | 1.74 d                 | 7.78 d                         | 19.52 de                          |
| V <sub>7</sub>              | 14.28 cd              | 2.51 c                 | 5.69 e                         | 23.11 c                           |
| V <sub>8</sub>              | 16.83 b               | 1.71 d                 | 9.85 c                         | 22.21 cd                          |
| V <sub>9</sub>              | 16.57 bc              | 1.74 d                 | 9.50 c                         | 22.54 cd                          |
| V <sub>10</sub>             | 13.10 d               | 1.40 e                 | 9.37 c                         | 17.40 e                           |
| <b>LSD<sub>(0.05)</sub></b> | <b>2.32</b>           | <b>0.19</b>            | <b>1.48</b>                    | <b>3.09</b>                       |
| <b>CV (%)</b>               | <b>7.82</b>           | <b>5.71</b>            | <b>8.95</b>                    | <b>6.50</b>                       |

V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

#### **4.2.10 Leaves hill<sup>-1</sup>**

Different rice genotypes significantly influenced the production of leaves hill<sup>-1</sup> of wild rice (Table 4.2.4). The maximum leaves hill<sup>-1</sup> (9.27) was obtained from *O. barthii* (V<sub>10</sub>) which was statistically similar with V<sub>1</sub>, on the other hand the minimum leaves hill<sup>-1</sup> (5.53) was obtained from *O. alta* (V<sub>2</sub>). Dangi *et al.* (2017) revealed that at harvest the varieties IR- 64, BPT-5204 and IET 24780 produced significantly highest leaves hill<sup>-1</sup> over rest of the tested varieties. The differences in production of leaves hill<sup>-1</sup> of rice genotypes may be attributed to their inherent characteristics. The findings of our investigation are corroborated with those of Siddiq *et al.* (2011), Thomas and Lal (2012); Dangi *et al.* (2017).

#### **4.2.11 Nodes plant<sup>-1</sup>**

Different rice species significantly influenced the production of nodes plant<sup>-1</sup> of wild rice (Table 4.2.4). The maximum nodes plant<sup>-1</sup> (7.40) was obtained from both *O. rufipogon* (V<sub>1</sub>) and *O. barthii* (V<sub>10</sub>) which were statistically at par with V<sub>5</sub>, on the other hand the minimum nodes plant<sup>-1</sup> (3.33) was obtained from *O. alta* (V<sub>2</sub>).

#### **4.2.12 Days to 1<sup>st</sup> flowering**

Days to 1<sup>st</sup> flowering of wild rice was significantly influenced by different species (Table 4.2.4). The delayed 1<sup>st</sup> flowering (232.00 days) was observed in *O. rufipogon* (V<sub>1</sub>) followed by *O. nivara* (V<sub>3</sub>) (227.00 days) and the earliest 1<sup>st</sup> flowering (107.00 days) was observed in both *O. latifolia* (V<sub>4</sub>) and *P. coactata* (V<sub>5</sub>). The results of present investigation for days to 1<sup>st</sup> flowering are conformity with the findings of Singh *et al.* (2013a); Chouhan *et al.* (2014a); Chouhan *et al.* (2014b) who reported that days to 1<sup>st</sup> flowering had significant difference with species variation and this might be due to the different life span of varieties.

#### **4.2.13 Growth duration**

Growth duration was significantly differed due to species variation of wild rice (Table 4.2.4). The longest growth duration (265.00 days) was observed in both *O. rufipogon* (V<sub>1</sub>) and *O. glaberrima* (V<sub>6</sub>) and the shortest growth duration (145.00 days) was observed in *O. alta* (V<sub>2</sub>) which was statistically similar with V<sub>4</sub> treatment. This might be due to genetic potentiality of varieties. Our results obtained in this experiment are

in agreement with those of Anjaneyulu *et al.* (2010); Singh *et al.* (2013a); Chouhan *et al.* (2014a).

**Table 4.2.4 Leaves hill<sup>-1</sup>, nodes plant<sup>-1</sup>, days to 1<sup>st</sup> flowering and growth duration of wild species of rice**

| Treatments        | Leaves hill <sup>-1</sup><br>(no.) | Nodes plant <sup>-1</sup><br>(no.) | Days to 1 <sup>st</sup><br>flowering | Growth duration<br>(days) |
|-------------------|------------------------------------|------------------------------------|--------------------------------------|---------------------------|
| V <sub>1</sub>    | 8.80 ab                            | 7.40 a                             | 232.00 a                             | 265.00 a                  |
| V <sub>2</sub>    | 5.53 e                             | 3.33 e                             | 198.30 c                             | 145.00 f                  |
| V <sub>3</sub>    | 7.53 cd                            | 5.87 cd                            | 227.00 ab                            | 260.00 b                  |
| V <sub>4</sub>    | 6.73 d                             | 6.47 bc                            | 107.30 d                             | 146.70 f                  |
| V <sub>5</sub>    | 7.13 cd                            | 7.00 ab                            | 107.00 d                             | 150.00 e                  |
| V <sub>6</sub>    | 8.17 bc                            | 5.53 d                             | 221.70 b                             | 265.00 a                  |
| V <sub>7</sub>    | 7.73 cd                            | 6.40 bc                            | 197.70 c                             | 230.00 d                  |
| V <sub>8</sub>    | 7.73 cd                            | 6.47 bc                            | 198.30 c                             | 230.00 d                  |
| V <sub>9</sub>    | 7.53 cd                            | 6.53 bc                            | 204.00 c                             | 230.00 d                  |
| V <sub>10</sub>   | 9.27 a                             | 7.40 a                             | 202.00 c                             | 235.00 c                  |
| <b>LSD (0.05)</b> | <b>1.06</b>                        | <b>0.82</b>                        | <b>8.79</b>                          | <b>2.24</b>               |
| <b>CV (%)</b>     | <b>8.11</b>                        | <b>7.64</b>                        | <b>2.70</b>                          | <b>0.60</b>               |

V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

#### 4.2.14 Leaf area hill<sup>-1</sup>

Species effect significantly influenced leaf area hill<sup>-1</sup> of wild rice at different DAT (Table 4.2.5). The maximum leaf area hill<sup>-1</sup> (390.30, 2535.00, 4309.00, 4832.00 and 3797.00 cm<sup>2</sup> at 25, 50, 75, 100 DAT and harvest, respectively) were found from *O. latifolia* (V<sub>4</sub>) which was statistically similar only with V<sub>3</sub> treatment at 75 DAT. The minimum leaf area hill<sup>-1</sup> (85.74, 265.10, 538.30, 701.00 and 571.50 cm<sup>2</sup> at 25, 50, 75, 100 DAT and harvest, respectively) were distinctly found from *P. coactata* (V<sub>5</sub>). The rest of the treatments produced the intermediate leaf area hill<sup>-1</sup>. The leaf area of plant is one of the major determinants of its growth. It is the ratio of leaf area to its ground area (Radford, 1967) and it is the functional size of the standing crop on unit land area (Hunt, 1978). It depends on the growth, number of leaves plant<sup>-1</sup>, population density and leaf senescence (Khan, 1981). Our results are in harmony with those obtained by Islam *et al.* (2013); Sarker *et al.* (2013); Sokoto and Muhammad (2014) who reported that leaf area differ with species variation due to different genetic make-up.

**Table 4.2.5 Leaf area hill<sup>-1</sup> of wild species of rice**

| Treatments                  | Leaf area hill <sup>-1</sup> (cm <sup>2</sup> ) at different days after transplanting (DAT) |               |               |               |               |
|-----------------------------|---------------------------------------------------------------------------------------------|---------------|---------------|---------------|---------------|
|                             | 25                                                                                          | 50            | 75            | 100           | At Harvest    |
| V <sub>1</sub>              | 328.30 b                                                                                    | 2066.00 bc    | 3637.00 bc    | 3964.00 bc    | 1998.00 e     |
| V <sub>2</sub>              | 251.70 c                                                                                    | 1906.00 cd    | 3598.00 bc    | 3922.00 bc    | 2372.00 d     |
| V <sub>3</sub>              | 319.50 b                                                                                    | 2074.00 bc    | 3879.00 ab    | 4174.00 b     | 2694.00 c     |
| V <sub>4</sub>              | 390.30 a                                                                                    | 2535.00 a     | 4309.00 a     | 4832.00 a     | 3797.00 a     |
| V <sub>5</sub>              | 85.74 d                                                                                     | 265.10 f      | 538.30 e      | 701.00 e      | 571.50 g      |
| V <sub>6</sub>              | 335.00 b                                                                                    | 2176.00 b     | 3763.00 b     | 4102.00 b     | 3193.00 b     |
| V <sub>7</sub>              | 243.70 c                                                                                    | 1701.00 de    | 3147.00 d     | 3430.00 d     | 3261.00 b     |
| V <sub>8</sub>              | 239.80 c                                                                                    | 1676.00 de    | 3099.00 d     | 3378.00 d     | 2737.00 c     |
| V <sub>9</sub>              | 254.30 c                                                                                    | 1778.00 de    | 3289.00 cd    | 3585.00 cd    | 2514.00 d     |
| V <sub>10</sub>             | 229.60 c                                                                                    | 1607.00 e     | 2990.00 d     | 3259.00 d     | 1572.00 f     |
| <b>LSD<sub>(0.05)</sub></b> | <b>28.06</b>                                                                                | <b>241.70</b> | <b>433.70</b> | <b>491.70</b> | <b>176.20</b> |
| <b>CV (%)</b>               | <b>6.11</b>                                                                                 | <b>7.92</b>   | <b>7.84</b>   | <b>8.11</b>   | <b>4.16</b>   |

V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

#### 4.2.15 Leaf area index

Leaf area index (LAI) was significantly differed by different species of wild rice at different DAT (Table 4.2.6). Similar trend was found in case of production of LAI and the highest LAI (0.63, 4.12, 7.00, 7.85 and 6.17 at 25, 50, 75, 100 DAT and harvest, respectively) were recorded from *O. latifolia* (V<sub>4</sub>) which was statistically similar only with V<sub>3</sub> treatment at 75 DAT. The minimum LAI (0.14, 0.43, 0.87, 1.14 and 0.93 at 25, 50, 75, 100 DAT and harvest, respectively) were distinctly found from *P. coactata* (V<sub>5</sub>). The rest of the treatments scored the intermediate LAI. The higher productivity of a crop depends on the persistence of high LAI over a greater part of its vegetative phase. The rate of crop photosynthesis depends on the LAI. After germination LAI increases and reaches the peak levels after that it declines due to increased senescence. Leaf area index was also significantly and positively associated with grain yield. Leaf area index (LAI) increased progressively from tillering to panicle initiation stage and thereafter declined after flowering (Mia and Shamsuddin, 2011). Our results are in line with those found by Islam *et al.* (2013); Sarker *et al.* (2013); Sokoto and Muhammad (2014) who reported that leaf area differ with species variation due to different genetic make-up.

**Table 4.2.6 Leaf area index of wild species of rice**

| Treatments                  | Leaf area index at different days after transplanting (DAT) |             |             |             |             |
|-----------------------------|-------------------------------------------------------------|-------------|-------------|-------------|-------------|
|                             | 25                                                          | 50          | 75          | 100         | At Harvest  |
| V <sub>1</sub>              | 0.53 b                                                      | 3.36 bc     | 5.91 bc     | 6.44 bc     | 3.25 e      |
| V <sub>2</sub>              | 0.41 c                                                      | 3.10 cd     | 5.85 bc     | 6.37 bc     | 3.86 d      |
| V <sub>3</sub>              | 0.52 b                                                      | 3.37 bc     | 6.30 ab     | 6.78 b      | 4.38 c      |
| V <sub>4</sub>              | 0.63 a                                                      | 4.12 a      | 7.00 a      | 7.85 a      | 6.17 a      |
| V <sub>5</sub>              | 0.14 d                                                      | 0.43 f      | 0.87 e      | 1.14 e      | 0.93 g      |
| V <sub>6</sub>              | 0.55 b                                                      | 3.53 b      | 6.12 b      | 6.66 b      | 5.19 b      |
| V <sub>7</sub>              | 0.40 c                                                      | 2.76 de     | 5.11 d      | 5.57 d      | 5.30 b      |
| V <sub>8</sub>              | 0.39 c                                                      | 2.72 e      | 5.04 d      | 5.49 d      | 4.48 c      |
| V <sub>9</sub>              | 0.42 c                                                      | 2.89 de     | 5.34 cd     | 5.82 cd     | 4.09 cd     |
| V <sub>10</sub>             | 0.37 c                                                      | 2.61 e      | 4.86 d      | 5.30 d      | 2.55 f      |
| <b>LSD<sub>(0.05)</sub></b> | <b>0.05</b>                                                 | <b>0.36</b> | <b>0.71</b> | <b>0.72</b> | <b>0.41</b> |
| <b>CV (%)</b>               | <b>5.87</b>                                                 | <b>7.36</b> | <b>7.84</b> | <b>7.36</b> | <b>5.97</b> |

V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

#### 4.2.16 Chlorophyll content on leaf

The chlorophyll content on leaf significantly varied among the species of wild rice during all the growth stages (Table 4.2.7). The results exposed that, the maximum chlorophyll content on leaf (38.97, 40.77, 41.27, 42.97 and 35.07 % at 25, 50, 75, 100 DAT and harvest, respectively) were achieved from *O. latifolia* (V<sub>4</sub>) which were statistically at par with V<sub>5</sub> and V<sub>2</sub> at 25 DAT; with V<sub>5</sub>, V<sub>2</sub> and V<sub>7</sub> at 50 and 75 DAT; with V<sub>5</sub>, V<sub>2</sub>, V<sub>9</sub> and V<sub>8</sub> at 100 DAT and finally with V<sub>5</sub>, V<sub>2</sub>, V<sub>7</sub> and V<sub>1</sub> at harvest. At 25, 50 and 100 DAT, the minimum chlorophyll content on leaf (27.03, 29.93 and 32.87 %, respectively) were achieved by *O. barthii* (V<sub>10</sub>) which was statistically at par with V<sub>3</sub> and V<sub>6</sub> at 100 DAT. At 75 DAT the minimum chlorophyll content on leaf (33.53%) was achieved from V<sub>6</sub> treatment which was statistically at par with V<sub>1</sub>, V<sub>8</sub>, V<sub>9</sub> and V<sub>10</sub>. And finally at harvest the minimum chlorophyll content on leaf (29.30%) was achieved by *O. rufipogon* (V<sub>1</sub>) treatment which was statistically at par with V<sub>6</sub>, V<sub>8</sub>, V<sub>9</sub>, V<sub>10</sub>, V<sub>1</sub> and V<sub>7</sub> treatments. Kiran *et al.* (2013) reported that the total Chl content was highest in DRRH-3, followed by PA-6444 and *O. glaberrima*, Accession (ACC.) No. IR 104033. The lowest Chl content was found in *O. glaberrima*, ACC. No. IR 101800. Genotypes maintaining higher leaf Chl (both Chl a and b) during the



growth period may be considered as potential donors for their ability to produce higher biomass and photosynthetic capacity (Hassan *et al.* 2009). Significant variations in SPAD values (Chl content) among different *Oryza* species have been reported by Zhao *et al.* (2010). The higher Chl content was also reported for wild rice species by Yeo *et al.* (1994). Zhao *et al.* (2010) reported that among 17 *Oryza* species, *O. rufipogon* and *O. australiensis* exhibited the highest Chl content and photosynthesis ability, and they suggested that *O. rufipogon* was the best wild resource species for improving rice photosynthesis.

**Table 4.2.7 Chlorophyll content on leaf of wild species of rice**

| Treatments                  | Chlorophyll content on leaf (%) at different days after transplanting (DAT) |             |             |             |             |
|-----------------------------|-----------------------------------------------------------------------------|-------------|-------------|-------------|-------------|
|                             | 25                                                                          | 50          | 75          | 100         | At Harvest  |
| V <sub>1</sub>              | 32.63 d                                                                     | 34.03 cd    | 35.07 cd    | 38.57 b-d   | 31.97 a-c   |
| V <sub>2</sub>              | 37.23 ab                                                                    | 39.03 ab    | 40.57 a     | 41.63 ab    | 34.13 ab    |
| V <sub>3</sub>              | 35.30 bc                                                                    | 35.67 b-d   | 38.83 a-c   | 35.40 de    | 29.30 c     |
| V <sub>4</sub>              | 38.97 a                                                                     | 40.77 a     | 41.27 a     | 42.97 a     | 35.07 a     |
| V <sub>5</sub>              | 37.90 a                                                                     | 39.17 ab    | 40.63 a     | 41.77 ab    | 34.30 a     |
| V <sub>6</sub>              | 31.83 d                                                                     | 34.70 cd    | 33.53 d     | 36.53 c-e   | 29.67 c     |
| V <sub>7</sub>              | 35.47 bc                                                                    | 37.58 a-c   | 39.37 ab    | 36.97 cd    | 32.60 a-c   |
| V <sub>8</sub>              | 32.83 d                                                                     | 33.97 d     | 35.17 cd    | 39.37 a-d   | 30.00 c     |
| V <sub>9</sub>              | 33.33 cd                                                                    | 34.50 cd    | 35.47 b-d   | 39.90 a-c   | 30.23 bc    |
| V <sub>10</sub>             | 27.03 e                                                                     | 29.93 e     | 35.83 b-d   | 32.87 e     | 30.27 bc    |
| <b>LSD<sub>(0.05)</sub></b> | <b>2.39</b>                                                                 | <b>3.56</b> | <b>4.04</b> | <b>4.00</b> | <b>3.90</b> |
| <b>CV (%)</b>               | <b>4.06</b>                                                                 | <b>5.77</b> | <b>6.27</b> | <b>6.03</b> | <b>7.16</b> |

V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

#### 4.2.17 Shoot dry weight hill<sup>-1</sup>

Shoot dry weight hill<sup>-1</sup> of wild rice was significantly influenced by different species (Table 4.2.8). The results showed that, the maximum shoot dry weight hill<sup>-1</sup> (202.10 g) was produced by *O. nivara* (V<sub>3</sub>) which was statistically similar with V<sub>4</sub> and the minimum one (39.79 g) was distinctly produced by *P. coactata* (V<sub>5</sub>).

#### 4.2.18 Root dry weight hill<sup>-1</sup>

Root dry weight hill<sup>-1</sup> of wild rice was significantly varied by different genotypes (Table 4.2.8). The results revealed that, the maximum root dry weight hill<sup>-1</sup> (188.10 g) was produced by *O. nivara* (V<sub>3</sub>) which was statistically similar with V<sub>4</sub> and the minimum root dry weight hill<sup>-1</sup> (47.38 g) was produced by *P. coactata* (V<sub>5</sub>) which was statistically similar with V<sub>10</sub> treatment.

#### 4.2.19 Total dry weight hill<sup>-1</sup>

Total dry weight hill<sup>-1</sup> of wild rice was significantly differed by different species (Table 4.2.8). The results exposed that, the maximum total dry weight hill<sup>-1</sup> (390.50 g) was produced by *O. nivara* (V<sub>3</sub>) which was statistically similar with V<sub>4</sub>, V<sub>6</sub> and V<sub>1</sub> and the minimum total dry weight hill<sup>-1</sup> (79.16 g) was produced by *P. coactata* (V<sub>5</sub>). Chamely *et al.* (2015) reported that variety BRRI dhan28 produced the highest dry matter than other tested varieties. Roy *et al.* (2014a) revealed that the variety BRRI dhan48 was superior in relation to total dry matter weight hill<sup>-1</sup> and the lowest total dry matter weight hill<sup>-1</sup> was observed in BRRI dhan42. The significant variation in total dry matter weight hill<sup>-1</sup> among the species was also reported by Ahmed (2006); Amin *et al.* (2006).

**Table 4.2.8 Shoot and root dry weight of wild species of rice**

| Treatments            | Shoot dry weight<br>hill <sup>-1</sup> (g) | Root dry weight<br>hill <sup>-1</sup> (g) | Total dry weight<br>hill <sup>-1</sup> (g) |
|-----------------------|--------------------------------------------|-------------------------------------------|--------------------------------------------|
| V <sub>1</sub>        | 183.80 b-d                                 | 173.60 b                                  | 357.00 ab                                  |
| V <sub>2</sub>        | 170.40 d-f                                 | 122.50 e                                  | 295.60 d                                   |
| V <sub>3</sub>        | 202.10 a                                   | 188.10 a                                  | 390.50 a                                   |
| V <sub>4</sub>        | 197.00 ab                                  | 179.50 ab                                 | 376.90 ab                                  |
| V <sub>5</sub>        | 39.79 h                                    | 47.38 f                                   | 79.160 f                                   |
| V <sub>6</sub>        | 185.70 bc                                  | 170.40 b                                  | 356.40 ab                                  |
| V <sub>7</sub>        | 181.10 c-e                                 | 155.00 c                                  | 336.70 bc                                  |
| V <sub>8</sub>        | 158.60 f                                   | 111.50 e                                  | 270.40 d                                   |
| V <sub>9</sub>        | 167.60 ef                                  | 137.90 d                                  | 303.90 cd                                  |
| V <sub>10</sub>       | 67.94 g                                    | 52.61 f                                   | 120.80 e                                   |
| LSD <sub>(0.05)</sub> | <b>14.40</b>                               | <b>13.41</b>                              | <b>40.30</b>                               |
| CV (%)                | <b>5.40</b>                                | <b>5.84</b>                               | <b>8.14</b>                                |

V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

#### 4.2.20 Dry matter weight hill<sup>-1</sup>

Dry matter weight hill<sup>-1</sup> was varied significantly by species variation at different DAT (Table 4.2.9). The result of the experiment revealed that, the highest dry matter weight hill<sup>-1</sup> (94.34, 190.20 and 346.80 g at 50, 75 and 100 DAT, respectively) was produced by *O. latifolia* (V<sub>4</sub>) which was statistically similar with V<sub>1</sub>, V<sub>6</sub> and V<sub>3</sub> at 75 and 100 DAT. At 25 DAT, the highest dry matter weight hill<sup>-1</sup> (27.68 g) was produced by *O. rufipogon* (V<sub>1</sub>) which was statistically similar with V<sub>4</sub> and V<sub>3</sub>. At harvest, the highest dry matter weight hill<sup>-1</sup> (390.60 g) was produced by *O. nivara* (V<sub>3</sub>) which was statistically similar with V<sub>6</sub> and V<sub>1</sub>. The lowest dry matter weight hill<sup>-1</sup> (9.23, 15.14, 35.40, 69.25 and 79.16 g at 25, 50, 75, 100 DAT and harvest, respectively) were produced by *P. coactata* (V<sub>5</sub>) which was statistically similar with V<sub>10</sub> at 50 and 100 DAT. Chamely *et al.* (2015) reported that variety BRRI dna28 produced the highest dry matter than other tested varieties. Roy *et al.* (2014a) revealed that the variety BRRI dhan48 was superior in relation to total dry matter weight hill<sup>-1</sup> and the lowest total dry matter weight hill<sup>-1</sup> was observed in BRRI dhan42. The significant variation in total dry matter weight hill<sup>-1</sup> among the varieties was also reported by Ahmed (2006); Amin *et al.* (2006).

**Table 4.2.9 Leaf dry matter hill<sup>-1</sup> of wild species of rice**

| Treatments                  | Dry matter weight hill <sup>-1</sup> (g) at different days after transplanting (DAT) |             |              |              |              |
|-----------------------------|--------------------------------------------------------------------------------------|-------------|--------------|--------------|--------------|
|                             | 25                                                                                   | 50          | 75           | 100          | At Harvest   |
| V <sub>1</sub>              | 27.68 a                                                                              | 81.98 b     | 182.80 a     | 334.00 a     | 357.00 ab    |
| V <sub>2</sub>              | 22.18 bc                                                                             | 60.95 d     | 148.90 bc    | 275.90 b     | 295.60 cd    |
| V <sub>3</sub>              | 27.58 a                                                                              | 80.61 bc    | 180.60 a     | 331.90 a     | 390.60 a     |
| V <sub>4</sub>              | 27.60 a                                                                              | 94.34 a     | 190.20 a     | 346.80 a     | 376.90 ab    |
| V <sub>5</sub>              | 9.23 e                                                                               | 15.14 f     | 35.40 f      | 69.25 d      | 79.160 f     |
| V <sub>6</sub>              | 24.05 b                                                                              | 74.37 c     | 182.00 a     | 334.80 a     | 356.40 ab    |
| V <sub>7</sub>              | 21.40 c                                                                              | 62.13 d     | 158.70 b     | 297.30 b     | 336.70 bc    |
| V <sub>8</sub>              | 17.72 d                                                                              | 42.94 e     | 116.70 d     | 237.40 c     | 270.40 d     |
| V <sub>9</sub>              | 20.19 c                                                                              | 59.77 d     | 136.60 c     | 271.30 b     | 303.90 cd    |
| V <sub>10</sub>             | 7.317 e                                                                              | 19.06 f     | 50.90 e      | 98.18 d      | 120.80 e     |
| <b>LSD<sub>(0.05)</sub></b> | <b>2.24</b>                                                                          | <b>6.29</b> | <b>14.84</b> | <b>31.13</b> | <b>41.41</b> |
| <b>CV (%)</b>               | <b>6.36</b>                                                                          | <b>6.20</b> | <b>6.26</b>  | <b>6.99</b>  | <b>8.36</b>  |

V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

#### 4.2.21 Crop growth rate

Crop growth rate is a measure of the increase in size, mass or number of crops over a period of time. The increase can be plotted as a logarithmic or exponential curve in many cases. Different varieties were found significant in respect of crop growth rate (CGR) of wild rice (Table 4.2.10). The maximum CGR (43.37 g m<sup>-2</sup>d<sup>-1</sup>) at 25-50 DAT was observed from *O. latifolia* (V<sub>4</sub>). At 50-75 the maximum CGR (69.95 g m<sup>-2</sup>d<sup>-1</sup>) was observed from *O. glaberrima* (V<sub>6</sub>) which was statistically similar with V<sub>1</sub> and V<sub>3</sub>. At 75-100 DAT the maximum CGR (101.80 g m<sup>-2</sup>d<sup>-1</sup>) was observed from *O. latifolia* (V<sub>4</sub>) which was statistically similar with V<sub>6</sub>, V<sub>1</sub> and V<sub>3</sub> treatments. At 100 DAT-harvest the maximum CGR (38.11 g m<sup>-2</sup>d<sup>-1</sup>) was observed from *O. nivara* (V<sub>3</sub>). The minimum CGR (3.84, 13.17, 22.00 and 6.44 g m<sup>-2</sup>d<sup>-1</sup> at 25-50, 50-75, 75-100 DAT, 100 DAT and harvest, respectively) were distinctly observed from *P. coactata* (V<sub>5</sub>).

**Table 4.2.10 Crop growth rate of wild species of rice**

| Treatments                  | Crop growth rate (g m <sup>-2</sup> d <sup>-1</sup> ) at different days after transplanting (DAT) |             |             |                |
|-----------------------------|---------------------------------------------------------------------------------------------------|-------------|-------------|----------------|
|                             | 25-50                                                                                             | 50-75       | 75-100      | 100-At Harvest |
| V <sub>1</sub>              | 35.29 b                                                                                           | 65.50 ab    | 98.33 a     | 14.94 d        |
| V <sub>2</sub>              | 25.19 d                                                                                           | 57.15 c     | 82.58 cd    | 12.77 d        |
| V <sub>3</sub>              | 34.46 bc                                                                                          | 65.04 ab    | 98.31 a     | 38.11 a        |
| V <sub>4</sub>              | 43.37 a                                                                                           | 62.29 bc    | 101.8 a     | 19.57 c        |
| V <sub>5</sub>              | 3.84 g                                                                                            | 13.17 f     | 22.00 f     | 6.44 e         |
| V <sub>6</sub>              | 32.71 c                                                                                           | 69.95 a     | 99.29 a     | 14.08 d        |
| V <sub>7</sub>              | 26.47 d                                                                                           | 62.79 b     | 90.08 b     | 25.58 b        |
| V <sub>8</sub>              | 16.39 e                                                                                           | 47.97 d     | 78.43 d     | 21.40 c        |
| V <sub>9</sub>              | 25.72 d                                                                                           | 49.95 d     | 87.53 bc    | 21.20 c        |
| V <sub>10</sub>             | 7.63 f                                                                                            | 20.70 e     | 30.73 e     | 14.73 d        |
| <b>LSD<sub>(0.05)</sub></b> | <b>2.16</b>                                                                                       | <b>5.28</b> | <b>6.03</b> | <b>2.36</b>    |
| <b>CV (%)</b>               | <b>5.02</b>                                                                                       | <b>5.99</b> | <b>4.46</b> | <b>7.30</b>    |

V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

#### 4.2.22 Relative growth rate

Different species significantly varied in respect of relative growth rate (RGR) of wild rice (Table 4.2.11). At 25-50 DAT the maximum RGR ( $19.64 \text{ g g}^{-1} \text{ d}^{-1}$ ) was scored by  $V_6$  treatment which was statistically similar with rest of the treatments except  $V_5$ ,  $V_8$  and  $V_{10}$  treatments. At 50-75 and 75-100 DAT the maximum RGR ( $17.38$  and  $12.33 \text{ g g}^{-1} \text{ d}^{-1}$ , respectively) were scored by  $V_8$  treatment which was statistically similar with  $V_{10}$  and  $V_7$  at 50-75 DAT; with  $V_9$ ,  $V_{10}$  and  $V_4$  at 75-100 DAT. At 100 DAT-harvest, the maximum RGR ( $3.67 \text{ g g}^{-1} \text{ d}^{-1}$ ) was scored by  $V_{10}$ . The minimum RGR ( $8.62$ ,  $3.60$  and  $1.44 \text{ g g}^{-1} \text{ d}^{-1}$  at 25-50, 50-75 and 75-100 DAT, respectively) was scored by  $V_5$  treatment. At 100 DAT-harvest, the minimum RGR ( $1.09 \text{ g g}^{-1} \text{ d}^{-1}$ ) was scored by  $V_6$  treatment which was statistically similar with  $V_1$  and  $V_2$ . Poorter and Remkes (1990) and Roetman and Sterk (1986) reported that genotypic variation in RGR may be have an explanation for the observed differences. The more a plant invests in leaf area, the higher the total carbon gain and the faster growth will be. Allocation of dry matter to leaves is higher in fast-growing species. Roy *et al.* (2014a) revealed that the variety BRRI dhan48 was superior in relation to RGR, in contrast, the lowest RGR in BRRI dhan42. The findings of our experiment also supported by other researchers who found similar outcome in their studies on *Taraxacum* microspecies (Roetman and Sterk 1986), for two *Plantago* subspecies (Dijkstra and Lambers 1986) and for eight wild species (Poorter, 1989).

#### 4.2.23 Net assimilation rate

Species has significant effect on net assimilation rate (NAR) of wild rice at different DAT (Table 4.2.12). The results showed that, the maximum NAR ( $0.103 \text{ g cm}^{-2} \text{ d}^{-1}$ ) was recorded from *O. latifolia* ( $V_4$ ) at 25-50 DAT which was statistically similar with rest of the treatments except  $V_2$ ,  $V_5$ ,  $V_8$  and  $V_{10}$ . Again the maximum NAR ( $0.093$  and  $0.097 \text{ g cm}^{-2} \text{ d}^{-1}$  at 50-75, 75-100 DAT, respectively) were recorded from *P. coactata* ( $V_5$ ). At 100 DAT-harvest, the maximum NAR ( $0.030 \text{ g cm}^{-2} \text{ d}^{-1}$ ) was recorded from both *P. coactata* ( $V_5$ ) and *O. nivara* ( $V_3$ ) which were statistically similar with rest of the treatments except  $V_1$ ,  $V_2$  and  $V_4$ . The minimum NAR ( $0.030$ ,  $0.023$  and  $0.027 \text{ g cm}^{-2} \text{ d}^{-1}$  at 25-50, 50-75 and 75-100 DAT, respectively) were recorded from *O. barthii* ( $V_{10}$ ). Finally at 100 DAT-harvest, the minimum NAR

(0.010 g cm<sup>-2</sup> d<sup>-1</sup>) was recorded from V<sub>1</sub>, V<sub>2</sub> and V<sub>4</sub> treatments which were statistically similar with rest of the treatments except V<sub>3</sub> and V<sub>5</sub>.

**Table 4.2.11 Relative growth rate of wild species of rice**

| Treatments                  | Relative growth rate (g g <sup>-1</sup> d <sup>-1</sup> ) at different days after transplanting (DAT) |             |             |                |
|-----------------------------|-------------------------------------------------------------------------------------------------------|-------------|-------------|----------------|
|                             | 25-50                                                                                                 | 50-75       | 75-100      | 100-At Harvest |
| V <sub>1</sub>              | 19.55 a                                                                                               | 13.43 d-f   | 10.29 de    | 1.16 f         |
| V <sub>2</sub>              | 17.27 a-c                                                                                             | 12.80 f     | 10.56 c-e   | 1.20 f         |
| V <sub>3</sub>              | 19.48 a                                                                                               | 14.14 de    | 9.60 e      | 2.83 b         |
| V <sub>4</sub>              | 19.48 a                                                                                               | 13.15 ef    | 11.34 a-c   | 1.45 e         |
| V <sub>5</sub>              | 8.62 d                                                                                                | 3.597 g     | 1.44 f      | 2.33 c         |
| V <sub>6</sub>              | 19.64 a                                                                                               | 15.53 bc    | 10.60 c-e   | 1.09 f         |
| V <sub>7</sub>              | 18.52 ab                                                                                              | 16.30 ab    | 10.90 b-d   | 2.16 cd        |
| V <sub>8</sub>              | 15.40 c                                                                                               | 17.38 a     | 12.33 a     | 2.13 cd        |
| V <sub>9</sub>              | 18.88 ab                                                                                              | 14.36 cd    | 11.92 ab    | 1.97 d         |
| V <sub>10</sub>             | 16.78 bc                                                                                              | 17.00 a     | 11.46 a-c   | 3.67 a         |
| <b>LSD<sub>(0.05)</sub></b> | <b>2.38</b>                                                                                           | <b>1.21</b> | <b>1.05</b> | <b>0.21</b>    |
| <b>CV (%)</b>               | <b>8.00</b>                                                                                           | <b>5.12</b> | <b>6.06</b> | <b>6.09</b>    |

V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

Poorter and Remkes (1990) observed that an increase in NAR may require an increased rate of photo-synthesis, which can be realized by extra investment in the photosynthetic apparatus. Alternatively, the balance between the amount of roots and the amount of leaf area could influence the water status of the leaves and hence the rate of photosynthesis.

#### 4.2.24 Leaf area duration

The leaf area duration (LAD) was significantly influenced by different species of wild rice at different DAT (Table 4.2.13). The results showed that, the maximum LAD (365.70, 855.50, 1143.00 and 1079.00 dm<sup>2</sup> at 25-50, 50-75, 75-100 DAT and 100 DAT-harvest, respectively) were distinctly obtained from *O. latifolia* (V<sub>4</sub>) and the minimum LAD (43.85, 100.40, 154.90 and 146.60 dm<sup>2</sup> at 25-50, 50-75, 75-100 DAT and 100 DAT-harvest, respectively) were distinctly obtained from *P. coactata* (V<sub>5</sub>).

**Table 4.2.12 Net assimilation rate of wild species of rice**

| Treatments                  | NAR (g cm <sup>-2</sup> d <sup>-1</sup> ) at different days after transplanting (DAT) |             |             |                |
|-----------------------------|---------------------------------------------------------------------------------------|-------------|-------------|----------------|
|                             | 25-50                                                                                 | 50-75       | 75-100      | 100-At Harvest |
| V <sub>1</sub>              | 0.100 ab                                                                              | 0.063 bc    | 0.070 b     | 0.010 b        |
| V <sub>2</sub>              | 0.083 bc                                                                              | 0.057 bc    | 0.060 b     | 0.010 b        |
| V <sub>3</sub>              | 0.097 ab                                                                              | 0.060 bc    | 0.067 b     | 0.030 a        |
| V <sub>4</sub>              | 0.103 a                                                                               | 0.050 c     | 0.060 b     | 0.010 b        |
| V <sub>5</sub>              | 0.067 cd                                                                              | 0.093 a     | 0.097 a     | 0.030 a        |
| V <sub>6</sub>              | 0.087 ab                                                                              | 0.067 bc    | 0.067 b     | 0.017 ab       |
| V <sub>7</sub>              | 0.097 ab                                                                              | 0.070 b     | 0.073 b     | 0.023 ab       |
| V <sub>8</sub>              | 0.057 d                                                                               | 0.057 bc    | 0.067 b     | 0.020 ab       |
| V <sub>9</sub>              | 0.087 ab                                                                              | 0.053 bc    | 0.067 b     | 0.020 ab       |
| V <sub>10</sub>             | 0.030 e                                                                               | 0.023 d     | 0.027 c     | 0.020 ab       |
| <b>LSD<sub>(0.05)</sub></b> | <b>0.02</b>                                                                           | <b>0.02</b> | <b>0.02</b> | <b>0.02</b>    |
| <b>CV (%)</b>               | <b>6.45</b>                                                                           | <b>8.52</b> | <b>8.69</b> | <b>13.21</b>   |

V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

**Table 4.2.13 Leaf area duration of wild species of rice**

| Treatments                  | LAD (dm <sup>2</sup> days) at different days after transplanting (DAT) |              |               |                |
|-----------------------------|------------------------------------------------------------------------|--------------|---------------|----------------|
|                             | 25-50                                                                  | 50-75        | 75-100        | 100-At Harvest |
| V <sub>1</sub>              | 299.30 bc                                                              | 712.90 b     | 950.10 bc     | 745.20 cd      |
| V <sub>2</sub>              | 269.80 cd                                                              | 688.10 bc    | 940.00 bc     | 786.70 c       |
| V <sub>3</sub>              | 299.20 bc                                                              | 744.10 b     | 1007.00 b     | 858.50 b       |
| V <sub>4</sub>              | 365.70 a                                                               | 855.50 a     | 1143.00 a     | 1079.00 a      |
| V <sub>5</sub>              | 43.85 f                                                                | 100.40 e     | 154.90 e      | 146.60 f       |
| V <sub>6</sub>              | 313.90 b                                                               | 742.40 b     | 983.20 b      | 911.90 b       |
| V <sub>7</sub>              | 243.10 de                                                              | 606.00 d     | 822.10 d      | 719.70 cd      |
| V <sub>8</sub>              | 239.40 de                                                              | 596.90 d     | 809.70 d      | 714.40 d       |
| V <sub>9</sub>              | 254.10 de                                                              | 633.50 cd    | 859.20 cd     | 762.30 cd      |
| V <sub>10</sub>             | 229.60 e                                                               | 574.60 d     | 781.10 d      | 603.90 e       |
| <b>LSD<sub>(0.05)</sub></b> | <b>33.00</b>                                                           | <b>70.51</b> | <b>100.10</b> | <b>70.25</b>   |
| <b>CV (%)</b>               | <b>7.52</b>                                                            | <b>6.57</b>  | <b>6.90</b>   | <b>5.59</b>    |

V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

#### 4.2.25 Absolute growth rate

The absolute growth rate (AGR) was significantly influenced by different species of wild rice at different DAT (Table 4.2.14). The results showed that, the maximum AGR (0.90, 2.08 and 0.48g day<sup>-1</sup> hill<sup>-1</sup> at 25-50, 75-100 DAT and 100 DAT-harvest, respectively) were found from *O. latifolia* (V<sub>4</sub>) which was statistically similar with V<sub>2</sub> at 25-50 DAT. At 50-75 DAT the maximum AGR (1.25 g day<sup>-1</sup> hill<sup>-1</sup>) was found from *O. alta* (V<sub>2</sub>). The minimum AGR (0.31 and 0.94 g day<sup>-1</sup> hill<sup>-1</sup> at 25-50 and 75-100 DAT, respectively) were found from *O. nivara* (V<sub>3</sub>) which was statistically similar with V<sub>9</sub> at 25-50 DAT; with V<sub>10</sub>, V<sub>1</sub> and V<sub>6</sub> at 75-100 DAT. At 50-75 DAT the minimum AGR (0.52 g day<sup>-1</sup> hill<sup>-1</sup>) was found from *O. glaberrima* (V<sub>6</sub>) which was statistically similar with V<sub>9</sub> treatment. Finally at 100 DAT-harvest, the minimum AGR (0.16 g day<sup>-1</sup> hill<sup>-1</sup>) was found from V<sub>3</sub>, V<sub>6</sub> and V<sub>7</sub> treatments which was statistically similar with V<sub>8</sub>, V<sub>9</sub> and V<sub>1</sub> treatments.

**Table 4.2.14 Absolute growth rate wild species of rice**

| Treatments        | AGR (g day <sup>-1</sup> hill <sup>-1</sup> ) at different days after transplanting (DAT) |             |             |                |
|-------------------|-------------------------------------------------------------------------------------------|-------------|-------------|----------------|
|                   | 25-50                                                                                     | 50-75       | 75-100      | 100-At Harvest |
| V <sub>1</sub>    | 0.71 b                                                                                    | 0.88 c      | 1.00 ef     | 0.21 c         |
| V <sub>2</sub>    | 0.88 a                                                                                    | 1.25 a      | 1.31 c      | 0.28 b         |
| V <sub>3</sub>    | 0.31 e                                                                                    | 0.64 d      | 0.94 f      | 0.16 c         |
| V <sub>4</sub>    | 0.90 a                                                                                    | 1.12 b      | 2.08 a      | 0.48 a         |
| V <sub>5</sub>    | 0.51 c                                                                                    | 0.71 d      | 1.19 d      | 0.27 b         |
| V <sub>6</sub>    | 0.42 d                                                                                    | 0.52 e      | 1.06 ef     | 0.16 c         |
| V <sub>7</sub>    | 0.67 b                                                                                    | 0.89 c      | 1.19 d      | 0.16 c         |
| V <sub>8</sub>    | 0.41 d                                                                                    | 0.66 d      | 1.85 b      | 0.18 c         |
| V <sub>9</sub>    | 0.33 e                                                                                    | 0.54 e      | 1.08 de     | 0.18 c         |
| V <sub>10</sub>   | 0.48 cd                                                                                   | 0.81 c      | 0.98 ef     | 0.31 b         |
| <b>LSD (0.05)</b> | <b>0.08</b>                                                                               | <b>0.09</b> | <b>0.12</b> | <b>0.05</b>    |
| <b>CV (%)</b>     | <b>8.72</b>                                                                               | <b>7.09</b> | <b>5.37</b> | <b>11.28</b>   |

V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

#### 4.2.26 Specific leaf area

The specific leaf area (SLA) was significantly differed by species variation of wild rice at different DAT (Table 4.2.15). The results showed that, the maximum SLA (84.76, 59.53, 33.46 and 13.00 cm<sup>2</sup> g<sup>-1</sup> at 25-50, 50-75, 75-100 DAT and 100 DAT-



harvest, respectively) were distinctly achieved from *O. barthii* (V<sub>10</sub>). The minimum SLA (17.45, 15.21 and 10.13 cm<sup>2</sup> g<sup>-1</sup> at 25-50, 50-75 and 75-100 DAT, respectively) were achieved from *P. coactata* (V<sub>5</sub>) which was statistically similar with V<sub>1</sub>, V<sub>7</sub> and V<sub>6</sub> at 50-75 DAT; with V<sub>1</sub>, V<sub>7</sub>, V<sub>6</sub> and V<sub>3</sub> at 75-100 DAT. At 100 DAT-harvest minimum SLA (5.60 cm<sup>2</sup> g<sup>-1</sup>) was achieved from *O. rufipogon* (V<sub>1</sub>) which was statistically similar with V<sub>5</sub>.

**Table 4.2.15 Specific leaf area of wild species of rice**

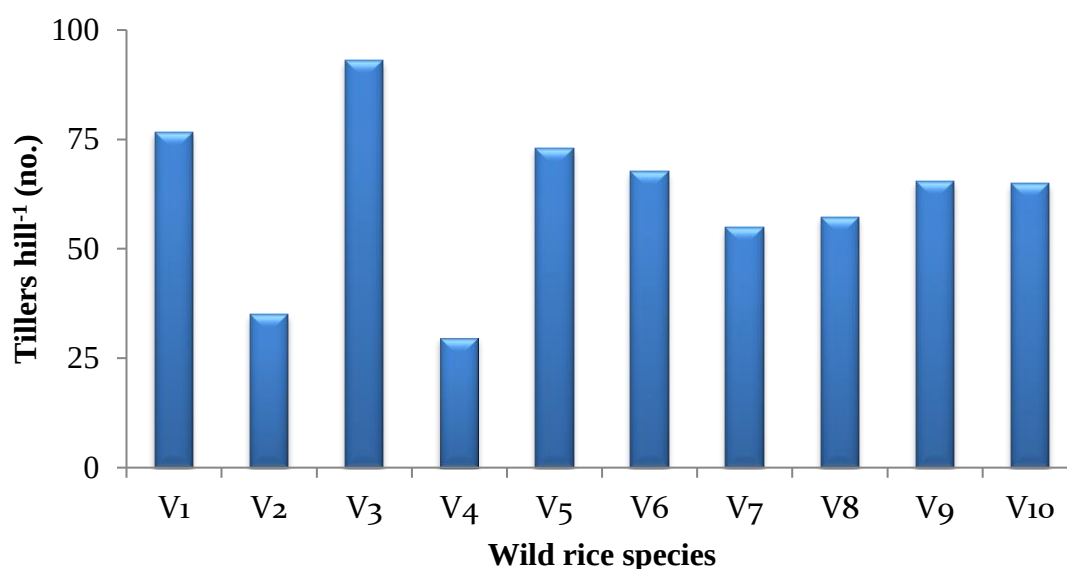
| Treatments                  | SLA (cm <sup>2</sup> g <sup>-1</sup> ) at different days after transplanting (DAT) |              |              |                |
|-----------------------------|------------------------------------------------------------------------------------|--------------|--------------|----------------|
|                             | 25-50                                                                              | 50-75        | 75-100       | 100-At Harvest |
| V <sub>1</sub>              | 25.20 c                                                                            | 19.91 cd     | 11.86 bc     | 5.60 f         |
| V <sub>2</sub>              | 31.22 c                                                                            | 24.17 bc     | 14.24 b      | 8.02 d         |
| V <sub>3</sub>              | 25.73 c                                                                            | 21.47 bc     | 12.58 bc     | 6.90 e         |
| V <sub>4</sub>              | 26.89 c                                                                            | 22.66 bc     | 13.94 b      | 10.07 b        |
| V <sub>5</sub>              | 17.45 d                                                                            | 15.21 d      | 10.13 c      | 5.95 f         |
| V <sub>6</sub>              | 29.26 c                                                                            | 20.74 cd     | 12.26 bc     | 8.96 c         |
| V <sub>7</sub>              | 27.40 c                                                                            | 19.83 cd     | 11.54 bc     | 6.91 e         |
| V <sub>8</sub>              | 38.99 b                                                                            | 26.56 b      | 14.23 b      | 8.65 cd        |
| V <sub>9</sub>              | 29.75 c                                                                            | 24.07 bc     | 13.22 b      | 8.28 cd        |
| V <sub>10</sub>             | 84.76 a                                                                            | 59.53 a      | 33.46 a      | 13.00 a        |
| <b>LSD<sub>(0.05)</sub></b> | <b>6.06</b>                                                                        | <b>5.76</b>  | <b>2.72</b>  | <b>0.85</b>    |
| <b>CV (%)</b>               | <b>10.49</b>                                                                       | <b>13.20</b> | <b>10.74</b> | <b>6.03</b>    |

V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

#### 4.2.27 Tillers hill<sup>-1</sup>

The tillers hill<sup>-1</sup> of wild rice was significantly influenced by different gentypes (Figure 4.2.1). The maximum tillers hill<sup>-1</sup> (93.00) was distinctly produced by *O. nivara* (V<sub>3</sub>) and the minimum tillers hill<sup>-1</sup> (29.67) was produced by *O. latifolia* (V<sub>4</sub>) which was statistically similar with V<sub>2</sub> treatment. This might be due to the diversity of genetic make-up of varieties and ability to accumulate the photosynthates in the vegetative plant parts. Debnath (2010) reported that BRRI dhan29 produced maximum number of tillers hill<sup>-1</sup> compared to BRRI hybrid dhan2. Shrestha *et al.* (2021) reported that the number of tillers per plant varied from NR 11410-B-B-9 (6) to Sunaulo sugandha (15). Chamely *et al.* (2015) also reported that the highest number of total tillers hill<sup>-1</sup> (12.71) was recorded in the variety BRRI dhan29 which was statistically similar with

the variety BRRI dhan28 and the lowest number of total tillers hill<sup>-1</sup> was observed in BRRI dhan45. Our present investigation results are similar to the results of Gangashetty *et al.* (2013); Roy *et al.* (2014b); Dangi *et al.* (2017); Kumar *et al.* (2017) who stating that species variation affected the tillers hill<sup>-1</sup> of rice.



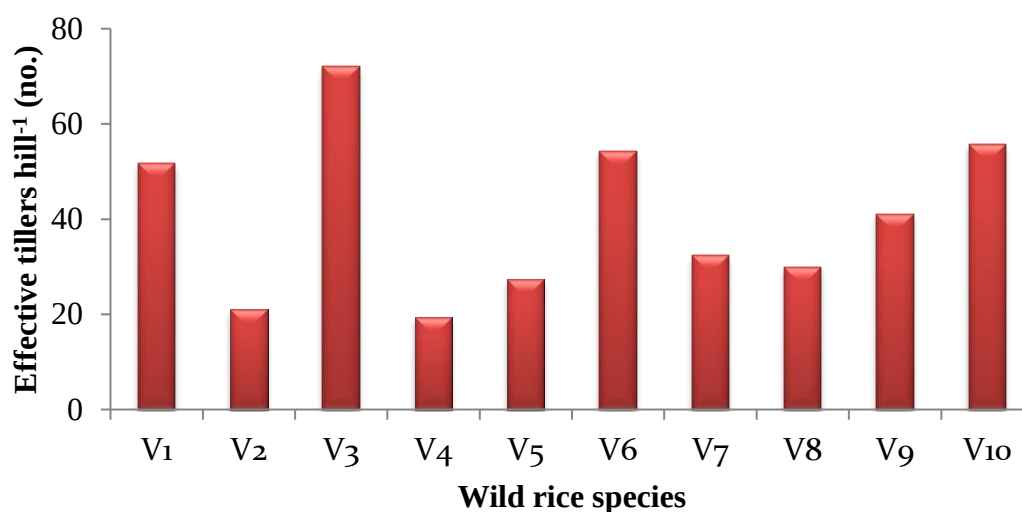
V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

**Figure 4.2.1 Tillers hill<sup>-1</sup> of wild species of rice (LSD 0.05=7.43)**

#### 4.2.28 Effective tillers hill<sup>-1</sup>

The effective tillers hill<sup>-1</sup> of wild rice was significantly varied by different species (Figure 4.2.2). The maximum effective tillers hill<sup>-1</sup> (72.00) was distinctly produced by *O. nivara* (V<sub>3</sub>) and the minimum effective tillers hill<sup>-1</sup> (19.33) was produced by *O. latifolia* (V<sub>4</sub>) which was statistically similar with V<sub>2</sub> treatment. *O. nivara* produced 272.48% more effective tillers hill<sup>-1</sup> than wild rice genotype *O. latifolia*. The diversity in the genetic make-up of the species is the cause of the variability in the number of effective tillers plant<sup>-1</sup>. Kumar *et al.* (2017) reported that the higher number of effective tillers might be attributed to higher affinity of these varieties to produce more number of tillers m<sup>-2</sup> in early growing period followed by differential ability of cultivars to utilize the fertilizer nutrients as well as partitioning of photoassimilates. Rice grain yield is heavily influenced by effective tillering ability. Too few tillers result in fewer panicles, whereas too many tillers result in high tiller mortality, undersized panicles, poor grain filling, and reduced grain yield (Peng *et al.*, 1994).

Productive tillers are one of the most important yield components, as the final yield is mostly determined by the number of panicles bearing tillers per unit area (Roy *et al.*, 2014a). Kumar *et al.* (2017) reviewed that rice variety PAC-837 recorded significantly higher effective tillers  $m^{-2}$  (264.00), which was however, statistically at par with DRRH-3. Chamely *et al.* (2015) also reported that the highest number of effective tillers  $hill^{-1}$  (11.07) was recorded in the variety BRRI dhan29 and the lowest one was observed in BRRI dhan45. Chouhan *et al.* (2014b) showed that number of effective tillers  $plant^{-1}$  varied from 3.50 to 10.15 with mean of 7.19 and 65.71 % accessions had more than 6 tillers  $plant^{-1}$ . The findings of our research are collaborate with those reported by Mahajan *et al.* (2012); Roy *et al.* (2014a); Shiyam *et al.* (2014); Shrestha *et al.* (2021) who stated that number of effective tillers  $hill^{-1}$  was varied with variety.



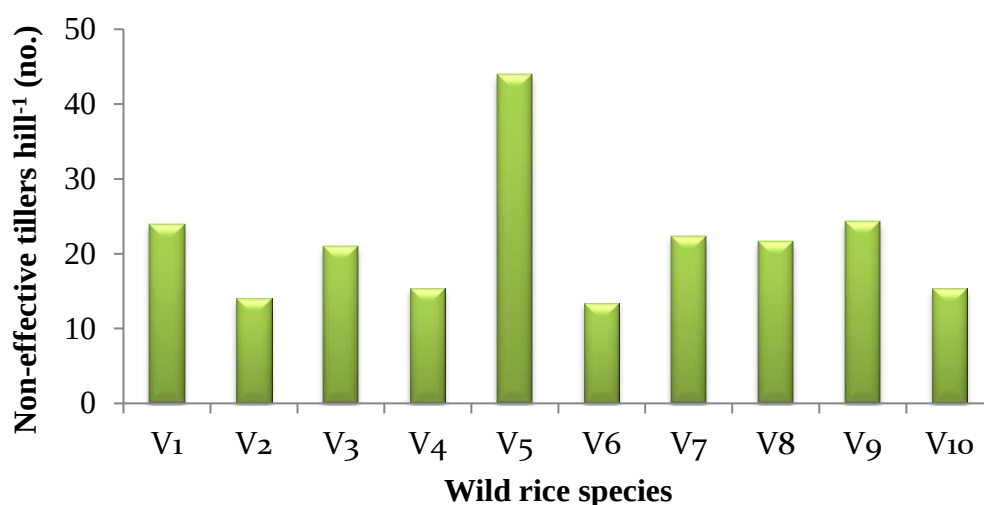
V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

**Figure 4.2.2 Effective tillers  $hill^{-1}$  of wild species of rice (LSD  $_{0.05}=4.52$ )**

#### **4.2.29 Non-effective tillers $hill^{-1}$**

The non-effectivetillers  $hill^{-1}$  of wild rice was significantly differed by different varieties (Figure 4.2.3). The maximum non-effective tillers  $hill^{-1}$  (44.00) was distinctly produced by *P. coactata* (V<sub>5</sub>) and the minimum non effectivetillers  $hill^{-1}$  (13.33) was produced by *O. glaberrima* (V<sub>6</sub>) which was statistically similar with V<sub>2</sub>, V<sub>4</sub> and V<sub>10</sub> treatments. The results of our experiment are not similar with the findings of Ashrafuzzaman (2006); Debnath (2010). But the similar findings are also reported

by Chouhan *et al.* (2014b); Shiyam *et al.* (2014); Roy *et al.* (2014a) who found significant variation among varieties in respect of number of ineffective tillers hill<sup>-1</sup>.

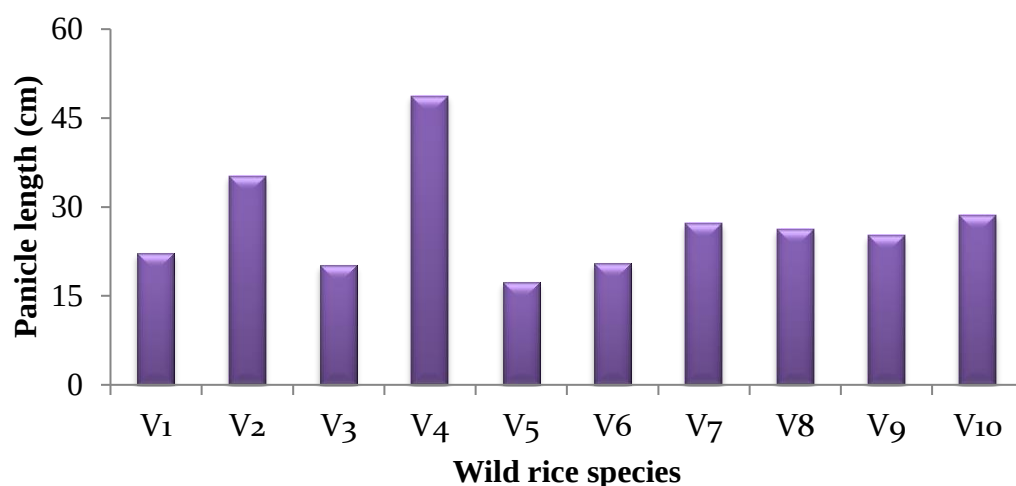


V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

**Figure 4.2.3 Non-effective tillers hill<sup>-1</sup> of wild species of rice (LSD <sub>0.05</sub>=3.60)**

#### 4.2.30 Panicle length

The species variation of wild rice had significant variation on the panicle length of wild rice (Figure 4.2.4). The data revealed that, the longest panicle (48.73 cm) was observed from (V<sub>4</sub>) treatment and the shortest one (17.27 cm) was observed from *P. coactata* (V<sub>5</sub>) which showed similarity with treatment V<sub>3</sub>. The variation as assessed might be due to genetic characters of the varieties primarily influenced by the heredity. Chouhan *et al.* (2014b) reported that panicle length varied from 17.72 to 28.50 cm with mean of 23.09 cm and 68.57% accessions had intermediate type. Shrestha *et al.* (2021) also reported that the panicle length ranged from NR 11182-B-21 (21 cm) to NR 11196- B-3-3 (30.9 cm). Chamely *et al.* (2015) presented the longest panicle (23.19 cm) was found in the variety BRRI dhan29 and the smallest one was observed in BRRI dhan45. Dangi *et al.* (2017) Variety IR-64 produced maximum panicle length (23.55 cm while variety Kalanamak attained minimum the value. Our present investigation findings are conformity with the finding of Debnath *et al.* (2012); Gohain (2014); Hossain *et al.* (2014a); Tiwari *et al.* (2015) who observed that varieties differed significantly in respect of panicle length.

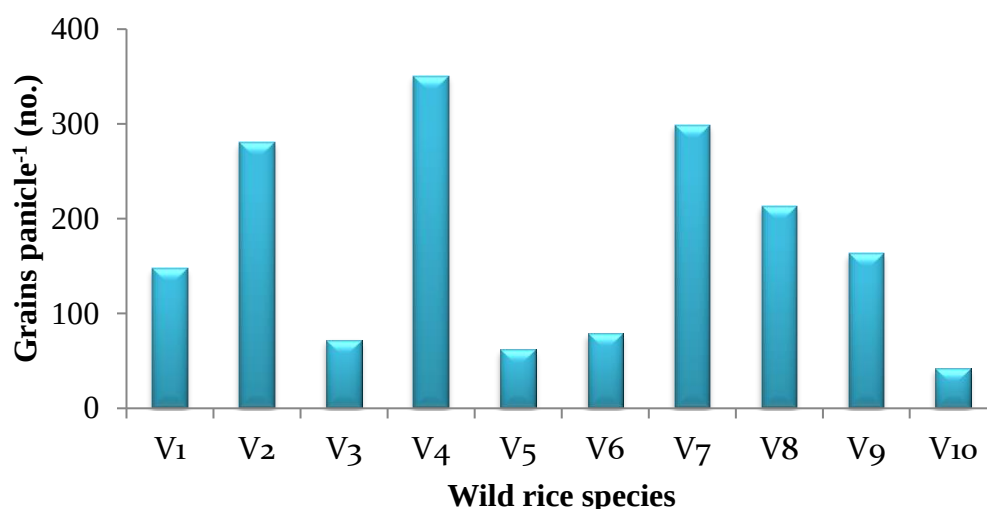


V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

**Figure 4.2.4 Panicle length of wild species of rice (LSD  $_{0.05}=3.12$ )**

#### 4.2.31 Grains panicle<sup>-1</sup>

The species variation of wild rice exerted significant effect on the grains panicle<sup>-1</sup> of wild rice (Figure 4.2.5). The data revealed that, the maximum grains panicle<sup>-1</sup> (350.70) was distinctly observed from *O. latifolia* (V<sub>4</sub>) and the minimum grains panicle<sup>-1</sup> (42.00) was distinctly observed from *O. barthii* (V<sub>10</sub>). Species differences regarding the number of grains panicle<sup>-1</sup> was probably due to their genetic make-up and also due to the variation in photosynthetic assimilate accumulation especially after heading. Kumar *et al.* (2017) observed higher number of grains panicle<sup>-1</sup> were recorded in rice variety DRRH-3 followed by PR-115 and lower number of grains panicle<sup>-1</sup> were reported by PR-121. Chamely *et al.* (2015) confirmed that the highest number of grains panicle<sup>-1</sup> (159.55) was recorded in the variety BRRI dhan29 which was about double compare to the variety BBRI dhan45 and about 1.5 fold more than the variety BRRI dhan28. Chouhan *et al.* (2014b) noted that total number of grains panicle<sup>-1</sup> varied from 54.61 to 267.29 with mean of 107.32 among the tested rice varieties. Dangi *et al.* (2017) Variety IR- 64 produced maximum number of grains panicle<sup>-1</sup> (129.44) while variety Kalanamak attained minimum value for number of grains panicle<sup>-1</sup>. Variation in number of grains panicle<sup>-1</sup> with rice varieties was also reported by Hossain *et al.* (2014a); Ramanjaneyulu *et al.* (2014); Singh and Kumar (2014); Tiwari *et al.* (2015); Dangi *et al.* (2017); Kumar *et al.* (2017).

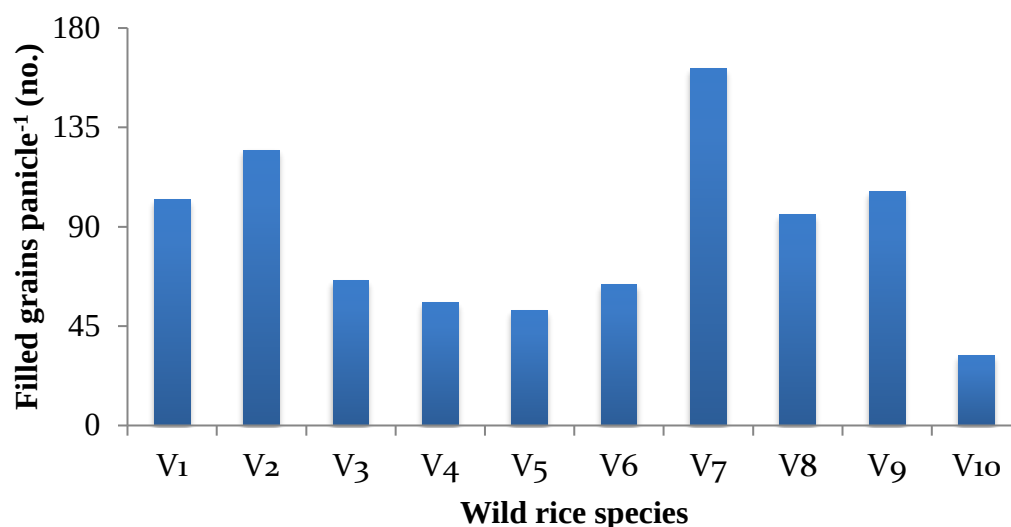


V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

**Figure 4.2.5 Grains panicle<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=14.43)**

#### 4.2.32 Filled grains panicle<sup>-1</sup>

The species variation of wild rice exerted significant influence on the filled grains panicle<sup>-1</sup> (Figure 4.2.6). The data showed that, the maximum filled grains panicle<sup>-1</sup> (161.70) was distinctly produced by *O. longistaminata* (V<sub>7</sub>) and the minimum filled grains panicle<sup>-1</sup> (31.67) was distinctly produced by *O. barthii* (V<sub>10</sub>). Wild rice genotype *O. longistaminata* produced 410.58% more filled grains panicle<sup>-1</sup> than *O. barthii*. Shrestha *et al.* (2021) stated that one of the most critical yields determining features is the number of filled grains per panicle. Gravois and McNew (1993) found that filled grains panicle<sup>-1</sup> had a beneficial direct effect on rice yield. The higher number of filled grains panicle<sup>-1</sup> might be attributed to genetic make-up, higher affinity of these varieties to produce more photosynthates and differential ability of cultivars to partitioning of these photosynthates from source to sink (Yesuf and Balcha, 2014; Jahan *et al.*, 2020). Chouhan *et al.* (2014b) presented that the filled grains panicle<sup>-1</sup> varied from 19.12 to 231.90 with mean of 69.65. Dangi *et al.* (2017) reported that the variety IR-64 produced maximum number of filled grains panicle<sup>-1</sup> (116.22) and while variety Kalanamak attained minimum value for filled grains panicle<sup>-1</sup>. The present investigation results are conformity with the finding of Tiwari *et al.* (2015); Dangi *et al.* (2017); Jahan *et al.* (2020); Shrestha *et al.* (2021).

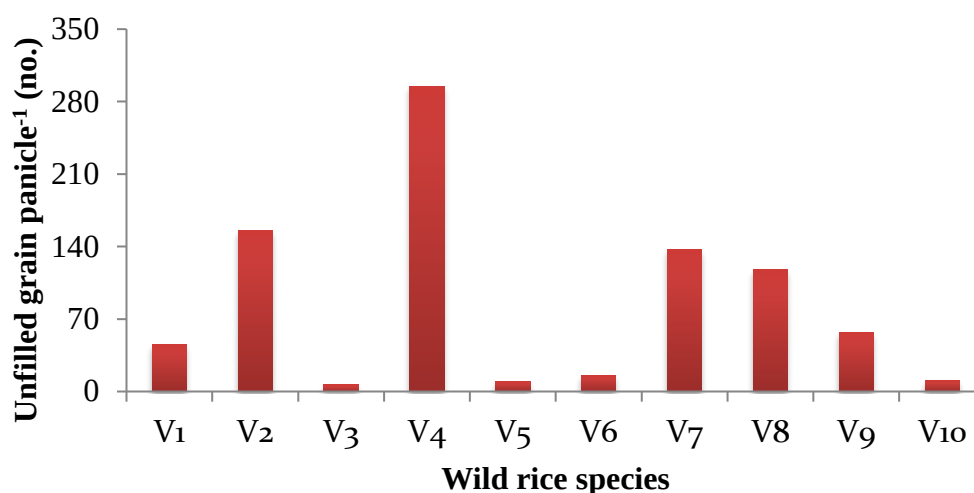


V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

**Figure 4.2.6 Filled grains panicle<sup>-1</sup> of wild species of rice (LSD 0.05=9.84)**

#### 4.2.33 Unfilled grains panicle<sup>-1</sup>

Different varieties of wild rice exerted significant difference on the unfilled grains panicle<sup>-1</sup> (Figure 4.2.7). The data showed that, the maximum unfilled grains panicle<sup>-1</sup> (295.00) was distinctly obtained from *O. latifolia* (V<sub>4</sub>) and the minimum unfilled grains panicle<sup>-1</sup> (6.33) was obtained from *O. nivara* (V<sub>3</sub>) which was closely similar with V<sub>10</sub> and V<sub>5</sub> treatments. The reasons for differences in producing unfilled grains panicle<sup>-1</sup> might be due to the variation in genetic make-up of the species that might be influenced by heredity. Dangi *et al.* (2017) found that the number of unfilled grains panicle<sup>-1</sup> was significantly lowest (13.58 and 14.61) in IR- 64 and BPT-5204 varieties, respectively over other varieties. These results are in agreement with the findings of Dhanwani *et al.* (2013); Tiwari *et al.*,(2015); Jahan *et al.* (2020) who observed the that the production of unfilled grains panicle<sup>-1</sup> differed from variety to variety.



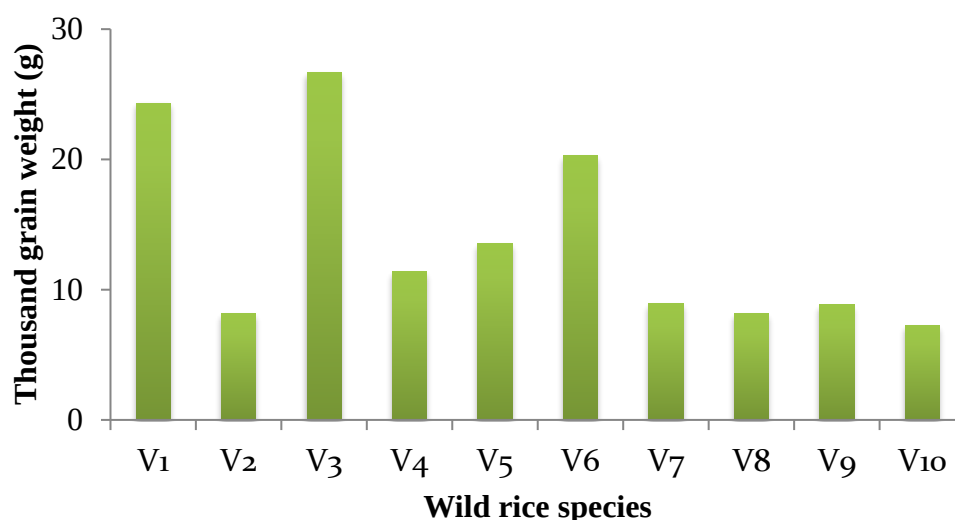
V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

**Figure 4.2.7 Unfilled grains panicle<sup>-1</sup> of wild species of rice (LSD <sub>0.05</sub>=7.47)**

#### 4.2.34 Thousand grain weight

The thousand grain weight was significantly affected by different varieties of wild rice (Figure 4.2.8). The results of the experiment revealed that, the maximum thousand grain weight (26.66 g) was recorded from *O. nivara* (V<sub>3</sub>) and the minimum thousand grain weight (7.22 g) was recorded from *O. barthii* (V<sub>10</sub>) which was statistically similar with V<sub>2</sub>, V<sub>8</sub> and V<sub>9</sub> treatments. Wild rice genotype *O. nivara* scored 269.25% more thousand grain weight than the genotype *O. barthii*. These results might be due to ability of this cultivar to partition more dry matter from source to sink. Similarly, Kastura and Nakaide (2011) concluded that the rice varieties with greater sink capacity and source activity plant<sup>-1</sup> could produce more thousand grain weight under aerobic conditions. Chouhan *et al.* (2014b) reported that test weight is the key characters for high yield and it varied from 14.10 to 33.50 g with mean of 23.53 g, and showed presence of high variability among the tested varieties. Dangi *et al.* (2017) recorded highest thousand grain weight (23.39 g) in variety IR64 compare to that Kalanamak which produced lowest thousand grain weight. The result of our present findings also supported by the findings of Roy *et al.* (2014a); Shiyam *et al.* (2014); Singh and Kumar (2014); Tiwari *et al.* (2015); Kumar *et al.* (2017) who concluded that the thousand grains weight depends on species genetic potentiality.





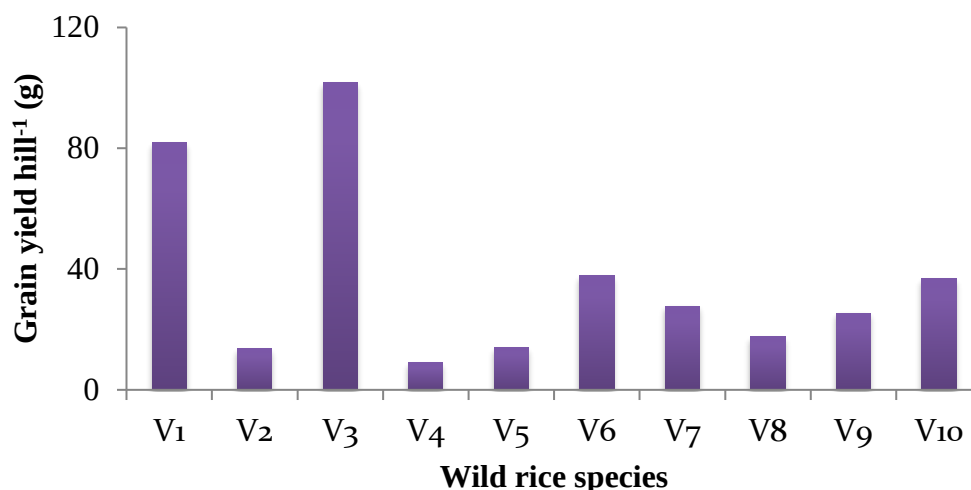
V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

**Figure 4.2.8 Thousand grain weight of wild species of rice (LSD  $_{0.05}=1.70$ )**

#### 4.2.35 Grain yield hill<sup>-1</sup>

The grain yield hill<sup>-1</sup> significantly influenced by different varieties of wild rice (Figure 4.2.9). The results of the investigation revealed that, the maximum grainyield hill<sup>-1</sup> (101.90 g) was distinctly produced by *O. nivara* (V<sub>3</sub>) and the minimum grainyield hill<sup>-1</sup> (9.00 g) was produced by *O. latifolia* (V<sub>4</sub>) which was statistically similar with V<sub>2</sub> and V<sub>5</sub> treatments. *O. nivara* produced 1032.22% more grain than *O. latifolia*. The highest yield of seed might be attributed to maximum yield contributing characters of rice genotypes. To maintain high productivity levels, genetic diversity is essential (Tripathi *et al.*, 2013). There was also a lot of variation in seed production across the twelve coarse rice genotypes (Zahid *et al.*, 2005). Chouhan *et al.* (2014b) reported that grain yield plant<sup>-1</sup> varied from 7.89 to 36.98 g with mean of 23.04 g showed high variability in grain yield plant<sup>-1</sup>. Shrestha *et al.* (2021) reported that that grain yielddranged from 2.45 t ha<sup>-1</sup> (Sunaulo Sugandha) to 5.65 t ha<sup>-1</sup> (NR10676-B-3-3-3). Rice genotypes NR 10676-B-1-3-3-3 (5.65 t ha<sup>-1</sup>) produced the highest yield, followed by NR10410-89-3-2-1-1 (5.54 t ha<sup>-1</sup>). Dangi *et al.* (2017) found that the variety IR 64 being at par with BPT-5204 resulted in significantly highest grain yield (42.98 q ha<sup>-1</sup>) which was 9.07, 11.68, 15.01 and 16.49% higher than that produced by BPT-5204, IET 24780, IET 23824 and Sahbhaghi, respectively. Roy *et al.* (2014a) recorded highest grain yield (3.97 t ha<sup>-1</sup>) from variety BRRI dhan48 and the lowest one (2.58 t ha<sup>-1</sup>) was observed in BRRI dhan42. The results of our investigation are

conformity with the earlier reports of Ghosh and Sharma (2012); Mahajan *et al.* (2012); Worede *et al.* (2014); Kumar *et al.* (2017); Shrestha *et al.* (2021) who concluded that the grain yield of rice varied with species variation.



V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

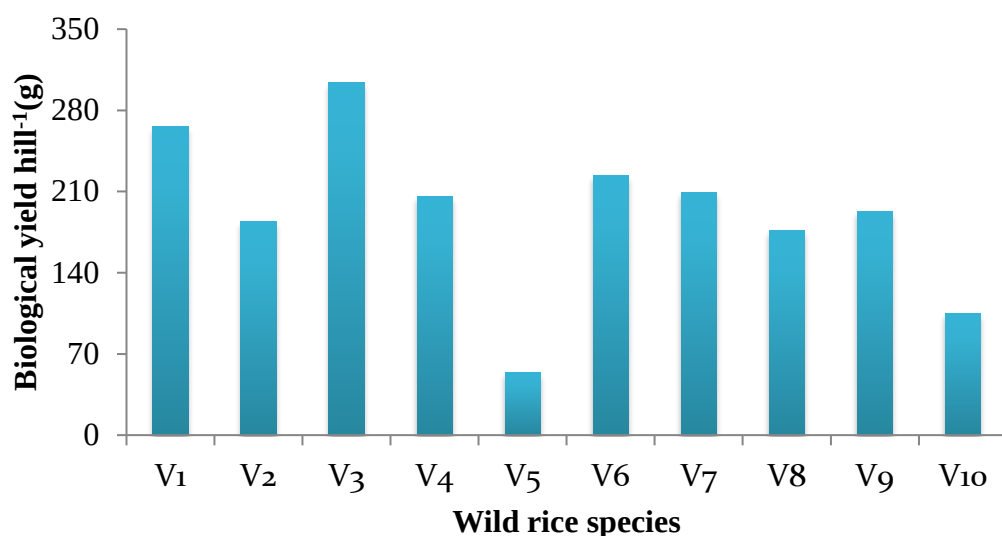
**Figure 4.2.9 Grain yield hill<sup>-1</sup> of wild rice (LSD<sub>0.05</sub>=7.89)**

#### 4.2.36 Biological yield hill<sup>-1</sup>

Different varieties were found significant in respect of biological yield hill<sup>-1</sup> of wild rice (Figure 4.2.10). The result revealed that, the maximum biological yield hill<sup>-1</sup> (303.90 g) was distinctly produced by *O. nivara* (V<sub>3</sub>) and the minimum biological yield hill<sup>-1</sup> (53.92 g) was distinctly produced by *P. coactata* (V<sub>5</sub>). Our results are in harmony with those obtained by Gohain (2014); Singh and Kumar (2014); Tiwari *et al.* (2015); Dangi *et al.* (2017) who reported variable in biological yield among the varieties.

#### 4.2.37 Harvest index

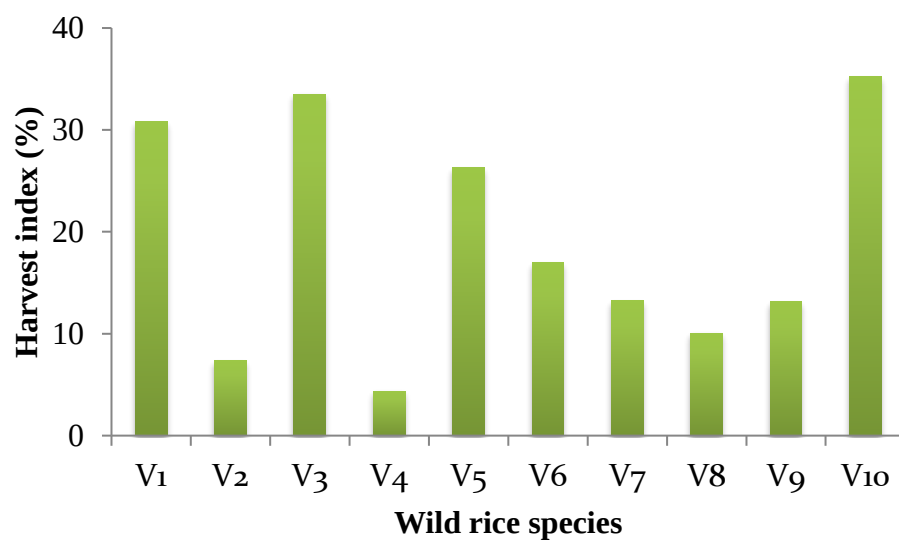
Species variation of wild rice found significant in respect of harvest index (Figure 4.2.11). The data revealed that the maximum harvest index (35.25 %) was recorded from *O. barthii* (V<sub>10</sub>) which was statistically similar with V<sub>3</sub> and the minimum harvest index (4.37 %) was distinctly recorded from *O. latifolia* (V<sub>4</sub>). Ndaeyo *et al.* (2008); Mahajan *et al.* (2012) reported differential ability of partitioning of dry matter and utilization of available nutrients by various varieties of rice which confirm the variations in harvest index.



V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

**Figure 4.2.10 Biological yield hill<sup>-1</sup> of wild species of rice (LSD <sub>0.05</sub>=17.70)**

Kumar *et al.* (2017) Rice variety PAC-837 recorded significantly higher harvest index which were however, statistically at par with DRRH-3. Dangi *et al.* (2017) showed that the variety Chittimuthyalu gave the maximum harvest index (33.80%) followed by Anjali (33.61%), while minimum value (28.94%) observed from IR-64. The result of our present investigation are in agreement with the findings of Rahman *et al.* (2012); Chamely *et al.* (2015); Tiwari *et al.*, (2015); Dangi *et al.* (2017) who reported that harvest index varied due to species variations.



V<sub>1</sub>= *Oryza rufipogon*, V<sub>2</sub>= *O. alta*, V<sub>3</sub>= *O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Poterricia coactata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata* and V<sub>10</sub>= *O. barthii*

**Figure 4.2.11 Harvest index of wild species of rice (LSD<sub>0.05</sub>=2.34)**

### **4.3 Experiment 3: Growth and yield dynamics of selected rice genotypes under drought stress condition**

#### **4.3.1 Plant height**

##### **4.3.1.1 Effect of species**

Plant height of the wild species of rice varied significantly among the rice genotypes (Table 4.3.1). Result revealed that the tallest plant (184.90 cm) was recorded in *O. latifolia* (V<sub>11</sub>) rice genotypes and the shortest plant (84.12 cm) was recorded in *Pottericia coaractata* (V<sub>10</sub>) rice genotype which was statistically similar with V<sub>7</sub>. Similar findings also reported by Zubaer *et al.* (2007) who revealed that the highest plant height was observed in Basmati followed by Binadhan 4 and RD 2585 at all growth stages. Variation in plant height among the genotypes also indicates that different genotypes had different genetic makeup and water requirement.

##### **4.3.1.2 Effect of drought stress**

Plant height of the wild rice did not vary significantly between the drought stress (Table 4.3.1). Numerically the taller plant (134.88 cm) and shorter (130.43 cm) were recorded from D<sub>1</sub> (no drought stress) and D<sub>2</sub> (40-45% field capacity) treatments, respectively. Though plant height was not significantly influenced by drought stress but it reduced plant height to some extent. Growth is accomplished through cell division, cell enlargement and differentiation. The quality and quantity of plant growth depend on these events, which are affected by water deficit in cell growth, one of the most drought-sensitive physiological processes (Taiz and Zeiger, 2006). Plant experiences drought stress either when the water supply to roots becomes difficult or when the transpiration rate becomes very high. It severely impairs growth, development and ultimately the production of rice (Tripathy *et al.*, 2000; Manikavelu *et al.*, 2006). Our findings are not in harmony with those obtained by Sokoto and Muhammad (2014); Fen *et al.* (2015) and Pandey and Shukla (2015) who indicate that plant height decreased with increasing drought stress.

**Table 4.3.1 Effect of species and drought stress on plant height, leaves plant<sup>-1</sup>, nodes plant<sup>-1</sup> and root length of wild species of rice**

| Treatments                      | Plant height (cm) | Leaves plant <sup>-1</sup> (no.) | Nodes plant <sup>-1</sup> (no.) | Root length (cm) |
|---------------------------------|-------------------|----------------------------------|---------------------------------|------------------|
| <b>Effect of species</b>        |                   |                                  |                                 |                  |
| V <sub>1</sub>                  | 158.30 bc         | 5.70 b-d                         | 4.33 bc                         | 28.03 c          |
| V <sub>2</sub>                  | 147.50 d          | 6.13 ab                          | 3.73 d-f                        | 37.38 b          |
| V <sub>3</sub>                  | 119.00 f          | 5.87 bc                          | 4.63 ab                         | 26.95 c          |
| V <sub>4</sub>                  | 121.30 f          | 6.47 a                           | 4.83 a                          | 17.72 e          |
| V <sub>5</sub>                  | 133.40 e          | 5.97 b                           | 4.13 cd                         | 21.90 d          |
| V <sub>6</sub>                  | 122.60 f          | 5.38 de                          | 3.87 de                         | 13.45 f          |
| V <sub>7</sub>                  | 88.98 g           | 5.27 de                          | 3.67 ef                         | 17.60 e          |
| V <sub>8</sub>                  | 150.30 cd         | 5.70 b-d                         | 4.13 cd                         | 17.85 e          |
| V <sub>9</sub>                  | 167.60 b          | 5.32 de                          | 3.33 f                          | 37.20 b          |
| V <sub>10</sub>                 | 84.12 g           | 4.57 f                           | 4.47 a-c                        | 17.63 e          |
| V <sub>11</sub>                 | 184.90 a          | 5.50 c-e                         | 4.35 bc                         | 43.17 a          |
| V <sub>12</sub>                 | 113.80 f          | 5.23 e                           | 4.57 a-c                        | 23.85 d          |
| <b>LSD<sub>(0.05)</sub></b>     | <b>9.85</b>       | <b>0.47</b>                      | <b>0.46</b>                     | <b>2.13</b>      |
| <b>CV (%)</b>                   | <b>6.39</b>       | <b>7.18</b>                      | <b>9.55</b>                     | <b>7.25</b>      |
| <b>Effect of drought stress</b> |                   |                                  |                                 |                  |
| D <sub>1</sub>                  | 134.88            | 5.89 a                           | 4.41 a                          | 26.48 a          |
| D <sub>2</sub>                  | 130.43            | 5.29 b                           | 3.93 b                          | 23.98 b          |
| <b>LSD<sub>(0.05)</sub></b>     | <b>NS</b>         | <b>0.25</b>                      | <b>0.25</b>                     | <b>1.14</b>      |
| <b>CV (%)</b>                   | <b>6.39</b>       | <b>7.18</b>                      | <b>9.55</b>                     | <b>7.25</b>      |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*, D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

#### 4.3.1.3 Interaction effect of species and drought stress

Plant height of the wild rice varied significantly due to the interaction between rice genotypes and drought stress (Table 4.3.2). Result revealed that the tallest plant (185.90 cm) was recorded in V<sub>11</sub>D<sub>1</sub> treatment combination which was statistically similar with V<sub>11</sub>D<sub>2</sub> and the shortest plant (82.97 cm) was recorded in V<sub>10</sub>D<sub>2</sub> treatment combination which was statistically similar with V<sub>7</sub>D<sub>2</sub>, V<sub>10</sub>D<sub>1</sub> and V<sub>7</sub>D<sub>1</sub>. Similar findings were also reported by Zubaer *et al.* (2007) who revealed that the highest plant height (164.0 cm) was observed in the treatment combination of Basmati with 100% FC which is statistically similar to Basmati with 70% FC (160.3 cm) which was followed by the treatment combination Binadhan 4 with 100% FC (152.9). But RD 2585 with 40% FC showed the shortest plant (88.0 cm). Ahmadikhah and Marufinia (2016) also stated the similar opinion.

**Table 4.3.2 Interaction effect of species and drought stress on plant height, leaves plant<sup>-1</sup>, nodes plant<sup>-1</sup> and root length of wild species of rice**

| Treatments                     | Plant height<br>(cm) | Leaves plant <sup>-1</sup><br>(no.) | Nodes plant <sup>-1</sup><br>(no.) | Root length<br>(cm) |
|--------------------------------|----------------------|-------------------------------------|------------------------------------|---------------------|
| V <sub>1</sub> D <sub>1</sub>  | 161.70 b-d           | 6.07 b-f                            | 4.80 b                             | 29.00 d             |
| V <sub>1</sub> D <sub>2</sub>  | 154.90 c-e           | 5.33 h-j                            | 3.87 d-f                           | 27.07 de            |
| V <sub>2</sub> D <sub>1</sub>  | 150.30 de            | 6.60 ab                             | 4.13 c-e                           | 41.10 a             |
| V <sub>2</sub> D <sub>2</sub>  | 144.70 e-g           | 5.67 d-i                            | 3.33 f                             | 33.67 c             |
| V <sub>3</sub> D <sub>1</sub>  | 121.30 h-j           | 6.27 a-d                            | 4.80 b                             | 28.90 d             |
| V <sub>3</sub> D <sub>2</sub>  | 116.70 j             | 5.47 f-j                            | 4.47 b-d                           | 25.00 ef            |
| V <sub>4</sub> D <sub>1</sub>  | 122.90 h-j           | 6.80 a                              | 5.47 a                             | 18.43 h-j           |
| V <sub>4</sub> D <sub>2</sub>  | 119.60 ij            | 6.13 b-e                            | 4.20 b-e                           | 17.00 jk            |
| V <sub>5</sub> D <sub>1</sub>  | 135.10 f-h           | 6.33 a-c                            | 4.60 bc                            | 23.60 f             |
| V <sub>5</sub> D <sub>2</sub>  | 131.70 g-i           | 5.60 e-i                            | 3.67 ef                            | 20.20 g-i           |
| V <sub>6</sub> D <sub>1</sub>  | 125.30 h-j           | 5.67 d-i                            | 4.13 c-e                           | 13.90 l             |
| V <sub>6</sub> D <sub>2</sub>  | 119.90 ij            | 5.10 h-k                            | 3.60 ef                            | 13.00 l             |
| V <sub>7</sub> D <sub>1</sub>  | 93.50 k              | 5.47 f-j                            | 3.60 ef                            | 20.53 gh            |
| V <sub>7</sub> D <sub>2</sub>  | 84.47 k              | 5.07 i-k                            | 3.73 ef                            | 14.67 kl            |
| V <sub>8</sub> D <sub>1</sub>  | 152.20 de            | 6.00 b-g                            | 4.40 b-d                           | 18.23 h-j           |
| V <sub>8</sub> D <sub>2</sub>  | 148.40 d-f           | 5.40 g-j                            | 3.87 d-f                           | 17.47 i-k           |
| V <sub>9</sub> D <sub>1</sub>  | 168.90 b             | 5.53 e-i                            | 3.40 f                             | 37.90 b             |
| V <sub>9</sub> D <sub>2</sub>  | 166.20 bc            | 5.10 h-k                            | 3.27 f                             | 36.50 bc            |
| V <sub>10</sub> D <sub>1</sub> | 85.27 k              | 4.60 k                              | 4.40 b-d                           | 17.80 h-j           |
| V <sub>10</sub> D <sub>2</sub> | 82.97 k              | 4.53 k                              | 4.53 bc                            | 17.47 i-k           |
| V <sub>11</sub> D <sub>1</sub> | 185.90 a             | 5.73 c-h                            | 4.47 b-d                           | 43.80 a             |
| V <sub>11</sub> D <sub>2</sub> | 184.00 a             | 5.27 h-j                            | 4.23 b-e                           | 42.53 a             |
| V <sub>12</sub> D <sub>1</sub> | 116.00 j             | 5.60 e-i                            | 4.73 bc                            | 24.57 ef            |
| V <sub>12</sub> D <sub>2</sub> | 111.70 j             | 4.87 jk                             | 4.40 b-d                           | 23.13 fg            |
| <b>LSD (0.05)</b>              | <b>13.93</b>         | <b>0.66</b>                         | <b>0.66</b>                        | <b>3.01</b>         |
| <b>CV (%)</b>                  | <b>6.39</b>          | <b>7.18</b>                         | <b>9.55</b>                        | <b>7.25</b>         |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*; D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

Plant height decreased under drought stress. The maximum decrease of plant height (9.66%) was counted from FR13A (Check variety as drought tolerant) (V<sub>7</sub>) and the minimum decrease of plant height (1.02%) was counted from wild rice genotype *O. latifolia* (V<sub>11</sub>) (Table 4.3.3).

**Table 4.3.3 Plant height of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 161.70                           | 154.90                | 4.21                         |
| V <sub>2</sub>  | 150.30                           | 144.70                | 3.73                         |
| V <sub>3</sub>  | 121.30                           | 116.70                | 3.79                         |
| V <sub>4</sub>  | 122.90                           | 119.60                | 2.69                         |
| V <sub>5</sub>  | 135.10                           | 131.70                | 2.52                         |
| V <sub>6</sub>  | 125.30                           | 119.90                | 4.31                         |
| V <sub>7</sub>  | 93.50                            | 84.47                 | 9.66                         |
| V <sub>8</sub>  | 152.20                           | 148.40                | 2.50                         |
| V <sub>9</sub>  | 168.90                           | 166.20                | 1.60                         |
| V <sub>10</sub> | 85.27                            | 82.97                 | 2.70                         |
| V <sub>11</sub> | 185.90                           | 184.00                | 1.02                         |
| V <sub>12</sub> | 116.00                           | 111.70                | 3.71                         |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potiericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

### 4.3.2 Leaves plant<sup>-1</sup>

#### 4.3.2.1 Effect of species

There was a significant variation observed in the leaves plant<sup>-1</sup> due to different wild rice genotypes (Table 4.3.1). Result showed that the maximum leaves plant<sup>-1</sup> (6.47) was observed from *O. barthii* (V<sub>4</sub>) which was statistically similar with *O. punctata* (V<sub>2</sub>) (6.13) and the minimum leaves plant<sup>-1</sup> (4.57) was observed from *P. coaractata* (V<sub>10</sub>). The results of our investigation indicate that different genotypes had different genetic potentiality for leaf production. Zubaer *et al.* (2007) reported that Binadhan 4 produced the highest number of leaves hill<sup>-1</sup> (100.40) followed by Basmati (91.11) and RD 2585 (80.11).

#### 4.3.2.2 Effect of drought stress

There was a significant variation observed in the leaves plant<sup>-1</sup> due to drought stress (Table 4.3.1). Result showed that the higher leaves plant<sup>-1</sup> (5.89) was observed from D<sub>1</sub> treatment and the lower leaves plant<sup>-1</sup> (5.29) was observed from D<sub>2</sub> treatment. Wahid and Rasul (2005); Farooq *et al.* (2009b) reported that a major effect of drought is reduction in photosynthesis, produce less amount of assimilates, which arises by a decrease in leaf expansion, impaired photosynthetic machinery, premature leaf



senescence and associated reduction in leaf production plant<sup>-1</sup>. Pandey and Shukla (2015) explained that the reduction might be due to rapid decline in cell division and leaf elongation under drought stress condition. Schuppler *et al.* (1998) also reported that plants generally limit the number and area of leaves in response to drought stress just to cut down the water budget at the cost of yield loss. The results of our study are in agreement with Farooq *et al.* (2010); Cerqueira *et al.* (2013); Sokoto and Muhammad (2014); Pandey and Shukla (2015) who reported that Water stress resulted in production of lower number of leaves.

#### **4.3.2.3 Interaction effect of species and drought stress**

There was a significant variation observed in the leaves plant<sup>-1</sup> due to the interaction of rice genotypes and drought stress (Table 4.3.2). Result showed that the maximum leaves plant<sup>-1</sup> (6.80) was observed from V<sub>4</sub>D<sub>1</sub> treatment combination which was statistically similar with V<sub>2</sub>D<sub>1</sub>, V<sub>5</sub>D<sub>1</sub> and V<sub>3</sub>D<sub>1</sub> and the minimum leaves plant<sup>-1</sup> (4.53) was observed from V<sub>10</sub>D<sub>2</sub> treatment combination which was statistically similar with V<sub>10</sub>D<sub>1</sub>, V<sub>12</sub>D<sub>2</sub>, V<sub>7</sub>D<sub>2</sub>, V<sub>9</sub>D<sub>2</sub> and V<sub>6</sub>D<sub>2</sub>. Similar findings also reported by Zubaer *et al.* (2007) who revealed the treatment combination Binadhan 4 with 100 %FC produced the highest number of leaves per hill and the RD 12585 with 40% FC produced the lowest number.

The maximum decrease of leaves plant<sup>-1</sup> (14.14%) was counted from wild rice genotype *O. punctata* (V<sub>2</sub>) and the minimum decrease of leaves plant<sup>-1</sup> (1.46%) was counted from wild rice genotype *Potericia coaractata* (V<sub>10</sub>) (Table 4.3.4).

#### **4.3.3 Nodes plant<sup>-1</sup>**

##### **4.3.3.1 Effect of species**

Significant difference on nodes plant<sup>-1</sup> in the rice species was observed due to species difference (Table 4.3.1). The highest nodes plant<sup>-1</sup> (4.83) was obtained from *O. barthii* (V<sub>4</sub>) which was statistically similar with V<sub>3</sub>, V<sub>10</sub> and V<sub>12</sub> whereas the lowest nodes plant<sup>-1</sup> (3.33) was obtained from *O. alta* (V<sub>9</sub>) which was statistically similar with V<sub>7</sub> and V<sub>2</sub>.

**Table 4.3.4 Leaves plant<sup>-1</sup> of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 6.07                             | 5.33                  | 12.10                        |
| V <sub>2</sub>  | 6.60                             | 5.67                  | 14.14                        |
| V <sub>3</sub>  | 6.27                             | 5.47                  | 12.77                        |
| V <sub>4</sub>  | 6.80                             | 6.13                  | 9.81                         |
| V <sub>5</sub>  | 6.33                             | 5.60                  | 11.57                        |
| V <sub>6</sub>  | 5.67                             | 5.10                  | 10.01                        |
| V <sub>7</sub>  | 5.47                             | 5.07                  | 7.32                         |
| V <sub>8</sub>  | 6.00                             | 5.40                  | 10.00                        |
| V <sub>9</sub>  | 5.53                             | 5.10                  | 7.83                         |
| V <sub>10</sub> | 4.60                             | 4.53                  | 1.46                         |
| V <sub>11</sub> | 5.73                             | 5.27                  | 8.13                         |
| V <sub>12</sub> | 5.60                             | 4.87                  | 13.09                        |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potiericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### 4.3.3.2 Effect of drought stress

Significant difference on nodes plant<sup>-1</sup> in the rice species was observed due to drought stress variation (Table 4.4.1). The higher nodes plant<sup>-1</sup> (4.41) was obtained from D<sub>1</sub> whereas the lower nodes plant<sup>-1</sup> (3.93) was obtained from D<sub>2</sub> treatment.

#### 4.3.3.3 Interaction effect of species and drought stress

Significant difference on nodes plant<sup>-1</sup> in the rice species was observed due to the interaction of species and drought stress (Table 4.3.2). The highest nodes plant<sup>-1</sup> (5.47) was obtained from V<sub>4</sub>D<sub>1</sub> followed by V<sub>1</sub>D<sub>1</sub> (4.80) and V<sub>3</sub>D<sub>1</sub> (4.80) whereas the lowest nodes plant<sup>-1</sup> (3.27) was obtained from V<sub>9</sub>D<sub>2</sub> which was statistically similar with V<sub>9</sub>D<sub>1</sub>, V<sub>7</sub>D<sub>2</sub>, V<sub>7</sub>D<sub>1</sub>, V<sub>6</sub>D<sub>2</sub>, V<sub>5</sub>D<sub>2</sub>, V<sub>8</sub>D<sub>2</sub>, V<sub>2</sub>D<sub>2</sub> and V<sub>1</sub>D<sub>2</sub>.

The maximum decrease of nodes plant<sup>-1</sup> (23.18%) was counted from wild rice genotype *O. barthii* (V<sub>4</sub>) and the increase of nodes plant<sup>-1</sup> (3.69%) was counted from rice genotype FR13A (Check variety as drought tolerant) (V<sub>7</sub>) (Table 4.3.5).

**Table 4.3.5 Nodes plant<sup>-1</sup> of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease (%) |
|-----------------|----------------------------------|-----------------------|--------------|
| V <sub>1</sub>  | 4.80                             | 3.87                  | 19.44        |
| V <sub>2</sub>  | 4.13                             | 3.33                  | 19.36        |
| V <sub>3</sub>  | 4.80                             | 4.47                  | 6.94         |
| V <sub>4</sub>  | 5.47                             | 4.20                  | 23.18        |
| V <sub>5</sub>  | 4.60                             | 3.67                  | 20.28        |
| V <sub>6</sub>  | 4.13                             | 3.60                  | 12.90        |
| V <sub>7</sub>  | 3.60                             | 3.73                  | -3.69        |
| V <sub>8</sub>  | 4.40                             | 3.87                  | 12.11        |
| V <sub>9</sub>  | 3.40                             | 3.27                  | 3.91         |
| V <sub>10</sub> | 4.40                             | 4.53                  | -3.02        |
| V <sub>11</sub> | 4.47                             | 4.23                  | 5.24         |
| V <sub>12</sub> | 4.73                             | 4.40                  | 7.04         |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### 4.3.4 Root length

##### 4.3.4.1 Effect of species

Root length was significantly varied due to species variation of wild rice genotypes (Table 4.3.1). Result showed that the longest root (43.17 cm) was found from *O. latifolia* (V<sub>11</sub>) and the shortest one (13.45 cm) was found from *O. glaberrima* (V<sub>6</sub>). Saha *et al.* (2019) reported that drought stress decreased the length of root in BRRI dhan-30, BRRI dhan-32, BRRI dhan-34, BRRI dhan-38 and BRRI dhan-56 by 45.71, 41.94, 33.73, 31.59 and 23.98%, respectively at 10 days of treatment whereas BRRI Dhan-56 showed the least decrease of root length under stress. Bhavyasree *et al.* (2019) revealed that the maximum root length was observed in *O. barthii* (19.5 cm) followed by *O. glumaepatula* (18.9 cm) in drought stress conditions. Minimum decrease in root length was observed in *O. nivara*. The wild *Oryza* species are having the capacity to withstand several stresses especially the water stress as an adaptation to the extreme environments they grow Vaughan *et al.* (2008). Bhavyasree *et al.* (2019); Upadhyaya and Panda (2019) also reported that cultivated accessions showed more susceptibility compared to the wild accessions in the context of growth parameter of rice and wild accessions showing a better adaptability under water stress than cultivated ones. The presence of drought resistance in *O. rufipogon* and *O.*

*officinalis* accessions were also reported by Feng *et al.* (2012) by assessing morphological and physiological traits related to drought tolerance. He observed stronger drought resistance in *O. officinalis* accessions as in their study; along with higher root mass in deeper soil levels were also observed under water deficit among *O. rufipogon* and *O. longistaminata* accessions as compared with *O. sativa* by Liu *et al.* (2004). The results of our investigation are in agreement with Khan *et al.* (2001); Shaibu (2018); Kang and Futakuchi (2019) who clarified that under drought stress the root length of rice genotypes is decreased with varied extent.

#### **4.3.4.2 Effect of drought stress**

Root length of wild rice was significantly varied due to drought stress (Table 4.3.1). Result showed that the longer root (26.48 cm) was found from D<sub>1</sub> and the shorter one (23.98 cm) was found from D<sub>2</sub>. Blum (2011); Pandey and Shukla (2015) reported that under drought stress plant growth and development reduces as a consequence of poor root development, with reduced leaf-surface traits (form, shape, composition of cuticular wax, leaf pubescence and leaf color), which affect the radiation load on the leaf canopy, delay in or reduced rate of normal plant senescence as it approaches maturity, and inhibition of stem reserves. Drought tolerance is a complex trait governed by many physiological and biochemical properties of plants. Genotypes that have deep, coarse roots with a high ability of branching and penetration, higher root-to-shoot ratio is reported as one of the important component trait of drought avoidance (Wang and Yamauchi, 2006 and Kavar *et al.*, 2007). Farooq *et al.* (2009b) and Kavar *et al.* (2007) explained that since roots are the only source to acquire water from soil, the root growth, its density, proliferation and size are key responses of plants to drought stress. Roots are the key plant organ for adaptation to drought. If tolerance is defined as the ability to maintain leaf area and growth under prolonged vegetative stage stress, the main basis of variation appears to be constitutive root system architecture that allows the maintenance of more favorable plant water status (Nguyen *et al.*, 1997). Hoogenboom *et al.* (1987); Saha *et al.* (2019) reported that root length is an important trait of plant varieties in the drought stress condition and roots play an important role in plant survival during periods of drought. In general, species with the presence of more secondary root mass in the deeper soil zone suggesting absorption of more water or moisture and thus helping them to withstand under water stress condition (Leishman and Westoby, 1994; Kavar *et al.*, 2007; Kijoji *et al.*,

2013). Siaga *et al.* (2018) emphasized that heavily branching roots with high surface area in limited rhizosphere are needed to maximize water uptake. Fine root as branched from coarse root also increases hydraulic conductance of plant by increasing surface area and volume of root contact with soil water, increasing root hydraulic conductivity by reducing apoplastic barrier of water absorption (Comas *et al.*, 2013). The results of our experiment are similar to the results of Neelam *et al.* (2018); Saha *et al.* (2019); Kartika *et al.* (2020) who reported that under drought stress long root system might be helpful for attaining proper growth and development of rice genotypes.

#### **4.3.4.3 Interaction effect of species and drought stress**

Root length of wild rice was significantly varied due to the interaction of wild rice genotypes and drought stress (Table 4.3.2). Result showed that the longest root (43.80 cm) was found from V<sub>11</sub>D<sub>1</sub> which was statistically at par with V<sub>11</sub>D<sub>2</sub> and V<sub>2</sub>D<sub>1</sub> and the shortest one (13.00 cm) was found from V<sub>6</sub>D<sub>2</sub> which was statistically at par only with V<sub>6</sub>D<sub>1</sub>.

The maximum decrease of root length (28.54%) was counted from rice genotype FR13A (Check variety as drought tolerant) (V<sub>7</sub>) and the minimum decrease of root length (1.85%) was counted from wildrice genotype *Potrericia coaractata* (V<sub>10</sub>) (Table 4.3.6).

#### **4.3.5 Normal leaf length**

##### **4.3.5.1 Effect of species**

Significant difference on normal leaf length in the studied wild rice was observed due to species variation (Table 4.3.7). The result of our investigation revealed that the longest normal leaf (51.88 cm) was achieved from *O. latifolia* (V<sub>11</sub>) and the shortest normal leaf (8.87 cm) was achieved from *P. coaractata* (V<sub>10</sub>).

##### **4.3.5.2 Effect of drought stress**

Significant difference on normal leaf length in the studied wild rice was observed due to drought stress (Table 4.3.7). The result of our investigation revealed that the longer normal leaf (23.02 cm) was achieved from D<sub>1</sub> and the shorter normal leaf (21.39 cm)

was achieved from D<sub>2</sub> treatment. Our findings are consistent with those of Blum (2011); Pandey and Shukla (2015) who reported that drought stress reduce the leaf length.

**Table 4.3.6 Root length of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 29.00                            | 27.07                 | 6.66                         |
| V <sub>2</sub>  | 41.10                            | 33.67                 | 18.08                        |
| V <sub>3</sub>  | 28.90                            | 25.00                 | 13.49                        |
| V <sub>4</sub>  | 18.43                            | 17.00                 | 7.76                         |
| V <sub>5</sub>  | 23.60                            | 20.20                 | 14.41                        |
| V <sub>6</sub>  | 13.90                            | 13.00                 | 6.47                         |
| V <sub>7</sub>  | 20.53                            | 14.67                 | 28.54                        |
| V <sub>8</sub>  | 18.23                            | 17.47                 | 4.17                         |
| V <sub>9</sub>  | 37.90                            | 36.50                 | 3.69                         |
| V <sub>10</sub> | 17.80                            | 17.47                 | 1.85                         |
| V <sub>11</sub> | 43.80                            | 42.53                 | 2.90                         |
| V <sub>12</sub> | 24.57                            | 23.13                 | 5.86                         |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### 4.3.5.3 Interaction effect of species and drought stress

Significant difference on normal leaf length in the studied wild rice interaction with drought stress (Table 4.3.8). The result of our investigation revealed that the longest normal leaf (52.61 cm) was achieved from V<sub>11</sub>D<sub>1</sub> which was statistically at par only with V<sub>11</sub>D<sub>2</sub> and the shortest normal leaf (8.77 cm) was achieved from V<sub>10</sub>D<sub>2</sub> which was statistically at par only with V<sub>10</sub>D<sub>1</sub>.

The maximum decrease of normal leaf length (23.89%) was counted from wild rice genotype *O. punctata* (V<sub>2</sub>) and the minimum decrease of normal leaf length (2.17%) was counted from rice genotype FR13A (Check variety as drought tolerant) (V<sub>7</sub>) (Table 4.3.9).

**Table 4.3.7 Effect of species and drought stress on normal leaf characteristics of wild species of rice**

| Treatments                      | Normal leaf length (cm) | Normal leaf breadth (cm) | Normal leaf length breadth ratio | Normal leaf area (cm <sup>2</sup> ) |
|---------------------------------|-------------------------|--------------------------|----------------------------------|-------------------------------------|
| <b>Effect of species</b>        |                         |                          |                                  |                                     |
| V <sub>1</sub>                  | 18.73 de                | 1.39 f                   | 13.46 e                          | 21.51 e                             |
| V <sub>2</sub>                  | 18.72 de                | 2.51 b                   | 7.45 h                           | 34.43 c                             |
| V <sub>3</sub>                  | 19.03 d                 | 1.45 f                   | 13.15 e                          | 22.83 e                             |
| V <sub>4</sub>                  | 23.34 c                 | 1.52 ef                  | 15.40 d                          | 32.95 c                             |
| V <sub>5</sub>                  | 26.86 b                 | 1.59 de                  | 16.95 c                          | 35.44 c                             |
| V <sub>6</sub>                  | 27.14 b                 | 1.47 ef                  | 18.56 b                          | 36.13 c                             |
| V <sub>7</sub>                  | 16.88 e                 | 1.77 c                   | 9.62 g                           | 21.52 e                             |
| V <sub>8</sub>                  | 19.49 d                 | 1.67 cd                  | 11.61 f                          | 28.41 d                             |
| V <sub>9</sub>                  | 18.61 de                | 3.34 a                   | 5.57 i                           | 43.50 b                             |
| V <sub>10</sub>                 | 8.87 f                  | 0.65 g                   | 13.70 e                          | 5.55 f                              |
| V <sub>11</sub>                 | 51.88 a                 | 2.52 b                   | 20.76 a                          | 99.23 a                             |
| V <sub>12</sub>                 | 16.89 e                 | 1.72 cd                  | 9.85 g                           | 25.63 de                            |
| <b>LSD<sub>(0.05)</sub></b>     | <b>1.87</b>             | <b>0.14</b>              | <b>1.36</b>                      | <b>4.42</b>                         |
| <b>CV (%)</b>                   | <b>7.24</b>             | <b>6.46</b>              | <b>8.98</b>                      | <b>11.21</b>                        |
| <b>Effect of drought stress</b> |                         |                          |                                  |                                     |
| D <sub>1</sub>                  | 23.02 a                 | 1.87 a                   | 12.94                            | 35.56 a                             |
| D <sub>2</sub>                  | 21.39 b                 | 1.73 b                   | 13.07                            | 32.30 b                             |
| <b>LSD<sub>(0.05)</sub></b>     | <b>1.00</b>             | <b>0.07</b>              | <b>NS</b>                        | <b>2.36</b>                         |
| <b>CV (%)</b>                   | <b>7.24</b>             | <b>6.46</b>              | <b>8.98</b>                      | <b>11.21</b>                        |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*; D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

### 4.3.6 Normal leaf breadth

#### 4.3.6.1 Effect of species

Wild rice genotypes imposed significant variation on normal leaf breadth (Table 4.3.7). The widest normal leaf (3.34 cm) was distinctly produced by *O. alta* (V<sub>9</sub>) and the narrowest normal leaf (0.65 cm) was distinctly produced by *P. coaractata* (V<sub>10</sub>).

#### 4.3.6.2 Effect of drought stress

Drought stress imposed significant variation on normal leaf breadth (Table 4.3.7). The wider normal leaf (1.87 cm) was produced by D<sub>1</sub> and the narrower normal leaf (1.73 cm) was produced by D<sub>2</sub>. Our results are in harmony with those obtained by Blum

(2011); Pandey and Shukla (2015) who reported that drought stress narrower the leaf size of rice.

**Table 4.3.8 Interaction effect of species and drought stress on normal leaf characteristics of wild species of rice**

| Treatments                     | Normal leaf length (cm) | Normal leaf breadth (cm) | Normal leaf length breadth ratio | Normal leaf area (cm <sup>2</sup> ) |
|--------------------------------|-------------------------|--------------------------|----------------------------------|-------------------------------------|
| V <sub>1</sub> D <sub>1</sub>  | 20.47 e-g               | 1.39 i                   | 14.59 f-h                        | 22.87 hi                            |
| V <sub>1</sub> D <sub>2</sub>  | 16.98 h-j               | 1.38 i                   | 12.33 ij                         | 20.16 i                             |
| V <sub>2</sub> D <sub>1</sub>  | 21.26 ef                | 2.59 bc                  | 8.18 no                          | 38.95 c                             |
| V <sub>2</sub> D <sub>2</sub>  | 16.18 j                 | 2.42 cd                  | 6.71 op                          | 29.90 e-g                           |
| V <sub>3</sub> D <sub>1</sub>  | 19.62 f-h               | 1.50 g-i                 | 13.04 h-j                        | 24.66 g-i                           |
| V <sub>3</sub> D <sub>2</sub>  | 18.45 g-j               | 1.39 i                   | 13.26 hi                         | 20.99 i                             |
| V <sub>4</sub> D <sub>1</sub>  | 24.15 cd                | 1.55 g-i                 | 15.57 d-f                        | 35.35 c-e                           |
| V <sub>4</sub> D <sub>2</sub>  | 22.54 de                | 1.48 hi                  | 15.23 e-g                        | 30.55 d-g                           |
| V <sub>5</sub> D <sub>1</sub>  | 27.29 b                 | 1.65 f-h                 | 16.54 c-e                        | 36.74 cd                            |
| V <sub>5</sub> D <sub>2</sub>  | 26.43 bc                | 1.52 g-i                 | 17.36 b-d                        | 34.15 c-f                           |
| V <sub>6</sub> D <sub>1</sub>  | 27.90 b                 | 1.52 g-i                 | 18.38 bc                         | 36.63 cd                            |
| V <sub>6</sub> D <sub>2</sub>  | 26.38 bc                | 1.41 i                   | 18.75 b                          | 35.64 c-e                           |
| V <sub>7</sub> D <sub>1</sub>  | 17.07 h-j               | 1.91 e                   | 8.93 mn                          | 22.72 hi                            |
| V <sub>7</sub> D <sub>2</sub>  | 16.70 ij                | 1.63 gh                  | 10.31 k-m                        | 20.32 i                             |
| V <sub>8</sub> D <sub>1</sub>  | 20.36 e-g               | 1.69 fg                  | 12.03 i-k                        | 28.71 f-h                           |
| V <sub>8</sub> D <sub>2</sub>  | 18.62 f-j               | 1.65 f-h                 | 11.18 j-l                        | 28.11 f-h                           |
| V <sub>9</sub> D <sub>1</sub>  | 19.10 f-i               | 3.33 a                   | 5.74 p                           | 47.28 b                             |
| V <sub>9</sub> D <sub>2</sub>  | 18.13 g-j               | 3.36 a                   | 5.39 p                           | 39.71 c                             |
| V <sub>10</sub> D <sub>1</sub> | 8.963 k                 | 0.67 j                   | 13.65 g-i                        | 5.58 j                              |
| V <sub>10</sub> D <sub>2</sub> | 8.767 k                 | 0.64 j                   | 13.75 f-i                        | 5.51 j                              |
| V <sub>11</sub> D <sub>1</sub> | 52.61 a                 | 2.76 b                   | 19.05 b                          | 101.0 a                             |
| V <sub>11</sub> D <sub>2</sub> | 51.16 a                 | 2.28 d                   | 22.47 a                          | 97.44 a                             |
| V <sub>12</sub> D <sub>1</sub> | 17.49 h-j               | 1.83 ef                  | 9.55 l-n                         | 26.18 g-i                           |
| V <sub>12</sub> D <sub>2</sub> | 16.29 j                 | 1.61 gh                  | 10.14 k-m                        | 25.08 g-i                           |
| <b>LSD<sub>(0.05)</sub></b>    | <b>2.64</b>             | <b>0.19</b>              | <b>1.92</b>                      | <b>6.25</b>                         |
| <b>CV (%)</b>                  | <b>7.24</b>             | <b>6.46</b>              | <b>8.98</b>                      | <b>11.21</b>                        |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coarctata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*; D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

#### 4.3.6.3 Interaction effect of species and drought stress

Interaction of wild rice genotypes and drought stress imposed significant variation on normal leaf breadth (Table 4.3.8). The widest normal leaf (3.36 cm) was produced by V<sub>9</sub>D<sub>2</sub> which was statistically similar with V<sub>9</sub>D<sub>1</sub> and the narrowest normal leaf (0.64 cm) was produced by V<sub>10</sub>D<sub>2</sub> which was statistically similar with V<sub>10</sub>D<sub>1</sub>.



**Table 4.3.9 Normal leaf length of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 20.47                            | 16.98                 | 17.05                        |
| V <sub>2</sub>  | 21.26                            | 16.18                 | 23.89                        |
| V <sub>3</sub>  | 19.62                            | 18.45                 | 5.96                         |
| V <sub>4</sub>  | 24.15                            | 22.54                 | 6.67                         |
| V <sub>5</sub>  | 27.29                            | 26.43                 | 3.15                         |
| V <sub>6</sub>  | 27.90                            | 26.38                 | 5.45                         |
| V <sub>7</sub>  | 17.07                            | 16.70                 | 2.17                         |
| V <sub>8</sub>  | 20.36                            | 18.62                 | 8.55                         |
| V <sub>9</sub>  | 19.10                            | 18.13                 | 5.08                         |
| V <sub>10</sub> | 8.96                             | 8.77                  | 2.19                         |
| V <sub>11</sub> | 52.61                            | 51.16                 | 2.76                         |
| V <sub>12</sub> | 17.49                            | 16.29                 | 6.86                         |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

The maximum decrease of normal leaf breadth (17.50%) was counted from wild rice genotype *O. latifolia* (V<sub>11</sub>) and the increase of normal leaf breadth (0.99%) was counted from wild rice genotype *O. alta* (V<sub>9</sub>) (Table 4.3.10).

**Table 4.3.10 Normal leaf breadth of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease (%) |
|-----------------|----------------------------------|-----------------------|--------------|
| V <sub>1</sub>  | 1.39                             | 1.38                  | 1.15         |
| V <sub>2</sub>  | 2.59                             | 2.42                  | 6.67         |
| V <sub>3</sub>  | 1.50                             | 1.39                  | 7.52         |
| V <sub>4</sub>  | 1.55                             | 1.48                  | 4.52         |
| V <sub>5</sub>  | 1.65                             | 1.52                  | 7.70         |
| V <sub>6</sub>  | 1.52                             | 1.41                  | 7.42         |
| V <sub>7</sub>  | 1.91                             | 1.63                  | 14.66        |
| V <sub>8</sub>  | 1.69                             | 1.65                  | 2.54         |
| V <sub>9</sub>  | 3.33                             | 3.36                  | -0.99        |
| V <sub>10</sub> | 0.67                             | 0.64                  | 4.50         |
| V <sub>11</sub> | 2.76                             | 2.28                  | 17.50        |
| V <sub>12</sub> | 1.83                             | 1.61                  | 12.17        |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

### **4.3.7 Normal leaf length breadth ratio**

#### **4.3.7.1 Effect of species**

Normal leaf length breadth ratio of wild rice was varied significantly due to species difference (Table 4.3.7). The maximum normal leaf length breadth ratio (20.76) was scored by *O. latifolia* (V<sub>11</sub>) and the minimum normal leaf length breadth ratio (7.45) was scored by *O. punctata* (V<sub>2</sub>).

#### **4.3.7.2 Effect of drought stress**

Normal leaf length breadth ratio of wild rice was not varied significantly due to drought stress (Table 4.3.7). Numerically the higher normal leaf length breadth ratio (13.07) was scored by D<sub>2</sub> and the lower normal leaf length breadth ratio (12.94) was scored by D<sub>1</sub>.

#### **4.3.7.3 Interaction effect of species and drought stress**

Normal leaf length breadth ratio of wild rice was varied significantly due to the interaction effect of species and drought stress (Table 4.3.8). The maximum normal leaf length breadth ratio (22.47) was scored by V<sub>11</sub>D<sub>2</sub> and the minimum normal leaf length breadth ratio (5.39) was scored by V<sub>9</sub>D<sub>2</sub> which was close related with V<sub>9</sub>D<sub>1</sub> and V<sub>2</sub>D<sub>2</sub>.

The maximum decrease of normal leaf ratio (17.96%) was observed from wild rice genotype *O. punctata* (V<sub>2</sub>) and the increase of normal leaf ratio (17.95%) was observed from wild rice genotype *O. latifolia* (V<sub>11</sub>) (Table 4.3.11).

### **4.3.8 Normal leaf area**

#### **4.3.8.1 Effect of species**

Wild rice species had significant influence on normal leaf area (Table 4.3.7). The result revealed that the maximum normal leaf area (99.23 cm<sup>2</sup>) was achieved by *O. latifolia* (V<sub>11</sub>) and the minimum normal leaf area (5.55 cm<sup>2</sup>) was achieved by *P. coaractata* (V<sub>10</sub>).

**Table 4.3.11 Normal leaf length breadth ratio of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 14.59                            | 12.33                 | 15.49                        |
| V <sub>2</sub>  | 8.18                             | 6.71                  | 17.96                        |
| V <sub>3</sub>  | 13.04                            | 13.26                 | -1.69                        |
| V <sub>4</sub>  | 15.57                            | 15.23                 | 2.18                         |
| V <sub>5</sub>  | 16.54                            | 17.36                 | -4.96                        |
| V <sub>6</sub>  | 18.38                            | 18.75                 | -2.01                        |
| V <sub>7</sub>  | 8.93                             | 10.31                 | -15.41                       |
| V <sub>8</sub>  | 12.03                            | 11.18                 | 7.07                         |
| V <sub>9</sub>  | 5.74                             | 5.39                  | 6.09                         |
| V <sub>10</sub> | 13.65                            | 13.75                 | -0.73                        |
| V <sub>11</sub> | 19.05                            | 22.47                 | -17.95                       |
| V <sub>12</sub> | 9.55                             | 10.14                 | -6.14                        |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### 4.3.8.2 Effect of drought stress

Drought stress had significant influence on normal leaf area (Table 4.3.7). The result revealed that the maximum normal leaf area (35.56 cm<sup>2</sup>) was achieved by D<sub>1</sub> and the minimum normal leaf area (32.30 cm<sup>2</sup>) was achieved by D<sub>2</sub>. Farooq *et al.* (2009b); Kumar *et al.* (2014a); Fen *et al.* (2015); Pandey and Shukla (2015) described that drought stress reduce turgor pressure in the cell, inhibited water flow through the xylem to the surrounding elongating cells, impaired mitosis, cell division of meristematic tissue, cell elongation and expansion ultimately caused reduction in leaf area of rice plant (Nonami, 1998; Kaya *et al.*, 2006; Hussain *et al.*, 2008; Farooq *et al.*, 2009b). The results of our experiment are in agreement with Zubaer *et al.* (2007); Farooq *et al.* (2009b); Pandey and Shukla (2015).

#### 4.3.8.3 Interaction effect of species and drought stress

Interaction of wild rice species and drought stress had significant influence on normal leaf area (Table 4.3.8). The result revealed that the maximum normal leaf area (101.00 cm<sup>2</sup>) was achieved by V<sub>11</sub>D<sub>1</sub> which was statistically similar with V<sub>11</sub>D<sub>2</sub> and the minimum normal leaf area (5.51 cm<sup>2</sup>) was achieved by V<sub>10</sub>D<sub>2</sub> which was statistically similar with V<sub>10</sub>D<sub>1</sub>. Our results are also supported by Zubaer *et al.* (2007)

who reported that the highest leaf area was found at 100% FC in all the rice genotypes. The leaf area was reduced with the reduction of moisture levels but the degree reduction was higher in Basmati (14.7 for 70%FC and 53.2% for 40%FC) cm. RD 2585 than in Bina dhan 4 (5.6% for 70%FC and 43.4% for 40% FC).

The maximum decrease of normal leaf area (23.23%) was observed from wild rice genotype *O. punctata* (V<sub>2</sub>) and the minimum decrease of normal leaf area (1.31%) was observed from wild rice genotype *Potericia coaractata* (V<sub>10</sub>) (Table 4.3.12).

**Table 4.3.12 Normal leaf area of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity (Control) | 40-45% field capacity | Decrease over control (%) |
|-----------------|-------------------------------|-----------------------|---------------------------|
| V <sub>1</sub>  | 22.87                         | 20.16                 | 11.85                     |
| V <sub>2</sub>  | 38.95                         | 29.90                 | 23.23                     |
| V <sub>3</sub>  | 24.66                         | 20.99                 | 14.88                     |
| V <sub>4</sub>  | 35.35                         | 30.55                 | 13.58                     |
| V <sub>5</sub>  | 36.74                         | 34.15                 | 7.05                      |
| V <sub>6</sub>  | 36.63                         | 35.64                 | 2.70                      |
| V <sub>7</sub>  | 22.72                         | 20.32                 | 10.56                     |
| V <sub>8</sub>  | 28.71                         | 28.11                 | 2.09                      |
| V <sub>9</sub>  | 47.28                         | 39.71                 | 16.01                     |
| V <sub>10</sub> | 5.58                          | 5.51                  | 1.31                      |
| V <sub>11</sub> | 101.00                        | 97.44                 | 3.52                      |
| V <sub>12</sub> | 26.18                         | 25.08                 | 4.20                      |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

### 4.3.9 Flag leaf length

#### 4.3.9.1 Effect of species

Significant variation on flag leaf length in the studied wild rice was observed due to species variation (Table 4.3.13). The result of our experiment showed that the longest flag leaf (42.97 cm) was achieved from *O. latifolia* (V<sub>11</sub>) and the shortest flag leaf (7.19 cm) was achieved from *P. coaractata* (V<sub>10</sub>).

#### 4.3.9.2 Effect of drought stress

Significant variation on flag leaf length in the studied wild rice was observed due to drought stress (Table 4.3.13). The result of our experiment showed that the longer flag leaf (14.90 cm) was achieved from D<sub>1</sub> and the shorter flag leaf (13.77 cm) was achieved from D<sub>2</sub> treatment. The importance of flag leaf in grain filling is well recognized. For grain filling under drought, either a relatively uncompromised or a favorably reprogrammed function of flag leaf is required to maintain synthesis and transport of photo assimilates (Biswal and Kohli, 2013). But under drought stress the flag leaf along with other leaves become reduce because drought stress reduce turgor pressure in the cell, retard water uptake, impaired cell division, elongation and expansion consequently reduce the flag leaf size (Kaya *et al.*, 2006; Hussain *et al.*, 2008). Schuppler *et al.* (1998) also reported that plants generally limit the area of leaves in response to drought stress just to cut down the water budget at the cost of yield loss. The results of our experiment are in agreement with Zubaer *et al.* (2007); Farooq *et al.* (2009b); Pandey and Shukla (2015).

#### 4.3.9.3 Interaction effect of species and drought stress

Significant variation on flag leaf length in the studied wild rice was observed due to the interaction of species variation and drought stress (Table 4.3.14). The result of our experiment showed that the longest flag leaf (44.00 cm) was achieved from V<sub>11</sub>D<sub>1</sub> and the shortest flag leaf (6.95 cm) was achieved from V<sub>10</sub>D<sub>2</sub> which was statistically at par with V<sub>10</sub>D<sub>1</sub> and V<sub>12</sub>D<sub>2</sub>.

The maximum decrease of flag leaf length (19.03%) was recorded from wild rice genotype *O. rufipogon* (V<sub>1</sub>) and the increase of flag leaf length (5.02%) was recorded from rice genotype FR13A (Check variety as drought tolerant) (V<sub>7</sub>) (Table 4.3.15).

**Table 4.3.13 Effect of species and drought stress on flag leaf characteristics of wild species of rice**

| Treatments                      | Flag leaf length (cm) | Flag leaf breadth (cm) | Flag leaf length breadth ratio | Flag leaf area (cm <sup>2</sup> ) |
|---------------------------------|-----------------------|------------------------|--------------------------------|-----------------------------------|
| <b>Effect of species</b>        |                       |                        |                                |                                   |
| V <sub>1</sub>                  | 13.60 bc              | 1.64 e                 | 8.28 d                         | 17.89 e                           |
| V <sub>2</sub>                  | 11.94 d               | 2.04 d                 | 5.85 f                         | 19.36 de                          |
| V <sub>3</sub>                  | 9.73 e                | 1.39 f                 | 7.03 e                         | 12.96 f                           |
| V <sub>4</sub>                  | 11.63 d               | 1.29 f                 | 9.05 c                         | 17.92 e                           |
| V <sub>5</sub>                  | 13.48 bc              | 2.34 c                 | 5.78 f                         | 22.97 c                           |
| V <sub>6</sub>                  | 12.41 cd              | 1.65 e                 | 7.53 e                         | 19.04 de                          |
| V <sub>7</sub>                  | 12.45 cd              | 2.01 d                 | 6.19 f                         | 18.99 de                          |
| V <sub>8</sub>                  | 14.12 b               | 1.95 d                 | 7.24 e                         | 19.70 d                           |
| V <sub>9</sub>                  | 13.40 bc              | 3.35 a                 | 4.05 g                         | 37.60 b                           |
| V <sub>10</sub>                 | 7.188 f               | 0.60 g                 | 11.86 b                        | 3.16 g                            |
| V <sub>11</sub>                 | 42.97 a               | 2.61 b                 | 16.45 a                        | 91.16 a                           |
| V <sub>12</sub>                 | 9.112 e               | 1.66 e                 | 5.97 f                         | 18.57 de                          |
| <b>LSD<sub>(0.05)</sub></b>     | <b>1.26</b>           | <b>0.15</b>            | <b>0.70</b>                    | <b>1.73</b>                       |
| <b>CV (%)</b>                   | <b>7.58</b>           | <b>6.66</b>            | <b>7.61</b>                    | <b>5.97</b>                       |
| <b>Effect of drought stress</b> |                       |                        |                                |                                   |
| D <sub>1</sub>                  | 14.90 a               | 1.94 a                 | 7.98                           | 25.79 a                           |
| D <sub>2</sub>                  | 13.77 b               | 1.81 b                 | 7.90                           | 24.10 b                           |
| <b>LSD<sub>(0.05)</sub></b>     | <b>0.68</b>           | <b>0.08</b>            | <b>NS</b>                      | <b>0.93</b>                       |
| <b>CV (%)</b>                   | <b>7.58</b>           | <b>6.66</b>            | <b>7.61</b>                    | <b>5.97</b>                       |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*; D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

#### 4.3.10 Flag leaf breadth

##### 4.3.10.1 Effect of species

Wild rice genotypes imposed significant difference on flag leaf breadth (Table 4.3.13). The widest flag leaf (3.35 cm) was produced by *O. alta* (V<sub>9</sub>) and the narrowest flag leaf (0.60 cm) was produced by *P. coaractata* (V<sub>10</sub>).

##### 4.3.10.2 Effect of drought stress

Drought stress imposed significant difference on flag leaf breadth (Table 4.3.13). The wider flag leaf (1.94 cm) was produced by D<sub>1</sub> and the narrower flag leaf (1.81 cm) was produced by D<sub>2</sub>.

#### 4.3.10.3 Interaction effect of species and drought stress

Interaction effect of wild rice genotypes and drought stress imposed significant difference on flag leaf breadth (Table 4.3.14). The widest flag leaf (3.70 cm) was produced by V<sub>9</sub>D<sub>1</sub> and the narrowest flag leaf (1.21 cm) was produced by V<sub>4</sub>D<sub>2</sub> which was statistically similar with V<sub>3</sub>D<sub>2</sub> and V<sub>4</sub>D<sub>1</sub>.

**Table 4.3.14 Interaction effect of species and drought stress on flag leaf characteristics of wild species of rice**

| Treatments                     | Flag leaf length (cm) | Flag leaf breadth (cm) | Flag leaf length breadth ratio | Flag leaf area (cm <sup>2</sup> ) |
|--------------------------------|-----------------------|------------------------|--------------------------------|-----------------------------------|
| V <sub>1</sub> D <sub>1</sub>  | 15.03 c               | 1.66 i                 | 9.01 c                         | 19.31 f-h                         |
| V <sub>1</sub> D <sub>2</sub>  | 12.17 f-h             | 1.61 ij                | 7.55 e                         | 16.47 i                           |
| V <sub>2</sub> D <sub>1</sub>  | 12.79 e-h             | 2.16 fg                | 5.91 gh                        | 20.74 ef                          |
| V <sub>2</sub> D <sub>2</sub>  | 11.08 h-j             | 1.92 h                 | 5.80 h                         | 17.99 g-i                         |
| V <sub>3</sub> D <sub>1</sub>  | 9.90 i-k              | 1.44 jk                | 6.89 e-g                       | 13.52 j                           |
| V <sub>3</sub> D <sub>2</sub>  | 9.55 jk               | 1.33 kl                | 7.17 ef                        | 12.40 j                           |
| V <sub>4</sub> D <sub>1</sub>  | 11.76 gh              | 1.37 kl                | 8.60 cd                        | 18.58 f-i                         |
| V <sub>4</sub> D <sub>2</sub>  | 11.49 g-i             | 1.21 l                 | 9.49 c                         | 17.25 hi                          |
| V <sub>5</sub> D <sub>1</sub>  | 14.21 c--e            | 2.42 de                | 5.88 h                         | 23.58 d                           |
| V <sub>5</sub> D <sub>2</sub>  | 12.75 e-h             | 2.25 ef                | 5.68 h                         | 22.36 de                          |
| V <sub>6</sub> D <sub>1</sub>  | 12.87 d-g             | 1.66 i                 | 7.77 de                        | 19.64 f-h                         |
| V <sub>6</sub> D <sub>2</sub>  | 11.95 f-h             | 1.64 ij                | 7.28 ef                        | 18.43 f-i                         |
| V <sub>7</sub> D <sub>1</sub>  | 12.15 f-h             | 2.01 gh                | 6.02 gh                        | 19.91 fg                          |
| V <sub>7</sub> D <sub>2</sub>  | 12.76 e-h             | 2.00 gh                | 6.36 f-h                       | 18.07 g-i                         |
| V <sub>8</sub> D <sub>1</sub>  | 14.65 cd              | 1.96 gh                | 7.44 e                         | 20.43 e-g                         |
| V <sub>8</sub> D <sub>2</sub>  | 13.60 c-f             | 1.94 h                 | 7.03 ef                        | 18.98 f-h                         |
| V <sub>9</sub> D <sub>1</sub>  | 14.05 c-e             | 3.70 a                 | 3.80 i                         | 39.52 b                           |
| V <sub>9</sub> D <sub>2</sub>  | 12.74 e-h             | 2.99 b                 | 4.29 i                         | 35.67 c                           |
| V <sub>10</sub> D <sub>1</sub> | 7.42 l                | 0.60 m                 | 11.98 b                        | 3.18 k                            |
| V <sub>10</sub> D <sub>2</sub> | 6.95 l                | 0.59 m                 | 11.73 b                        | 3.14 k                            |
| V <sub>11</sub> D <sub>1</sub> | 44.00 a               | 2.66 c                 | 16.52 a                        | 92.03 a                           |
| V <sub>11</sub> D <sub>2</sub> | 41.94 b               | 2.56 cd                | 16.39 a                        | 90.28 a                           |
| V <sub>12</sub> D <sub>1</sub> | 9.98 i-k              | 1.68 i                 | 5.94 gh                        | 19.00 f-h                         |
| V <sub>12</sub> D <sub>2</sub> | 8.25 kl               | 1.64 ij                | 6.00 gh                        | 18.13 g-i                         |
| <b>LSD (0.05)</b>              | <b>1.79</b>           | <b>0.21</b>            | <b>0.99</b>                    | <b>2.45</b>                       |
| <b>CV (%)</b>                  | <b>7.58</b>           | <b>6.66</b>            | <b>7.61</b>                    | <b>5.97</b>                       |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*; D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

**Table 4.3.15 Flag leaf length of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 15.03                            | 12.17                 | 19.03                        |
| V <sub>2</sub>  | 12.79                            | 11.08                 | 13.37                        |
| V <sub>3</sub>  | 9.90                             | 9.55                  | 3.48                         |
| V <sub>4</sub>  | 11.76                            | 11.49                 | 2.30                         |
| V <sub>5</sub>  | 14.21                            | 12.75                 | 10.27                        |
| V <sub>6</sub>  | 12.87                            | 11.95                 | 7.15                         |
| V <sub>7</sub>  | 12.15                            | 12.76                 | -5.02                        |
| V <sub>8</sub>  | 14.65                            | 13.60                 | 7.17                         |
| V <sub>9</sub>  | 14.05                            | 12.74                 | 9.32                         |
| V <sub>10</sub> | 7.42                             | 6.95                  | 6.33                         |
| V <sub>11</sub> | 44.00                            | 41.94                 | 4.68                         |
| V <sub>12</sub> | 9.98                             | 8.25                  | 17.34                        |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

The maximum decrease of flag leaf breadth (19.17%) was recorded from wild rice genotype *O. alta* (V<sub>9</sub>) and the minimum decrease of flag leaf breadth (0.79%) was recorded from rice genotype FR13A (Check variety as drought tolerant) (V<sub>7</sub>) (Table 4.3.16).

**Table 4.3.16 Flag leaf breadth wild rice due to drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 1.66                             | 1.61                  | 3.19                         |
| V <sub>2</sub>  | 2.16                             | 1.92                  | 11.23                        |
| V <sub>3</sub>  | 1.44                             | 1.33                  | 7.43                         |
| V <sub>4</sub>  | 1.37                             | 1.21                  | 11.49                        |
| V <sub>5</sub>  | 2.42                             | 2.25                  | 7.26                         |
| V <sub>6</sub>  | 1.66                             | 1.64                  | 1.03                         |
| V <sub>7</sub>  | 2.01                             | 2.00                  | 0.79                         |
| V <sub>8</sub>  | 1.96                             | 1.94                  | 1.17                         |
| V <sub>9</sub>  | 3.70                             | 2.99                  | 19.17                        |
| V <sub>10</sub> | 0.60                             | 0.59                  | 1.12                         |
| V <sub>11</sub> | 2.66                             | 2.56                  | 3.76                         |
| V <sub>12</sub> | 1.68                             | 1.64                  | 2.03                         |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*



### **4.3.11 Flag leaf length breadth ratio**

#### **4.3.11.1 Effect of species**

Flag leaf length breadth ratio of wild rice was significantly differed due to species variation (Table 4.3.13). The maximum flag leaf length breadth ratio (16.45) was scored by *O. latifolia* (V<sub>11</sub>) and the minimum flag leaf length breadth ratio (4.05) was scored by *O. alta* (V<sub>9</sub>).

#### **4.3.11.2 Effect of drought stress**

Flag leaf length breadth ratio of wild rice was not significantly differed due to drought stress (Table 4.3.13). Numerically the higher flag leaf length breadth ratio (7.98) was scored by D<sub>1</sub> treatment and the lower flag leaf length breadth ratio (7.90) was scored by D<sub>2</sub> treatment.

#### **4.3.11.3 Interaction effect of species and drought stress**

Flag leaf length breadth ratio of wild rice was significantly differed due to the interaction effect of species and drought stress (Table 4.3.14). The maximum flag leaf length breadth ratio (16.52) was scored by V<sub>11</sub>D<sub>1</sub> which was statistically at par with V<sub>11</sub>D<sub>2</sub> (16.39) and the minimum flag leaf length breadth ratio (3.80) was scored by V<sub>9</sub>D<sub>1</sub> which was statistically at par with V<sub>9</sub>D<sub>2</sub>.

The maximum decrease of flag leaf ratio (16.24%) was recorded from wild rice genotype *O. rufipogon* (V<sub>1</sub>) and the increase of flag leaf ratio (12.89%) was recorded from wild rice genotype *O. alta* (V<sub>9</sub>) (Table 4.3.17).

### **4.3.12 Flag leaf area**

#### **4.3.12.1 Effect of species**

Wild rice species had significant influence on flag leaf area (Table 4.3.13). The result revealed that the maximum flag leaf area (91.16 cm<sup>2</sup>) was achieved by *O. latifolia* (V<sub>11</sub>) and the minimum flag leaf area (3.16 cm<sup>2</sup>) was achieved by *P. coaractata* (V<sub>10</sub>).

**Table 4.3.17 Flag leaf length breadth ratio wild rice due to drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 9.01                             | 7.55                  | 16.24                        |
| V <sub>2</sub>  | 5.91                             | 5.80                  | 1.91                         |
| V <sub>3</sub>  | 6.89                             | 7.17                  | -4.06                        |
| V <sub>4</sub>  | 8.60                             | 9.49                  | -10.38                       |
| V <sub>5</sub>  | 5.88                             | 5.68                  | 3.45                         |
| V <sub>6</sub>  | 7.77                             | 7.28                  | 6.27                         |
| V <sub>7</sub>  | 6.02                             | 6.36                  | -5.60                        |
| V <sub>8</sub>  | 7.44                             | 7.03                  | 5.51                         |
| V <sub>9</sub>  | 3.80                             | 4.29                  | -12.89                       |
| V <sub>10</sub> | 11.98                            | 11.73                 | 2.09                         |
| V <sub>11</sub> | 16.52                            | 16.39                 | 0.79                         |
| V <sub>12</sub> | 5.94                             | 6.00                  | -1.01                        |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### 4.3.12.2 Effect of drought stress

Drought stress had significant influence on flag leaf area (Table 4.3.13). The result revealed that the higher flag leaf area (25.79 cm<sup>2</sup>) was achieved by D<sub>1</sub> and the lower flag leaf area (24.10 cm<sup>2</sup>) was achieved by D<sub>2</sub>.

#### 4.3.12.3 Interaction effect of species and drought stress

Interaction of wild rice species and drought stress had significant influence on flag leaf area (Table 4.3.14). The result revealed that the maximum flag leaf area (92.03 cm<sup>2</sup>) was achieved by V<sub>11</sub>D<sub>1</sub> which was statistically similar with V<sub>11</sub>D<sub>2</sub> and the minimum flag leaf area (3.14 cm<sup>2</sup>) was achieved by V<sub>10</sub>D<sub>2</sub> which was statistically similar with V<sub>10</sub>D<sub>1</sub>.

The maximum decrease of flag leaf area (14.71%) was recorded from wild rice genotype *O. rufipogon* (V<sub>1</sub>) and the minimum decrease of flag leaf area (1.26%) was recorded from wild rice genotype *Potericia coaractata* (V<sub>10</sub>) (Table 4.3.18).

**Table 4.3.18 Flag leaf area wild rice due to drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 19.31                            | 16.47                 | 14.71                        |
| V <sub>2</sub>  | 20.74                            | 17.99                 | 13.26                        |
| V <sub>3</sub>  | 13.52                            | 12.40                 | 8.28                         |
| V <sub>4</sub>  | 18.58                            | 17.25                 | 7.16                         |
| V <sub>5</sub>  | 23.58                            | 22.36                 | 5.17                         |
| V <sub>6</sub>  | 19.64                            | 18.43                 | 6.16                         |
| V <sub>7</sub>  | 19.91                            | 18.07                 | 9.24                         |
| V <sub>8</sub>  | 20.43                            | 18.98                 | 7.10                         |
| V <sub>9</sub>  | 39.52                            | 35.67                 | 9.74                         |
| V <sub>10</sub> | 3.18                             | 3.14                  | 1.26                         |
| V <sub>11</sub> | 92.03                            | 90.28                 | 1.90                         |
| V <sub>12</sub> | 19.00                            | 18.13                 | 4.58                         |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

### 4.3.13 Shoot dry weight hill<sup>-1</sup>

#### 4.3.13.1 Effect of species

Significant variation was found on shoot dry weight hill<sup>-1</sup> of wild rice due to different genotypes (Table 4.3.19). The maximum shoot dry weight hill<sup>-1</sup>(100.40 g) was recorded from *O. latifolia* (V<sub>11</sub>) and the minimum one (27.59 g) was recorded from *P. coaractata* (V<sub>10</sub>).

#### 4.3.13.2 Effect of drought stress

Significant variation was found on shoot dry weight hill<sup>-1</sup> of wild rice due to drought stress (Table 4.3.19). The higher shoot dry weight hill<sup>-1</sup>(75.21g) was recorded from D<sub>1</sub> and the lower one (65.64 g) was recorded from D<sub>2</sub>. Ji *et al.* (2012); Pandey and Shukla (2015) reported that drought stress affected the physiology and biochemical processes of rice, restricted the dry weights of stem as well as their lengths because under this condition hampered the cell division and elongation, reduce the photosynthetic process and accumulation of dry matter to the stem consequently reduce the dry weight of stem. Similar results also reported by Rodrigues *et al.* (1995); Usman *et al.* (2013) and Khan *et al.* (2017).

**Table 4.3.19 Effect of species and drought stress on shoot dry weight, root dry weight, total dry weight, days to 1<sup>st</sup> flowering and growth duration of wild species of rice**

| Treatments               | Shoot dry weight hill <sup>-1</sup> (g) |    | Root dry weight hill <sup>-1</sup> (g) |   | Total dry weight hill <sup>-1</sup> (g) |    | Days to 1 <sup>st</sup> flowering |   | Growth duration (day) |   |
|--------------------------|-----------------------------------------|----|----------------------------------------|---|-----------------------------------------|----|-----------------------------------|---|-----------------------|---|
| Effect of species        |                                         |    |                                        |   |                                         |    |                                   |   |                       |   |
| V <sub>1</sub>           | 78.90                                   | cd | 50.60                                  | c | 129.50                                  | d  | 95.00                             | c | 125.00                | c |
| V <sub>2</sub>           | 44.67                                   | f  | 28.96                                  | f | 73.63                                   | f  | 95.00                             | c | 125.00                | c |
| V <sub>3</sub>           | 81.71                                   | c  | 49.17                                  | c | 130.9                                   | d  | 100.00                            | b | 130.00                | b |
| V <sub>4</sub>           | 36.61                                   | g  | 28.57                                  | f | 65.18                                   | f  | 100.00                            | b | 130.00                | b |
| V <sub>5</sub>           | 78.68                                   | cd | 64.03                                  | b | 142.70                                  | c  | 95.00                             | c | 125.00                | c |
| V <sub>6</sub>           | 91.38                                   | b  | 61.50                                  | b | 152.90                                  | b  | 100.00                            | b | 130.00                | b |
| V <sub>7</sub>           | 72.54                                   | de | 32.88                                  | e | 105.40                                  | e  | 105.00                            | a | 135.00                | a |
| V <sub>8</sub>           | 68.77                                   | e  | 35.96                                  | e | 104.70                                  | e  | 105.00                            | a | 135.00                | a |
| V <sub>9</sub>           | 73.00                                   | de | 35.85                                  | e | 108.90                                  | e  | 105.00                            | a | 135.00                | a |
| V <sub>10</sub>          | 27.59                                   | h  | 12.72                                  | g | 40.31                                   | g  | 100.00                            | b | 125.00                | c |
| V <sub>11</sub>          | 100.40                                  | a  | 71.30                                  | a | 171.80                                  | a  | 105.00                            | a | 135.00                | a |
| V <sub>12</sub>          | 90.80                                   | b  | 44.58                                  | d | 135.40                                  | cd | 95.00                             | c | 125.00                | c |
| LSD <sub>(0.05)</sub>    | 6.98                                    |    | 3.79                                   |   | 9.30                                    |    | 2.11                              |   | 4.34                  |   |
| CV (%)                   | 8.53                                    |    | 7.58                                   |   | 7.06                                    |    | 1.81                              |   | 2.88                  |   |
| Effect of drought stress |                                         |    |                                        |   |                                         |    |                                   |   |                       |   |
| D <sub>1</sub>           | 75.21                                   | a  | 44.33                                  | a | 119.55                                  | a  | 100.00                            |   | 129.58                |   |
| D <sub>2</sub>           | 65.64                                   | b  | 41.69                                  | b | 107.33                                  | b  | 100.00                            |   | 129.58                |   |
| LSD <sub>(0.05)</sub>    | 3.73                                    |    | 2.03                                   |   | 4.98                                    |    | NS                                |   | NS                    |   |
| CV (%)                   | 8.53                                    |    | 7.58                                   |   | 7.06                                    |    | 1.81                              |   | 2.88                  |   |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*; D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

#### 4.3.13.3 Interaction effect of species and drought stress

Significant variation was found on shoot dry weight hill<sup>-1</sup> of wild rice due to different genotypes and drought stress (Table 4.3.20). The maximum shoot dry weight hill<sup>-1</sup> (101.60 g) was recorded from V<sub>11</sub>D<sub>1</sub> which was statistically similar with V<sub>11</sub>D<sub>2</sub>, V<sub>6</sub>D<sub>1</sub> and V<sub>12</sub>D<sub>1</sub> and the minimum one (26.05 g) was recorded from V<sub>10</sub>D<sub>2</sub> which was statistically similar with V<sub>10</sub>D<sub>1</sub> and V<sub>4</sub>D<sub>2</sub>.

The maximum decrease of shoot dry weight hill<sup>-1</sup> (25.46%) was found from wild rice genotype *O. barthii* (V<sub>4</sub>) and the minimum decrease of shoot dry weight hill<sup>-1</sup> (2.22%) was found from wild rice genotype *O. latifolia* (V<sub>11</sub>) (Table 4.3.21).

**Table 4.3.20 Interaction effect of species and drought stress on shoot dry weight, root dry weight, total dry weight, days to 1<sup>st</sup> flowering and growth duration of wild species of rice**

| Treatments                     | Shoot dry weight hill <sup>-1</sup> (g) | Root dry weight hill <sup>-1</sup> (g) | Total dry weight hill <sup>-1</sup> (g) | Days to 1 <sup>st</sup> flowering | Growth duration (day) |
|--------------------------------|-----------------------------------------|----------------------------------------|-----------------------------------------|-----------------------------------|-----------------------|
| V <sub>1</sub> D <sub>1</sub>  | 83.19 c-e                               | 52.51 fg                               | 135.70 de                               | 95.00 c                           | 125.00 b              |
| V <sub>1</sub> D <sub>2</sub>  | 74.61 e-g                               | 48.69 gh                               | 123.30 e-h                              | 95.00 c                           | 125.00 b              |
| V <sub>2</sub> D <sub>1</sub>  | 50.38 i                                 | 29.10 m-o                              | 79.48 k                                 | 95.00 c                           | 125.00 b              |
| V <sub>2</sub> D <sub>2</sub>  | 38.96 jk                                | 28.82 no                               | 67.78 kl                                | 95.00 c                           | 125.00 b              |
| V <sub>3</sub> D <sub>1</sub>  | 86.67 bc                                | 54.36 ef                               | 141.00 cd                               | 100.00 b                          | 130.00 ab             |
| V <sub>3</sub> D <sub>2</sub>  | 76.76 d-f                               | 43.98 hi                               | 120.70 f-h                              | 100.00 b                          | 130.00 ab             |
| V <sub>4</sub> D <sub>1</sub>  | 41.95 ij                                | 29.79 m-o                              | 71.74 kl                                | 100.00 b                          | 130.00 ab             |
| V <sub>4</sub> D <sub>2</sub>  | 31.27 kl                                | 27.35 o                                | 58.62 l                                 | 100.00 b                          | 130.00 ab             |
| V <sub>5</sub> D <sub>1</sub>  | 85.91 b-d                               | 65.81 bc                               | 151.70 bc                               | 95.00 c                           | 125.00 b              |
| V <sub>5</sub> D <sub>2</sub>  | 71.46 fg                                | 62.26 cd                               | 133.70 d-f                              | 95.00 c                           | 125.00 b              |
| V <sub>6</sub> D <sub>1</sub>  | 97.73 a                                 | 63.30 cd                               | 161.00 ab                               | 100.00 b                          | 130.00 ab             |
| V <sub>6</sub> D <sub>2</sub>  | 85.04 b-d                               | 59.69 de                               | 144.70 cd                               | 100.00 b                          | 130.00 ab             |
| V <sub>7</sub> D <sub>1</sub>  | 79.94 c-f                               | 34.01 k-n                              | 113.90 g-i                              | 105.00 a                          | 135.00 a              |
| V <sub>7</sub> D <sub>2</sub>  | 65.13 gh                                | 31.75 l-o                              | 96.89 j                                 | 105.00 a                          | 135.00 a              |
| V <sub>8</sub> D <sub>1</sub>  | 76.77 d-f                               | 35.89 j-l                              | 112.70 hi                               | 105.00 a                          | 135.00 a              |
| V <sub>8</sub> D <sub>2</sub>  | 60.76 h                                 | 36.03 j-l                              | 96.79 j                                 | 105.00 a                          | 135.00 a              |
| V <sub>9</sub> D <sub>1</sub>  | 74.56 e-g                               | 37.50 jk                               | 112.10 hi                               | 105.00 a                          | 135.00 a              |
| V <sub>9</sub> D <sub>2</sub>  | 71.45 fg                                | 34.20 k-m                              | 105.60 ij                               | 105.00 a                          | 135.00 a              |
| V <sub>10</sub> D <sub>1</sub> | 29.12 kl                                | 8.710 q                                | 37.83 m                                 | 100.00 b                          | 125.00 b              |
| V <sub>10</sub> D <sub>2</sub> | 26.05 l                                 | 16.73 p                                | 42.78 m                                 | 100.00 b                          | 125.00 b              |
| V <sub>11</sub> D <sub>1</sub> | 101.6 a                                 | 72.01 a                                | 173.60 a                                | 105.00 a                          | 135.00 a              |
| V <sub>11</sub> D <sub>2</sub> | 99.34 a                                 | 70.59 ab                               | 169.90 a                                | 105.00 a                          | 135.00 a              |
| V <sub>12</sub> D <sub>1</sub> | 94.81 ab                                | 48.96 gh                               | 143.80 cd                               | 95.00 c                           | 125.00 b              |
| V <sub>12</sub> D <sub>2</sub> | 86.79 bc                                | 40.20 ij                               | 127.00 e-g                              | 95.00 c                           | 125.00 b              |
| <b>LSD (0.05)</b>              | <b>9.87</b>                             | <b>5.36</b>                            | <b>13.16</b>                            | <b>2.98</b>                       | <b>6.14</b>           |
| <b>CV (%)</b>                  | <b>8.53</b>                             | <b>7.58</b>                            | <b>7.06</b>                             | <b>1.81</b>                       | <b>2.88</b>           |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*; D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

#### 4.3.14 Root dry weight hill<sup>-1</sup>

##### 4.3.14.1 Effect of species

Root dry weight hill<sup>-1</sup> of wild rice was significantly differed by species variation (Table 4.3.19). The maximum root dry weight hill<sup>-1</sup> (71.30 g) was obtained by V<sub>11</sub> and the minimum root dry weight hill<sup>-1</sup> (12.72 g) was obtained by V<sub>10</sub>. Production of higher root biomass could be depends on the genetic potentiality of a genotypes.

Comparatively the drought tolerant genotypes assimilated maximum root dry matter than the sensitive ones. The findings of our investigation are in line with the findings of Khan *et al.* (2017).

**Table 4.3.21 Shoot dry weight hill<sup>-1</sup> wild rice due to drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 83.19                            | 74.61                 | 10.31                        |
| V <sub>2</sub>  | 50.38                            | 38.96                 | 22.67                        |
| V <sub>3</sub>  | 86.67                            | 76.76                 | 11.43                        |
| V <sub>4</sub>  | 41.95                            | 31.27                 | 25.46                        |
| V <sub>5</sub>  | 85.91                            | 71.46                 | 16.82                        |
| V <sub>6</sub>  | 97.73                            | 85.04                 | 12.98                        |
| V <sub>7</sub>  | 79.94                            | 65.13                 | 18.53                        |
| V <sub>8</sub>  | 76.77                            | 60.76                 | 20.85                        |
| V <sub>9</sub>  | 74.56                            | 71.45                 | 4.17                         |
| V <sub>10</sub> | 29.12                            | 26.05                 | 10.54                        |
| V <sub>11</sub> | 101.60                           | 99.34                 | 2.22                         |
| V <sub>12</sub> | 94.81                            | 86.79                 | 8.46                         |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### 4.3.14.2 Effect of drought stress

Root dry weight hill<sup>-1</sup> of wild rice was significantly differed by drought stress (Table 4.3.19). The higher root dry weight hill<sup>-1</sup> (44.33 g) was obtained by D<sub>1</sub> and the lower root dry weight hill<sup>-1</sup> (41.69 g) was obtained by D<sub>2</sub>. Pandey and Shukla (2015) described that the structure and development of rice root system largely determines crop function under drought. Under mild water deficit, the root growth usually maintains while shoot growth is inhibited. This is because of the facts that, adjustment like, re-establishment of water potential gradient through osmotic alteration and increase in loosening ability of the cell wall, permit roots to resume growth under low water potential. Root dry mass and length are good predictor of rice yield under drought (Fageria and Moreira, 2011; Feng *et al.*, 2012). Rice genotypes that have deep, coarse roots with a high ability of branching and penetration and higher root to shoot ratio are reported as component traits of drought avoidance (Samson *et al.*, 2002; Wang and Yamauchi, 2006; Gowda *et al.*, 2011). Coarse roots have direct roles in drought resistance because larger diameter roots are related to penetration ability

(Nguyen *et al.*, 1997; Clark *et al.*, 2008) and branching, and they have greater xylem vessel radii and lower axial resistance to water flux (Yambao *et al.*, 1992). Capacity for deep root growth and large xylem diameters in deep roots may improve root acquisition of water when ample water at depth is available. While small xylem diameters in targeted seminal roots save soil water deep in the soil profile for use during crop maturation. According to Lopes and Reynolds (2010); Khan *et al.* (2017) the accumulation of carbohydrates in stem and root tissue may be another alternative strategy for adapting to drought stress, the latter being beneficial where water is available at depth. Under drought stress condition larger carbohydrate accumulation in root tissue of tolerant species suggest better osmotic adjustment in roots which may be of importance for the maintenance of vital processes and for recovery after drought (Nicolas *et al.*, 1985). So the of larger portion of dry matter accumulated into the root of comparatively tolerance genotypes represent the higher dry matter weight hill<sup>-1</sup>.

#### **4.3.14.3 Interaction effect of species and drought stress**

Root dry weight hill<sup>-1</sup> of wild rice was significantly differed by species variation and drought stress (Table 4.4.20). The maximum root dry weight hill<sup>-1</sup> (72.01 g) was obtained by V<sub>11</sub>D<sub>1</sub> which was statistically at par with V<sub>11</sub>D<sub>2</sub> and the minimum root dry weight hill<sup>-1</sup> (8.71 g) was obtained by V<sub>10</sub>D<sub>1</sub>.

The maximum decrease of root dry weight hill<sup>-1</sup> (19.09%) was found from wild rice genotype *O. nivara* (V<sub>3</sub>) and the increase of root dry weight hill<sup>-1</sup> (92.08%) was found from wild rice genotype *Potericia coaractata* (V<sub>10</sub>) (Table 4.3.22).

#### **4.3.15 Total dry weight hill<sup>-1</sup>**

##### **4. 3.15.1 Effect of species**

Wild rice species exerted significant difference of total dry weight hill<sup>-1</sup> (Table 4.3.19). The result showed that the maximum total dry weight hill<sup>-1</sup> (171.80 g) was observed from *O. latifolia* (V<sub>11</sub>) and the minimum total dry weight hill<sup>-1</sup> (40.31 g) was observed from *P. coaractata* (V<sub>10</sub>). Similar findings are also reported by Kartika *et al.* (2020) who explained that under drought stress RAM97 had the highest dry matter and Koshihikari had the lowest dry matter weight. The highest total dry matter accumulation was produced by RAM59, which was highly contributed by significant

increment of shoot as well as the root growth under drought stress conditions. This might be due to the genetic potentiality of the crop varieties.

**Table 4.3.22 Root dry weight hill<sup>-1</sup> wild rice due to drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 52.51                            | 48.69                 | 7.27                         |
| V <sub>2</sub>  | 29.10                            | 28.82                 | 0.96                         |
| V <sub>3</sub>  | 54.36                            | 43.98                 | 19.09                        |
| V <sub>4</sub>  | 29.79                            | 27.35                 | 8.19                         |
| V <sub>5</sub>  | 65.81                            | 62.26                 | 5.39                         |
| V <sub>6</sub>  | 63.30                            | 59.69                 | 5.70                         |
| V <sub>7</sub>  | 34.01                            | 31.75                 | 6.65                         |
| V <sub>8</sub>  | 35.89                            | 36.03                 | -0.39                        |
| V <sub>9</sub>  | 37.50                            | 34.20                 | 8.80                         |
| V <sub>10</sub> | 8.71                             | 16.73                 | -92.08                       |
| V <sub>11</sub> | 72.01                            | 70.59                 | 1.97                         |
| V <sub>12</sub> | 48.96                            | 40.20                 | 17.89                        |
| V <sub>12</sub> | 143.80                           | 127.00                | 11.68                        |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### 4.4.15.2 Effect of drought stress

Drought stress exerted significant difference of total dry weight hill<sup>-1</sup> (Table 4.3.19). The result showed that the higher total dry weight hill<sup>-1</sup> (119.55 g) observed from D<sub>1</sub> and the lower total dry weight hill<sup>-1</sup> (107.33 g) observed from D<sub>2</sub>. Hossain *et al.* (2020) reported that plant dry weight reduced progressively with the increment of drought stressed condition. The process of oxidative deterioration is due to water stress causes cell damage and reduction of nutrient uptake, photosynthesis rate and leaf area which might be responsible for the decrease in plant dry matter weight under lower soil moisture. Study reported that drought stress affects elongation and expansion growth, and prevent cell enlargement more than its division (Jaleel *et al.*, 2009). The capability to maintain plant fresh and dry weight under water limited conditions is desirable characters for drought tolerant. Moreover, a slight decrement growth during vegetative stage is acceptable as long as it does not cause yield reduction (Lakitan *et al.*, 2018). Zubaer *et al.* (2007) reported that total dry matter weight hill<sup>-1</sup> was maximum at 100% FC followed by 70% FC and it was lowest at



40% FC in all the rice genotype at all growing stages. The finding of our investigation was also in accordance with Lum *et al.* (2014); Pandey and Shukla (2015); Saha *et al.* (2019); Kartika *et al.* (2020) who reported that the significant reduction in dry matter weight of different organs as compared to control in rice varieties under water stress.

#### 4.3.15.3 Interaction effect of species and drought stress

Combined effect of wild rice species and drought stress exerted significant difference of total dry weight hill<sup>-1</sup> (Table 4.3.20). The result showed that the maximum total dry weight hill<sup>-1</sup> (173.60 g) observed from V<sub>11</sub>D<sub>1</sub> which was statistically similar with V<sub>11</sub>D<sub>2</sub> and V<sub>6</sub>D<sub>1</sub> and the minimum total dry weight hill<sup>-1</sup> (37.83 g) observed from V<sub>10</sub>D<sub>1</sub> which was statistically similar with V<sub>10</sub>D<sub>2</sub>. Research conducted by Zubaer *et al.* (2007) revealed that under drought stress, the reduction of dry matter weight hill<sup>-1</sup> for Basmati were (15.28% for 70% FC and 30.86% for 40% FC) and for RD2585 (18.79% for 70% FC and 40.21% for 40% FC) and for Binadhan 4 (11.82% for 70% and 27.27% for 40% FC). Hossain *et al.* (2020) also revealed that *Banglamoti* showed the maximum dry weight (9.07±0.66g plant<sup>-1</sup>) with 5 cm standing water and on the other hand, in case of *Atash balam* plant dry weight was comparatively very low under 50% of saturation level.

The maximum decrease of total dry weight hill<sup>-1</sup> (18.29%) was found from wild rice genotype *O. barthii* (V<sub>4</sub>) and the increase of total dry weight hill<sup>-1</sup> (13.08%) was found from wild rice genotype *Potericia coaractata* (V<sub>10</sub>) (Table 4.3.23).

**Table 4.3.23 Total dry weight hill<sup>-1</sup> wild rice due to drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 135.70                           | 123.30                | 9.14                         |
| V <sub>2</sub>  | 79.48                            | 67.78                 | 14.72                        |
| V <sub>3</sub>  | 141.00                           | 120.70                | 14.40                        |
| V <sub>4</sub>  | 71.74                            | 58.62                 | 18.29                        |
| V <sub>5</sub>  | 151.70                           | 133.70                | 11.87                        |
| V <sub>6</sub>  | 161.00                           | 144.70                | 10.12                        |
| V <sub>7</sub>  | 113.90                           | 96.89                 | 14.93                        |
| V <sub>8</sub>  | 112.70                           | 96.79                 | 14.12                        |
| V <sub>9</sub>  | 112.10                           | 105.60                | 5.80                         |
| V <sub>10</sub> | 37.83                            | 42.78                 | -13.08                       |
| V <sub>11</sub> | 173.60                           | 169.90                | 2.13                         |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potiericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### **4.3.16 Days to 1<sup>st</sup> flowering**

##### **4.3.16.1 Effect of species**

The results revealed that, there was significant difference for days to 1<sup>st</sup> flowering due to rice genotypes are presented in Table 4.3.19. Variety FR13A (V<sub>7</sub>) (Check variety as drought tolerant), BRRI Dhan29 (V<sub>8</sub>) (check variety as drought sensitive), *O. alta* (V<sub>9</sub>) and *O. latifolia* (V<sub>11</sub>) took maximum 105.00 days after transplanting to reach the 1<sup>st</sup> flowering stage and *O. rufipogon* (V<sub>1</sub>), *O. punctata* (V<sub>2</sub>), *O. longistaminata* (V<sub>5</sub>) and *O. officinalis* (V<sub>12</sub>) took minimum 95.00 days after transplanting to reach the 1<sup>st</sup> flowering stage.

##### **4.3.16.2 Effect of drought stress**

The results revealed that, there was no significant difference for days to 1<sup>st</sup> flowering due to drought stress are presented in Table 4.3.19. Both D<sub>1</sub> and D<sub>2</sub> took 100.00 days after transplanting to reach the 1<sup>st</sup> flowering stage.

##### **4.3.16.3 Interaction effect of species and drought stress**

The results revealed that, there was significant difference for days to 1<sup>st</sup> flowering due to rice genotypes and drought stress are presented in Table 4.3.20. Treatment combinations V<sub>7</sub>D<sub>1</sub>, V<sub>7</sub>D<sub>2</sub>, V<sub>8</sub>D<sub>1</sub>, V<sub>8</sub>D<sub>2</sub>, V<sub>9</sub>D<sub>1</sub>, V<sub>9</sub>D<sub>2</sub>, V<sub>11</sub>D<sub>1</sub> and V<sub>11</sub>D<sub>2</sub> took maximum 105.00 days after transplanting to reach the 1<sup>st</sup> flowering stage and V<sub>1</sub>D<sub>1</sub>, V<sub>1</sub>D<sub>2</sub>, V<sub>2</sub>D<sub>1</sub>, V<sub>2</sub>D<sub>2</sub>, V<sub>5</sub>D<sub>1</sub>, V<sub>5</sub>D<sub>2</sub>, V<sub>12</sub>D<sub>1</sub> and V<sub>12</sub>D<sub>2</sub> took minimum 95.00 days after transplanting to reach the 1<sup>st</sup> flowering stage.

Drought stress had no impact of days required to 1<sup>st</sup> flowering in the investigation (Table 4.3.24).

**Table 4.3.24 Days to 1<sup>st</sup> flowering wild rice due to drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 95.00                            | 95.00                 | 0.00                         |
| V <sub>2</sub>  | 95.00                            | 95.00                 | 0.00                         |
| V <sub>3</sub>  | 100.00                           | 100.00                | 0.00                         |
| V <sub>4</sub>  | 100.00                           | 100.00                | 0.00                         |
| V <sub>5</sub>  | 95.00                            | 95.00                 | 0.00                         |
| V <sub>6</sub>  | 100.00                           | 100.00                | 0.00                         |
| V <sub>7</sub>  | 105.00                           | 105.00                | 0.00                         |
| V <sub>8</sub>  | 105.00                           | 105.00                | 0.00                         |
| V <sub>9</sub>  | 105.00                           | 105.00                | 0.00                         |
| V <sub>10</sub> | 100.00                           | 100.00                | 0.00                         |
| V <sub>11</sub> | 105.00                           | 105.00                | 0.00                         |
| V <sub>12</sub> | 95.00                            | 95.00                 | 0.00                         |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### 4.3.17 Growth duration

##### 4.3.17.1 Effect of species

Growth duration of wild rice was significantly influenced by rice genotypes (Table 4.3.19). The V<sub>7</sub>, V<sub>8</sub>, V<sub>9</sub> and V<sub>11</sub> treatments required maximum 135.00 days after transplanting to reach the maturity stage. On the other hand minimum days to maturity (125.00 DAT) were required in V<sub>1</sub>, V<sub>2</sub>, V<sub>5</sub>, V<sub>10</sub> and V<sub>12</sub> treatments.

##### 4.3.17.2 Effect of drought stress

Growth duration of wild rice was not significantly influenced by drought stress (Table 4.3.19). Both D<sub>1</sub> and D<sub>2</sub> took 129.58 days after transplanting to reach the maturity stages.

##### 4.3.17.3 Interaction effect of species and drought stress

Growth duration of wild rice was significantly influenced by rice genotypes and drought stress (Table 4.3.20). The V<sub>7</sub>D<sub>1</sub>, V<sub>7</sub>D<sub>2</sub>, V<sub>8</sub>D<sub>1</sub>, V<sub>8</sub>D<sub>2</sub>, V<sub>9</sub>D<sub>1</sub>, V<sub>9</sub>D<sub>2</sub>, V<sub>11</sub>D<sub>1</sub> and V<sub>11</sub>D<sub>2</sub> treatment combinations required maximum 135.00 days after transplanting to reach the maturity stage which were statistically similar with V<sub>3</sub>D<sub>1</sub>, V<sub>3</sub>D<sub>2</sub>, V<sub>4</sub>D<sub>1</sub>, V<sub>4</sub>D<sub>2</sub>, V<sub>6</sub>D<sub>1</sub> and V<sub>6</sub>D<sub>2</sub>. On the other hand minimum days to maturity (125.00 DAT)

were required in V<sub>1</sub>D<sub>1</sub>, V<sub>1</sub>D<sub>2</sub>, V<sub>2</sub>D<sub>1</sub>, V<sub>2</sub>D<sub>2</sub>, V<sub>5</sub>D<sub>1</sub>, V<sub>5</sub>D<sub>2</sub>, V<sub>10</sub>D<sub>1</sub>, V<sub>10</sub>D<sub>2</sub>, V<sub>12</sub>D<sub>1</sub> and V<sub>12</sub>D<sub>2</sub> which were statistically similar with V<sub>3</sub>D<sub>1</sub>, V<sub>3</sub>D<sub>2</sub>, V<sub>4</sub>D<sub>1</sub>, V<sub>4</sub>D<sub>2</sub>, V<sub>6</sub>D<sub>1</sub> and V<sub>6</sub>D<sub>2</sub>.

Similarly drought stress had no impact on wild rice genotype to complete their life cycle (Table 4.3.25).

**Table 4.3.25 Growth duration of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 125.00                           | 125.00                | 0.00                         |
| V <sub>2</sub>  | 125.00                           | 125.00                | 0.00                         |
| V <sub>3</sub>  | 130.00                           | 130.00                | 0.00                         |
| V <sub>4</sub>  | 130.00                           | 130.00                | 0.00                         |
| V <sub>5</sub>  | 125.00                           | 125.00                | 0.00                         |
| V <sub>6</sub>  | 130.00                           | 130.00                | 0.00                         |
| V <sub>7</sub>  | 135.00                           | 135.00                | 0.00                         |
| V <sub>8</sub>  | 135.00                           | 135.00                | 0.00                         |
| V <sub>9</sub>  | 135.00                           | 135.00                | 0.00                         |
| V <sub>10</sub> | 135.00                           | 135.00                | 0.00                         |
| V <sub>11</sub> | 135.00                           | 135.00                | 0.00                         |
| V <sub>12</sub> | 135.00                           | 135.00                | 0.00                         |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Pottericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### 4.3.18 Relative water content

##### 4.3.18.1 Effect of species

Relative water content significantly differed by different wild species of rice (Table 4.3.26). Wild rice genotype *O. latifolia* (V<sub>11</sub>) scored the highest relative water content (94.24%) which was statistically similar with V<sub>10</sub> and V<sub>9</sub>. On the other hand, FR13A (V<sub>7</sub>) scored the lowest relative water content (84.94%) which was statistically similar with V<sub>8</sub> and V<sub>4</sub>. These results are in harmony with those obtained by Dien *et al.* (2019) who presented that variety DA8 showed the highest relative water content (60.62%), followed by Kinandang Patong (47.12%) and Malagkit Pirurutong (23.42%). The average leaf water content of all varieties declined dramatically from 78.59% at before drought treatment to 41.19% under moderate drought stress and 20.16% under severe drought stress. In a previous study (Dien *et al.*, 2017), DA8 and Thierno Bande exhibited bigger root systems compared to other varieties (with higher

values of total root length, root surface area and root volume). This suggested that DA8 and Thierno Bande remained higher ability in water absorption than other varieties. Khan *et al.* (2017) reported that in PR-115 and Super-7 varieties RWC was decreased by 25 and 33% respectively during the 10 days of drought. Keyvan (2010) also reported that in various wheat cultivars, the mean comparison mean of flag leaf RWC showed that Chamran cultivar with 73.58% has highest flag leaf RWC and Shahryar cultivar with 67.33% had lowest flag leaf RWC. Similar findings also reported by Kumar *et al.* (2014b); Larkunthod *et al.* (2018).

#### **4.3.18.2 Effect of drought stress**

Relative water content significantly differed by different drought stress (Table 4.3.26). D<sub>1</sub> scored the higher relative water content (91.18%). On the other hand D<sub>2</sub> scored the lower relative water content (87.75%). Relative water content (RWC) indicates that the water status of cells has a significant association with yield and stress tolerance (Almeselmani *et al.*, 2012). It is considered a measure of plant water status, reflecting the metabolic activity in tissues and used as a most meaningful determinant characters for drought tolerance (Anjum *et al.*, 2011). Relative water content of rice leaves is higher initially during leaf development and decreased as the dry matter accumulated and leaf matured (Siddique *et al.*, 2001). Drought stress is a decrease of soil water potential so plants reduce their osmotic potential for water absorption by congestion of soluble carbohydrates and proline and in other words osmotic regulation is performed (Martin *et al.*, 1993). It has been identified that among various mechanisms, osmotic adjustment, abscisic acid and induction of dehydrins may confer tolerance against drought injuries by maintaining high tissue water potential (Turner *et al.*, 2001). Therefore osmotic regulation will help to cell development and plant growth in water stress (Pessarkli, 1999). It is defined that decrease of relative water content close stomata and also after blocking of stomata will reduce photosynthesis rate (Cornic, 2000). It is reported that high relative water content is a resistant mechanism to drought, and that high relative water content is the result of more osmotic regulation or less elasticity of tissue cell wall (Ritchie *et al.*, 1990). With the accumulation of solutes, the osmotic potential of the cell is lowered, which attracts water into the cell and helps with turgor maintenance. The maintenance of turgor despite a decrease in leaf water volume is consistent with other studies of species with elastic cell walls. Osmotic adjustment helps to maintain the cell water

balance with the active accumulation of solutes in the cytoplasm, thereby minimizing the harmful effects of drought (Morgan, 1990). Osmotic adjustment is an important trait in delaying dehydrative damage in water-limited environments by continued maintenance of cell turgor and physiological processes (Taiz and Zeiger, 2006). The osmotic adjustment also facilitates a better translocation of pre-anthesis carbohydrate partitioning during grain filling (Subbarao *et al.*, 2000), while high turgor maintenance leads to higher photosynthetic rate and growth (Ludlow and Muchow, 1990). Osmotic adjustment is a mechanism to maintain water relations under osmotic stress. It involves the accumulation of a range of osmotically active molecules/ions including soluble sugars, sugar alcohols, proline, glycinebetaine, organic acids, calcium, potassium, chloride ions, etc. Under water deficit and as a result of solute accumulation, the osmotic potential of the cell is lowered, which attracts water into the cell and helps with the maintenance of turgor. As a mechanism, osmotic adjustment has been suggested as an important trait in postponing the dehydration stress in water scarce environments (Morgan, 1990). Thus crop productivity under water stress is dependent on relative water content (RWC) and osmotic potential. For better growth and development higher values of RWC and osmotic adjustment is required. During drought stress the relative water content of plant decreases to an extent of 60–80% with increase in osmotic potential of the plant cells (Singh *et al.*, 2015). This increases the level of osmolytes and ensures the plant to maintain its water content during drought enabling the plant to sustain its growth and yield (Blum, 2005). The difference of relative water content (RWC) has been reported as 18.6 and 21.80% for most resistant and most sensitive genotypes to drought stress in 2 years of experiment (Merah, 2001). In studies that performed on 4 cultivars of bread wheat, RWC reduced to 43% (from 88% to 45%) by moisture stress (Siddique *et al.*, 2000). Our investigated results are in accordance with Akram *et al.* (2013); Pandey and Shukla (2015); Tasmina *et al.* (2016); Khan *et al.* (2017); Hossain *et al.* (2020).

#### **4.3.18.3 Interaction effect of species and drought stress**

Relative water content was significantly differed by different wild rice species and drought stress (Table 4.3.27). V<sub>11</sub>D<sub>1</sub> scored the highest relative water content (95.23%) which was statistically similar with V<sub>10</sub>D<sub>1</sub>, V<sub>10</sub>D<sub>2</sub>, V<sub>11</sub>D<sub>2</sub>, V<sub>12</sub>D<sub>1</sub>, V<sub>9</sub>D<sub>1</sub> and V<sub>5</sub>D<sub>1</sub>. On the other hand V<sub>7</sub>D<sub>2</sub> scored the lowest relative water content (82.90%) which was statistically similar with V<sub>8</sub>D<sub>2</sub>, V<sub>4</sub>D<sub>2</sub>, V<sub>3</sub>D<sub>2</sub>, V<sub>2</sub>D<sub>2</sub>, V<sub>1</sub>D<sub>2</sub> and V<sub>7</sub>D<sub>1</sub>.

**Table 4.3.26 Water relation behavior of wild species of rice under drought stress**

| Treatments                      | Relative water content (%) | Water saturation deficit (%) | Water retention capacity | Water uptake capacity |
|---------------------------------|----------------------------|------------------------------|--------------------------|-----------------------|
| <b>Effect of species</b>        |                            |                              |                          |                       |
| V <sub>1</sub>                  | 88.73 de                   | 11.27 c-e                    | 3.77 de                  | 0.300 ef              |
| V <sub>2</sub>                  | 88.13 de                   | 11.87 b-d                    | 3.65 d-f                 | 0.300 ef              |
| V <sub>3</sub>                  | 88.00 de                   | 12.00 bc                     | 3.63 d-f                 | 0.298 f               |
| V <sub>4</sub>                  | 87.84 d-f                  | 12.16 bc                     | 3.75 d-f                 | 0.320 d               |
| V <sub>5</sub>                  | 89.47 c-e                  | 10.46 ef                     | 4.10 d                   | 0.310 de              |
| V <sub>6</sub>                  | 89.10 c-e                  | 10.90 de                     | 3.86 de                  | 0.302 ef              |
| V <sub>7</sub>                  | 84.94 f                    | 15.06 a                      | 2.74 g                   | 0.252 g               |
| V <sub>8</sub>                  | 87.31 ef                   | 12.69 b                      | 3.42 ef                  | 0.292 f               |
| V <sub>9</sub>                  | 91.99 a-c                  | 8.01 g                       | 5.46 c                   | 0.347 c               |
| V <sub>10</sub>                 | 93.33 ab                   | 6.67 h                       | 6.99 b                   | 0.387 b               |
| V <sub>11</sub>                 | 94.24 a                    | 5.76 h                       | 8.58 a                   | 0.410 a               |
| V <sub>12</sub>                 | 90.47 b-d                  | 9.53 f                       | 3.28 f                   | 0.212 h               |
| <b>LSD<sub>(0.05)</sub></b>     | <b>3.02</b>                | <b>1.07</b>                  | <b>0.47</b>              | <b>0.01</b>           |
| <b>CV (%)</b>                   | <b>2.9</b>                 | <b>8.72</b>                  | <b>9.19</b>              | <b>6.62</b>           |
| <b>Effect of drought stress</b> |                            |                              |                          |                       |
| D <sub>1</sub>                  | 91.18 a                    | 8.81 b                       | 5.23 a                   | 0.33 a                |
| D <sub>2</sub>                  | 87.75 b                    | 12.25 a                      | 3.64 b                   | 0.29 b                |
| <b>LSD<sub>(0.05)</sub></b>     | <b>1.61</b>                | <b>0.57</b>                  | <b>0.25</b>              | <b>0.01</b>           |
| <b>CV (%)</b>                   | <b>2.9</b>                 | <b>8.72</b>                  | <b>9.19</b>              | <b>6.62</b>           |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*; D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

The maximum decrease of relative water content (5.51%) was obtained from rice genotype BRRI Dhan29 (check variety as drought sensitive) (V<sub>8</sub>) and the minimum decrease of relative water content (1.77%) was obtained from wild rice genotype *Potericia coaractata* (V<sub>10</sub>) (Table 4.3.28).

### 4.3.19 Water saturation deficit

#### 4.3.19.1 Effect of species

Water saturation deficit is inversely related with Relative water content. Water saturation deficit was significantly varied by different wild rice species (Table 4.3.26). FR13A (V<sub>7</sub>) attained the maximum water saturation deficit (15.06%) and *O. latifolia* (V<sub>11</sub>) attained the minimum water saturation deficit (5.76%) which was statistically at par with V<sub>10</sub>.

**Table 4.3.27 Interaction effect of species and drought stress on the water relation behavior of wild species of rice**

| Treatments                     | Relative water content (%) | Water saturation deficit (%) | Water retention capacity | Water uptake capacity |
|--------------------------------|----------------------------|------------------------------|--------------------------|-----------------------|
| V <sub>1</sub> D <sub>1</sub>  | 90.60 b-e                  | 9.40 fg                      | 4.37 e-g                 | 0.313 ef              |
| V <sub>1</sub> D <sub>2</sub>  | 86.86 e-i                  | 13.14 cde                    | 3.17 ij                  | 0.287 hi              |
| V <sub>2</sub> D <sub>1</sub>  | 90.18 b-f                  | 9.82 fg                      | 4.20 e-g                 | 0.310 fg              |
| V <sub>2</sub> D <sub>2</sub>  | 86.08 f-i                  | 13.92 b-d                    | 3.10 ij                  | 0.290 h               |
| V <sub>3</sub> D <sub>1</sub>  | 90.22 b-f                  | 9.78 fg                      | 4.35 e-g                 | 0.323 ef              |
| V <sub>3</sub> D <sub>2</sub>  | 85.77 g-i                  | 14.23 bc                     | 2.91 jk                  | 0.273 ij              |
| V <sub>4</sub> D <sub>1</sub>  | 90.14 b-f                  | 9.86 fg                      | 4.32 e-g                 | 0.327 e               |
| V <sub>4</sub> D <sub>2</sub>  | 85.54 g-i                  | 14.46 bc                     | 3.19 ij                  | 0.313 ef              |
| V <sub>5</sub> D <sub>1</sub>  | 91.46 a-d                  | 8.41 gh                      | 4.80 e                   | 0.323 ef              |
| V <sub>5</sub> D <sub>2</sub>  | 87.49 d-h                  | 12.51 de                     | 3.39 h-j                 | 0.297 gh              |
| V <sub>6</sub> D <sub>1</sub>  | 90.61 b-e                  | 9.39 fg                      | 4.36 e-g                 | 0.310 fg              |
| V <sub>6</sub> D <sub>2</sub>  | 87.60 d-h                  | 12.40 e                      | 3.36 ij                  | 0.293 h               |
| V <sub>7</sub> D <sub>1</sub>  | 86.99 e-i                  | 13.01 c-e                    | 3.20 ij                  | 0.287 hi              |
| V <sub>7</sub> D <sub>2</sub>  | 82.90 i                    | 17.10 a                      | 2.27 k                   | 0.217 k               |
| V <sub>8</sub> D <sub>1</sub>  | 89.78 c-g                  | 10.22 f                      | 4.06 f-h                 | 0.313 ef              |
| V <sub>8</sub> D <sub>2</sub>  | 84.83 hi                   | 15.17 b                      | 2.78 jk                  | 0.270 j               |
| V <sub>9</sub> D <sub>1</sub>  | 93.16 a-c                  | 6.84 ij                      | 6.46 c                   | 0.377 c               |
| V <sub>9</sub> D <sub>2</sub>  | 90.83 b-e                  | 9.17 fg                      | 4.47 ef                  | 0.317 ef              |
| V <sub>10</sub> D <sub>1</sub> | 94.17 ab                   | 5.83 jk                      | 8.30 b                   | 0.423 b               |
| V <sub>10</sub> D <sub>2</sub> | 92.50 a-c                  | 7.50 hi                      | 5.67 d                   | 0.350 d               |
| V <sub>11</sub> D <sub>1</sub> | 95.23 a                    | 4.77 k                       | 10.61 a                  | 0.447 a               |
| V <sub>11</sub> D <sub>2</sub> | 93.25 a-c                  | 6.75 ij                      | 6.54 c                   | 0.373 c               |
| V <sub>12</sub> D <sub>1</sub> | 91.59 a-d                  | 8.41 gh                      | 3.72 g-i                 | 0.227 k               |
| V <sub>12</sub> D <sub>2</sub> | 89.35 c-g                  | 10.65 f                      | 2.85 jk                  | 0.197 l               |
| <b>LSD<sub>(0.05)</sub></b>    | <b>4.27</b>                | <b>1.51</b>                  | <b>0.67</b>              | <b>0.02</b>           |
| <b>CV (%)</b>                  | <b>2.90</b>                | <b>8.72</b>                  | <b>9.19</b>              | <b>6.62</b>           |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*; D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

#### 4.3.19.2 Effect of drought stress

Water saturation deficit was significantly varied by drought stress (Table 4.3.26). D<sub>2</sub> attained the maximum water saturation deficit (12.25%) and D<sub>1</sub> attained the minimum water saturation deficit (8.81%). Tasmina *et al.* (2016) described that water saturation deficit (WSD) is the deviation of water content from the leaf compared to the saturation level of that leaf at a particular situation. A higher water saturation deficit indicates that the plants are subjected to a greater degree of water deficit. The



increasing trend of WSD under water deficit condition was also reported by Baque *et al.* (2006); Islam (2008); Choudhury (2009); Mahmud (2012).

**Table 4.3.28 Relative water content of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity (Control) | 40-45% field capacity | Decrease over control (%) |
|-----------------|-------------------------------|-----------------------|---------------------------|
| V <sub>1</sub>  | 90.60                         | 86.86                 | 4.13                      |
| V <sub>2</sub>  | 90.18                         | 86.08                 | 4.55                      |
| V <sub>3</sub>  | 90.22                         | 85.77                 | 4.93                      |
| V <sub>4</sub>  | 90.14                         | 85.54                 | 5.10                      |
| V <sub>5</sub>  | 91.46                         | 87.49                 | 4.34                      |
| V <sub>6</sub>  | 90.61                         | 87.60                 | 3.32                      |
| V <sub>7</sub>  | 86.99                         | 82.90                 | 4.70                      |
| V <sub>8</sub>  | 89.78                         | 84.83                 | 5.51                      |
| V <sub>9</sub>  | 93.16                         | 90.83                 | 2.50                      |
| V <sub>10</sub> | 94.17                         | 92.50                 | 1.77                      |
| V <sub>11</sub> | 95.23                         | 93.25                 | 2.08                      |
| V <sub>12</sub> | 91.59                         | 89.35                 | 2.45                      |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### 4.3.19.3 Interaction effect of species and drought stress

Water saturation deficit was significantly varied by the interaction of wild rice species and drought stress (Table 4.3.27). V<sub>7</sub>D<sub>2</sub> attained the maximum water saturation deficit (17.10%) and V<sub>11</sub>D<sub>1</sub> attained the minimum water saturation deficit (4.77%) which was statistically at par with V<sub>10</sub>D<sub>1</sub>.

The maximum increase of water saturation deficit (48.75%) was obtained from wild rice genotype *O. longistaminata* (V<sub>5</sub>) and the minimum increase of water saturation deficit (26.63%) was obtained from wild rice genotype *O. officinalis* (V<sub>12</sub>) (Table 4.3.29).

#### 4.3.20 Water retention capacity

##### 4.3.20.1 Effect of species

Significant variation was found for water retention capacity among the wild rice varieties (Table 4.3.26). The result showed that the maximum water retention capacity

(8.58) was achieved by *O. latifolia* (V<sub>11</sub>) and the minimum water retention capacity (2.74) was achieved by FR13A (V<sub>7</sub>). The results obtained in our study are in agreement with the findings of Tasmina *et al.* (2016) who showed that BARI Gom 26 and Sourav had the lowest reduction in WRC and thus an indication of their tolerance to drought stress.

**Table 4.3.29 Water saturation deficit of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Increase over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 9.40                             | 13.14                 | 39.83                        |
| V <sub>2</sub>  | 9.82                             | 13.92                 | 41.75                        |
| V <sub>3</sub>  | 9.78                             | 14.23                 | 45.50                        |
| V <sub>4</sub>  | 9.86                             | 14.46                 | 46.61                        |
| V <sub>5</sub>  | 8.41                             | 12.51                 | 48.75                        |
| V <sub>6</sub>  | 9.39                             | 12.40                 | 32.06                        |
| V <sub>7</sub>  | 13.01                            | 17.10                 | 31.44                        |
| V <sub>8</sub>  | 10.22                            | 15.17                 | 48.43                        |
| V <sub>9</sub>  | 6.84                             | 9.17                  | 34.05                        |
| V <sub>10</sub> | 5.83                             | 7.50                  | 28.76                        |
| V <sub>11</sub> | 4.77                             | 6.75                  | 41.54                        |
| V <sub>12</sub> | 8.41                             | 10.65                 | 26.63                        |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### 4.3.20.2 Effect of drought stress

Significant variation was found for water retention capacity among the drought stress (Table 4.3.26). The result showed that the maximum water retention capacity (5.23) was achieved by D<sub>1</sub> and the minimum water retention capacity (3.64) was achieved by D<sub>2</sub>. Sangakkara *et al.* (1996) reported that plants grow under high moisture regimes maintain a higher water retention capacity (WRC) which might be due to lower destruction of plant tissues by moisture deficit. Our findings are close confirmation with the findings of Choudhury (2009) in French bean; Martinez *et al.* (2007) in *Phaseolus vulgaris*; Hossain *et al.* (2016); Tasmina *et al.* (2016); Saha *et al.* (2019) in rice who reported that under drought stress WRC decreased but the extent of reduction was differed with genotypic variation.

#### 4.3.20.3 Interaction effect of species and drought stress

Significant variation was found for water retention capacity between the wild rice genotypes and drought stress (Table 4.3.27). The result showed that the maximum water retention capacity (10.61) was achieved by V<sub>11</sub>D<sub>1</sub> and the minimum water retention capacity (2.27) was achieved by V<sub>7</sub>D<sub>2</sub> which was statistically similar with V<sub>8</sub>D<sub>2</sub>, V<sub>12</sub>D<sub>2</sub> and V<sub>3</sub>D<sub>2</sub>.

The maximum decrease of water retention capacity (38.33%) was obtained from wild rice genotype *O. latifolia* (V<sub>11</sub>) and the minimum decrease of water retention capacity (22.95%) was obtained from wild rice genotype *O. glaberrima* (V<sub>6</sub>) (Table 4.3.30).

**Table 4.3.30 Water retention capacity of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 4.37                             | 3.17                  | 27.53                        |
| V <sub>2</sub>  | 4.20                             | 3.10                  | 26.17                        |
| V <sub>3</sub>  | 4.35                             | 2.91                  | 33.22                        |
| V <sub>4</sub>  | 4.32                             | 3.19                  | 26.18                        |
| V <sub>5</sub>  | 4.80                             | 3.39                  | 29.36                        |
| V <sub>6</sub>  | 4.36                             | 3.36                  | 22.95                        |
| V <sub>7</sub>  | 3.20                             | 2.27                  | 28.90                        |
| V <sub>8</sub>  | 4.06                             | 2.78                  | 31.60                        |
| V <sub>9</sub>  | 6.46                             | 4.47                  | 30.85                        |
| V <sub>10</sub> | 8.30                             | 5.67                  | 31.71                        |
| V <sub>11</sub> | 10.61                            | 6.54                  | 38.33                        |
| V <sub>12</sub> | 3.72                             | 2.85                  | 23.33                        |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### 4.3.21 Water uptake capacity

##### 4.3.21.1 Effect of species

Water uptake capacity of rice was significantly influenced by different genotypes (Table 4.3.26). Result exposed that the maximum water uptake capacity (0.41) was observed in *O. latifolia* (V<sub>11</sub>) and the minimum water uptake capacity (0.21) was observed in *O. officinalis* (V<sub>12</sub>). Similar results were also described by Choudhury

(2009); Mahmud (2012); Tasmina *et al.* (2016) who depicted that the tolerance rice varieties possessed the highest WUC under water stress compared to other varieties.

#### 4.3.21.2 Effect of drought stress

Water uptake capacity of rice was significantly influenced by drought stress (Table 4.3.26). Result exposed that the maximum water uptake capacity (0.33) was observed in D<sub>1</sub> and the minimum water uptake capacity (0.29) was observed in D<sub>2</sub>. A decrease of WUC under water deficit condition was also reported by Abbad *et al.* (2004); Tasmina *et al.* (2016).

#### 4.3.21.3 Interaction effect of species and drought stress

Water uptake capacity of rice was significantly influenced by the interaction of different genotypes and drought stress (Table 4.3.27). Result exposed that the maximum water uptake capacity (0.45) was observed in V<sub>11</sub>D<sub>1</sub> and the minimum water uptake capacity (0.20) was observed in V<sub>12</sub>D<sub>2</sub>.

The maximum decrease of water uptake capacity (24.42%) was obtained from rice genotype FR13A (Check variety as drought tolerant) (V<sub>7</sub>) and the minimum decrease of water uptake capacity (5.39%) was obtained from wild rice genotype *O. glaberrima* (V<sub>6</sub>) (Table 4.3.31).

**Table 4.3.31 Water uptake capacity of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 0.31                             | 0.29                  | 8.49                         |
| V <sub>2</sub>  | 0.31                             | 0.29                  | 6.45                         |
| V <sub>3</sub>  | 0.32                             | 0.27                  | 15.47                        |
| V <sub>4</sub>  | 0.33                             | 0.31                  | 4.10                         |
| V <sub>5</sub>  | 0.32                             | 0.30                  | 8.23                         |
| V <sub>6</sub>  | 0.31                             | 0.29                  | 5.39                         |
| V <sub>7</sub>  | 0.29                             | 0.22                  | 24.42                        |
| V <sub>8</sub>  | 0.31                             | 0.27                  | 13.82                        |
| V <sub>9</sub>  | 0.38                             | 0.32                  | 15.93                        |
| V <sub>10</sub> | 0.42                             | 0.35                  | 17.32                        |
| V <sub>11</sub> | 0.45                             | 0.37                  | 16.43                        |
| V <sub>12</sub> | 0.23                             | 0.20                  | 13.23                        |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### 4.3.22 Chlorophyll a content on leaf

##### 4.3.22.1 Effect of species

Chlorophyll a content on leaf was significantly differed by different rice genotypes (Table 4.3.32). The maximum Chlorophyll a content on leaf (22.16 mg g<sup>-1</sup> FW) was obtained from *O. latifolia* (V<sub>11</sub>) which was statistically similar with V<sub>10</sub> and the minimum Chlorophyll a content on leaf (17.41 mg g<sup>-1</sup> FW) was obtained from *O. officinalis* (V<sub>12</sub>) which was statistically similar with V<sub>8</sub>, V<sub>5</sub>, V<sub>4</sub>, V<sub>3</sub> and V<sub>1</sub>. Kartika *et al.* (2020) reported that drought stress caused no significant chlorophyll reduction for *O. glaberrima* genotypes, but there was a sharp reduction in *O. sativa*. According to Pastori and Trippi (1992) resistant genotypes of wheat and corn had higher chlorophyll content than sensitive genotypes under the drought stress. Keyvan (2010) reported that chlorophyll a content decreased because of drought stress and decrease of chlorophyll a, was lowest in Chamran cultivar and highest in Shahryar cultivar. Similar results also reported by Ahmadikhah and Marufinia (2016).

##### 4.3.22.2 Effect of drought stress

Chlorophyll a content on leaf was significantly differed by drought stress (Table 4.3.32). The higher Chlorophyll a content on leaf (21.01 mg g<sup>-1</sup> FW) was obtained from D<sub>1</sub> and the lower Chlorophyll a content on leaf (17.12 mg g<sup>-1</sup> FW) was obtained from D<sub>2</sub>. Photosynthesis is an essential process to maintain crop growth and development, and it is well known that photosynthetic systems in higher plants are most sensitive to drought stress (Falk *et al.*, 1996). Chlorophyll is one of the important pigments of photosynthetic apparatus which absorbs light which transfers light energy to the reaction center of the photosystem and relative chlorophyll content has a positive relationship with photosynthetic rate (Guo and Li, 2000). According to Manivannan *et al.* (2007) chlorophyll is one of the major components of chloroplasts for photosynthesis which increases biomass production and grain yield (Pandey and Singh, 2010). Dalal and Tripathy (2012) showed that chlorophyll content was reduced under PEG-induced drought stress in rice seedlings. Ganji Arjenaki *et al.* (2012) also observed a reduction in chlorophyll content due to water stress at anthesis stage in

wheat. Exposure to drought stress leads to a significant effect in Chlorophyll a and Chlorophyll b contents (Ranjbarfordoei *et al.*, 2000). Cha-um *et al.* (2010); Mafakheri *et al.* (2010) reported a marked decrease in all physiological parameters due to drought stress in drought-sensitive rice and chickpea genotypes, respectively. Saeedipour (2012); Tasmina *et al.* (2016) reported that water deficits enhanced the senescence by accelerating loss of leaf chlorophyll and soluble proteins and the loss was more in sensitive one than tolerant one. According to Khayatnezhad (2012); Pastori and Trippi (1992) the genotypes of wheat and corn resistant to oxidative stress have higher chlorophyll content than sensitive genotypes. Similarly also stated by Gomes *et al.* (2008); Song and Banyo (2010) drought condition in Brazilian green dwarf coconut (*Cocos nucifera* L. nana) resulting in decreased leaf chlorophyll concentration per unit leaf area. A reason for decrease in chlorophyll content as affected by water deficit is that drought stress by producing reactive oxygen species (ROS), such as  $O_2^-$  and  $H_2O_2$ , can lead to lipid peroxidation and, consequently, chlorophyll destruction (Foyer *et al.*, 1994; Hirt and Shinozaki, 2004). Pandey and Shukla (2015) reported that the reduction in chlorophyll content may occur due to stress-induced impairment in pigment biosynthetic pathways or in pigment degradation, loss of the chloroplast membrane, and increased lipid peroxidation. In addition, with decreasing chlorophyll content due to the changing green color of the leaf into yellow, the reflectance of the incident radiation is increased (Schlemmer *et al.*, 2005). Chlorophyll helps plant to withstand consequences of drought. It has been reported that the decrease in photosynthesis leads to degradation of these pigments. These absorb light and thus perform several photochemical processes of photosynthesis (Polivka and Frank, 2010). These pigments also maintain  $CO_2$  assimilation rates and thus the proper functioning of the two photosystems of photosynthetic cells is ensured (Baker, 2008). Nikolaeva *et al.* (2010) revealed that the declined chlorophyll content from 13 to 15% in water-stressed wheat compared with well watered plants. The results of our present investigation are supported by Ahmadikhah and Marufinia (2016); Khan *et al.* (2017); Moonmoon *et al.* (2017) and Syamsia *et al.* (2018).

**Table 4.3.32 Effect of species and drought stress on chlorophyll, carotenoid and proline content of wild species of rice**

| Treatments                      | Chlorophyll a<br>content on leaf<br>(mg g <sup>-1</sup> FW) | Chlorophyll b<br>content on leaf<br>(mg g <sup>-1</sup> FW) | Carotenoid<br>content<br>(mg g <sup>-1</sup> FW) | Proline content<br>on leaf<br>(μmol g <sup>-1</sup> FW) |
|---------------------------------|-------------------------------------------------------------|-------------------------------------------------------------|--------------------------------------------------|---------------------------------------------------------|
| <b>Effect of species</b>        |                                                             |                                                             |                                                  |                                                         |
| V <sub>1</sub>                  | 18.03 cd                                                    | 13.82 cd                                                    | 4.49 e                                           | 0.465 cd                                                |
| V <sub>2</sub>                  | 19.00 c                                                     | 13.72 cd                                                    | 4.81 d                                           | 0.467 cd                                                |
| V <sub>3</sub>                  | 18.23 cd                                                    | 12.91 de                                                    | 4.50 e                                           | 0.475 c                                                 |
| V <sub>4</sub>                  | 18.51 cd                                                    | 13.65 cd                                                    | 5.12 c                                           | 0.498 b                                                 |
| V <sub>5</sub>                  | 18.04 cd                                                    | 14.01 c                                                     | 4.54 e                                           | 0.457 d                                                 |
| V <sub>6</sub>                  | 18.93 c                                                     | 13.94 c                                                     | 4.89 d                                           | 0.460 d                                                 |
| V <sub>7</sub>                  | 17.53 d                                                     | 12.23 e                                                     | 4.49 e                                           | 0.513 a                                                 |
| V <sub>8</sub>                  | 18.51 cd                                                    | 13.39 cd                                                    | 4.49 e                                           | 0.457 d                                                 |
| V <sub>9</sub>                  | 20.75 b                                                     | 15.26 b                                                     | 4.94 cd                                          | 0.423 e                                                 |
| V <sub>10</sub>                 | 21.66 ab                                                    | 15.89 ab                                                    | 5.48 b                                           | 0.390 f                                                 |
| V <sub>11</sub>                 | 22.16 a                                                     | 16.34 a                                                     | 5.72 a                                           | 0.380 f                                                 |
| V <sub>12</sub>                 | 17.41 d                                                     | 12.32 e                                                     | 3.83 f                                           | 0.457 d                                                 |
| <b>LSD<sub>(0.05)</sub></b>     | <b>1.16</b>                                                 | <b>0.95</b>                                                 | <b>0.23</b>                                      | <b>0.01</b>                                             |
| <b>CV (%)</b>                   | <b>5.23</b>                                                 | <b>5.85</b>                                                 | <b>4.07</b>                                      | <b>3.35</b>                                             |
| <b>Effect of drought stress</b> |                                                             |                                                             |                                                  |                                                         |
| D <sub>1</sub>                  | 21.01 a                                                     | 14.80 a                                                     | 5.23 a                                           | 0.40 b                                                  |
| D <sub>2</sub>                  | 17.12 b                                                     | 13.12 b                                                     | 4.33 b                                           | 0.51 a                                                  |
| <b>LSD<sub>(0.05)</sub></b>     | <b>0.62</b>                                                 | <b>0.51</b>                                                 | <b>0.12</b>                                      | <b>0.01</b>                                             |
| <b>CV (%)</b>                   | <b>5.23</b>                                                 | <b>5.85</b>                                                 | <b>4.07</b>                                      | <b>3.35</b>                                             |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*; D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

#### 4.3.22.3 Interaction effect of species and drought stress

Chlorophyll a content on leaf was significantly differed by different rice genotypes and drought stress (Table 4.3.33). The maximum Chlorophyll a content on leaf (23.01 mg g<sup>-1</sup> FW) was obtained from V<sub>11</sub>D<sub>1</sub> which was statistically similar with V<sub>10</sub>D<sub>1</sub>, V<sub>6</sub>D<sub>1</sub>, V<sub>2</sub>D<sub>1</sub>, V<sub>4</sub>D<sub>1</sub> and V<sub>9</sub>D<sub>1</sub> and the minimum Chlorophyll a content on leaf (14.89 mg g<sup>-1</sup> FW) was obtained from V<sub>12</sub>D<sub>2</sub> which was statistically similar V<sub>7</sub>D<sub>2</sub>, V<sub>4</sub>D<sub>2</sub>, V<sub>3</sub>D<sub>2</sub>, V<sub>2</sub>D<sub>2</sub>, V<sub>6</sub>D<sub>2</sub> and V<sub>8</sub>D<sub>2</sub>.

The maximum decrease of chlorophyll ‘a’ content on leaf (26.96%) was observed from wild rice genotype *O. nivara* (V<sub>3</sub>) and the minimum decrease of chlorophyll ‘a’ content on leaf (4.86%) was observed from wild rice genotype *Potericia coaractata* (V<sub>10</sub>) (Table 4.3.34).

**Table 4.3.33 Interaction effect of species and drought stress on chlorophyll, carotenoid and proline content of wild species of rice**

| Treatments                     | Chlorophyll a<br>content on leaf<br>(mg g <sup>-1</sup> FW) | Chlorophyll b<br>content on leaf<br>(mg g <sup>-1</sup> FW) | Carotenoid<br>content<br>(mg g <sup>-1</sup> FW) | Proline content<br>on leaf<br>(μmol g <sup>-1</sup> FW) |
|--------------------------------|-------------------------------------------------------------|-------------------------------------------------------------|--------------------------------------------------|---------------------------------------------------------|
| V <sub>1</sub> D <sub>1</sub>  | 19.44 ef                                                    | 14.63 d-f                                                   | 4.89 e-g                                         | 0.407 ij                                                |
| V <sub>1</sub> D <sub>2</sub>  | 16.62 g                                                     | 13.02 gh                                                    | 4.08 hi                                          | 0.523 d                                                 |
| V <sub>2</sub> D <sub>1</sub>  | 21.59 a-c                                                   | 14.99 b-e                                                   | 5.63 bc                                          | 0.417 hi                                                |
| V <sub>2</sub> D <sub>2</sub>  | 16.40 gh                                                    | 12.45 h-j                                                   | 3.99 h-j                                         | 0.517 de                                                |
| V <sub>3</sub> D <sub>1</sub>  | 21.07 b-e                                                   | 14.24 d-g                                                   | 5.16 de                                          | 0.410 ij                                                |
| V <sub>3</sub> D <sub>2</sub>  | 15.39 gh                                                    | 11.58 ij                                                    | 3.84 ij                                          | 0.540 c                                                 |
| V <sub>4</sub> D <sub>1</sub>  | 21.39 a-d                                                   | 14.83 c-e                                                   | 5.44 cd                                          | 0.427 gh                                                |
| V <sub>4</sub> D <sub>2</sub>  | 15.63 gh                                                    | 12.46 h-j                                                   | 4.80 fg                                          | 0.570 b                                                 |
| V <sub>5</sub> D <sub>1</sub>  | 19.32 f                                                     | 14.71 c-e                                                   | 4.87 e-g                                         | 0.407 ij                                                |
| V <sub>5</sub> D <sub>2</sub>  | 16.75 g                                                     | 13.30 f-h                                                   | 4.21 h                                           | 0.507 e                                                 |
| V <sub>6</sub> D <sub>1</sub>  | 21.98 ab                                                    | 15.42 a-d                                                   | 5.64 bc                                          | 0.410 ij                                                |
| V <sub>6</sub> D <sub>2</sub>  | 15.88 gh                                                    | 12.46 h-j                                                   | 4.13 hi                                          | 0.510 de                                                |
| V <sub>7</sub> D <sub>1</sub>  | 20.09 c-f                                                   | 13.27 gh                                                    | 5.08 ef                                          | 0.433 g                                                 |
| V <sub>7</sub> D <sub>2</sub>  | 14.97 h                                                     | 11.19 j                                                     | 3.90 h-j                                         | 0.593 a                                                 |
| V <sub>8</sub> D <sub>1</sub>  | 20.65 b-f                                                   | 13.88 e-g                                                   | 4.96 e-g                                         | 0.397 jk                                                |
| V <sub>8</sub> D <sub>2</sub>  | 16.37 gh                                                    | 12.90 g-i                                                   | 4.02 hi                                          | 0.517 de                                                |
| V <sub>9</sub> D <sub>1</sub>  | 21.45 a-d                                                   | 15.57 a-d                                                   | 5.18 de                                          | 0.383 k                                                 |
| V <sub>9</sub> D <sub>2</sub>  | 20.06 c-f                                                   | 14.96 c-e                                                   | 4.70 g                                           | 0.463 f                                                 |
| V <sub>10</sub> D <sub>1</sub> | 22.20 ab                                                    | 16.31 ab                                                    | 5.88 ab                                          | 0.363 l                                                 |
| V <sub>10</sub> D <sub>2</sub> | 21.12 b-d                                                   | 15.48 a-d                                                   | 5.09 ef                                          | 0.417 hi                                                |
| V <sub>11</sub> D <sub>1</sub> | 23.01 a                                                     | 16.67 a                                                     | 6.09 a                                           | 0.360 l                                                 |
| V <sub>11</sub> D <sub>2</sub> | 21.32 b-d                                                   | 16.02 a-c                                                   | 5.48 cd                                          | 0.400 j                                                 |
| V <sub>12</sub> D <sub>1</sub> | 19.94 d-f                                                   | 13.05 gh                                                    | 3.97 h-j                                         | 0.410 ij                                                |
| V <sub>12</sub> D <sub>2</sub> | 14.89 h                                                     | 11.59 ij                                                    | 3.68 j                                           | 0.503 e                                                 |
| <b>LSD<sub>(0.05)</sub></b>    | <b>1.64</b>                                                 | <b>1.34</b>                                                 | <b>0.32</b>                                      | <b>0.02</b>                                             |
| <b>CV (%)</b>                  | <b>5.23</b>                                                 | <b>5.85</b>                                                 | <b>4.07</b>                                      | <b>3.35</b>                                             |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*; D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

### 4.3.23 Chlorophyll b content on leaf

#### 4.3.23.1 Effect of species

Chlorophyll b content on leaf was varied significantly by different rice genotypes (Table 4.3.32). The maximum Chlorophyll b content on leaf (16.34 mg g<sup>-1</sup> FW) was found from *O. latifolia* (V<sub>11</sub>) which was statistically similar with V<sub>10</sub> and the minimum Chlorophyll b content on leaf (12.23 mg g<sup>-1</sup> FW) was found from FR13A (V<sub>7</sub>) which was statistically similar with V<sub>12</sub> and V<sub>3</sub>. Similar findings are also reported



by Keyvan (2010); Maisura *et al.* (2014) who revealed that Chlorophyll b content on leaf was reduced under drought stress and it varied with different rice genotypes might be due to their different genetic potentiality.

**Table 4.3.34 Chlorophyll ‘a’ content on leaf of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 19.44                            | 16.62                 | 14.51                        |
| V <sub>2</sub>  | 21.59                            | 16.40                 | 24.04                        |
| V <sub>3</sub>  | 21.07                            | 15.39                 | 26.96                        |
| V <sub>4</sub>  | 21.39                            | 15.63                 | 26.93                        |
| V <sub>5</sub>  | 19.32                            | 16.75                 | 13.30                        |
| V <sub>6</sub>  | 21.98                            | 15.88                 | 27.75                        |
| V <sub>7</sub>  | 20.09                            | 14.97                 | 25.49                        |
| V <sub>8</sub>  | 20.65                            | 16.37                 | 20.73                        |
| V <sub>9</sub>  | 21.45                            | 20.06                 | 6.48                         |
| V <sub>10</sub> | 22.20                            | 21.12                 | 4.86                         |
| V <sub>11</sub> | 23.01                            | 21.32                 | 7.34                         |
| V <sub>12</sub> | 19.94                            | 14.89                 | 25.33                        |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### 4.3.23.2 Effect of drought stress

Chlorophyll b content on leaf was varied significantly by drought stress (Table 4.3.32). The higher Chlorophyll b content on leaf (14.80 mg g<sup>-1</sup> FW) was found from D<sub>1</sub> and the lower Chlorophyll b content on leaf (13.12 mg g<sup>-1</sup> FW) was obtained from D<sub>2</sub>. Maisura *et al.* (2014) explained that drought stress caused a strong loss of chlorophyll in the photosynthetic reaction centers. Ashraf *et al.* (1994) reported that drought stress will reduce concentration of chlorophyll b more than chlorophyll a. Chlorophyll b serves as an antenna that collects light and transfers to the reaction center. Light energy is converted into chemical energy in the reaction center which can then be used in the reduction process of photosynthesis (Taiz and Zeiger, 1991). Result from the same research done in two lines of okra showed inverse fact to our research that drought can cause an increase in chlorophyll-b content (Jaleel *et al.*, 2009). Other research results showed that chlorophyll-a and chlorophyll-b are susceptible to dehydration (Farooq *et al.*, 2009b). Meanwhile, the decrease in

chlorophyll was associated with a reduction in the flux of nitrogen into the tissue, as well as alteration in activity of enzyme systems, such as nitrate reductase (Taiz and Zeiger, 1991). Chlorophyll plays an important part in the light harvesting process of photosynthesis and in reducing over energy (Anjum *et al.*, 2011). A reduced chlorophyll content is predicted to occur because the loss of the chloroplast membrane, excessive swelling in lamella vascular, and lipid peroxidation (Kaiser, 1987). Syamsia *et al.* (2018) revealed that the value of chlorophyll-b content on paddy leaf is lowest on drought treatment that is 0.141 compared with other treatments. According to Khayatnezhad (2012) synthesis of chlorophyll is very important, after heavy rains total of chlorophyll increased, but in dry time its value decreased. Chlorophyll-a and chlorophyll-b attributes for accumulation of solutes in cell sap through passive accumulation resulting from reduced cell size (Chutia and Borah, 2012) which significantly did osmotic adjustment in chickpea (Mafakheri *et al.*, 2010).

#### **4.3.23.3 Interaction effect of species and drought stress**

Chlorophyll b content on leaf was varied significantly by different rice genotypes and drought stress (Table 4.3.33). The maximum Chlorophyll b content on leaf (16.67 mg g<sup>-1</sup> FW) was found from V<sub>11</sub>D<sub>1</sub> which was statistically similar with V<sub>10</sub>D<sub>1</sub>, V<sub>11</sub>D<sub>2</sub>, V<sub>10</sub>D<sub>2</sub>, V<sub>9</sub>D<sub>1</sub> and V<sub>6</sub>D<sub>1</sub> and the minimum Chlorophyll b content on leaf (11.19 mg g<sup>-1</sup> FW) was found from V<sub>7</sub>D<sub>2</sub> which was statistically similar V<sub>12</sub>D<sub>2</sub>, V<sub>3</sub>D<sub>2</sub>, V<sub>2</sub>D<sub>2</sub>, V<sub>4</sub>D<sub>2</sub> and V<sub>6</sub>D<sub>2</sub>.

The maximum decrease of chlorophyll 'b' content on leaf (19.20%) was obtained from wild rice genotype *O. glaberrima* (V<sub>6</sub>) and the minimum decrease of chlorophyll 'b' content on leaf (3.90%) was obtained from wild rice genotype *O. latifolia* (V<sub>11</sub>) (Table 4.3.35).

#### **4.3.24 Carotenoid content**

##### **4.3.24.1 Effect of species**

Different rice varieties had significant influence on carotenoid content of rice (Table 4.3.32). Data revealed that the maximum carotenoid content (5.78 mg g<sup>-1</sup> FW) was

received from *O. latifolia* (V<sub>11</sub>) and the minimum carotenoid content (3.83 mg g<sup>-1</sup> FW) was received from *O. officinalis* (V<sub>12</sub>).

**Table 4.3.35 Chlorophyll ‘b’ content on leaf of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 14.63                            | 13.02                 | 11.00                        |
| V <sub>2</sub>  | 14.99                            | 12.45                 | 16.94                        |
| V <sub>3</sub>  | 14.24                            | 11.58                 | 18.68                        |
| V <sub>4</sub>  | 14.83                            | 12.46                 | 15.98                        |
| V <sub>5</sub>  | 14.71                            | 13.30                 | 9.59                         |
| V <sub>6</sub>  | 15.42                            | 12.46                 | 19.20                        |
| V <sub>7</sub>  | 13.27                            | 11.19                 | 15.67                        |
| V <sub>8</sub>  | 13.88                            | 12.90                 | 7.06                         |
| V <sub>9</sub>  | 15.57                            | 14.96                 | 3.92                         |
| V <sub>10</sub> | 16.31                            | 15.48                 | 5.09                         |
| V <sub>11</sub> | 16.67                            | 16.02                 | 3.90                         |
| V <sub>12</sub> | 13.05                            | 11.59                 | 11.19                        |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### 4.3.24.2 Effect of drought stress

Drought stress had significant influence on carotenoid content of rice (Table 4.3.32). Data revealed that the higher carotenoid content (5.23 mg g<sup>-1</sup> FW) was received from D<sub>1</sub> and the lower carotenoid content (4.33 mg g<sup>-1</sup> FW) was received from D<sub>2</sub>. Drought stress affects the biochemical processes in plant cells (Ai, 2011; Syamsia *et al.*, 2018). Carotenoids protect plants from oxidative damage caused by ROS production during drought and thus show several roles in drought tolerance (Loggini *et al.*, 1999; Ratnayaka *et al.*, 2003). Carotenoid pigments strengthen the photosystem during the water stress condition because it absorbs the excess light energy and transfers it to the photosystem. Carotenoids have capacity to scavenge singlet oxygen and lipid peroxy-radicals, as well as to inhibit lipid peroxidation and superoxide generation under dehydrative forces (Deltoro *et al.*, 1998). The results of our investigation are corroborated with the findings reported by Maisura *et al.* (2014); Khan *et al.* (2017); Syamsia *et al.* (2018) who concluded that drought stress reduces the carotenoids content in crop plants but the potent of reduction varied with genotypes drought tolerant capacity.

#### 4.3.24.3 Interaction effect of species and drought stress

Different rice varieties and drought stress had significant influence on carotenoid content of rice (Table 4.3.33). Data revealed that the maximum carotenoid content (6.09 mg g<sup>-1</sup> FW) was received from V<sub>11</sub>D<sub>1</sub> which was statistically similar with V<sub>10</sub>D<sub>1</sub> and the minimum carotenoid content (3.68 mg g<sup>-1</sup> FW) was received from V<sub>12</sub>D<sub>2</sub> was statistically similar with V<sub>3</sub>D<sub>2</sub>, V<sub>2</sub>D<sub>2</sub>, V<sub>7</sub>D<sub>2</sub> and V<sub>12</sub>D<sub>1</sub>.

The maximum decrease of carotenoids content (29.18%) was obtained from wild rice genotype *O. punctata* (V<sub>2</sub>) and the minimum decrease of carotenoids content (7.45%) was obtained from wild rice genotype *O. officinalis* (V<sub>12</sub>) (Table 4.3.36).

**Table 4.3.36 Carotenoids content of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 4.89                             | 4.08                  | 16.62                        |
| V <sub>2</sub>  | 5.63                             | 3.99                  | 29.18                        |
| V <sub>3</sub>  | 5.16                             | 3.84                  | 25.62                        |
| V <sub>4</sub>  | 5.44                             | 4.80                  | 11.66                        |
| V <sub>5</sub>  | 4.87                             | 4.21                  | 13.61                        |
| V <sub>6</sub>  | 5.64                             | 4.13                  | 26.87                        |
| V <sub>7</sub>  | 5.08                             | 3.90                  | 23.24                        |
| V <sub>8</sub>  | 4.96                             | 4.02                  | 18.84                        |
| V <sub>9</sub>  | 5.18                             | 4.70                  | 9.26                         |
| V <sub>10</sub> | 5.88                             | 5.09                  | 13.49                        |
| V <sub>11</sub> | 6.09                             | 5.48                  | 10.02                        |
| V <sub>12</sub> | 3.97                             | 3.68                  | 7.45                         |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### 4.3.25 Proline content on leaf

##### 4.3.25.1 Effect of species

Significant variation was found for proline content on leaf of wild rice due to different rice genotypes (Table 4.3.32). The data of our findings revealed that the maximum proline content on leaf (0.51 µmol g<sup>-1</sup> FW) was recorded from FR13A (V<sub>7</sub>) and the minimum proline content on leaf (0.38 µmol g<sup>-1</sup> FW) was recorded from *O. latifolia* (V<sub>11</sub>) which was statistically similar with V<sub>10</sub>. Similar results also reported by Dien et

*al.* (2019) who revealed that under drought stress conditions, DA8 and Thierno Bande rice varieties accumulated more proline than other varieties in 2015. In 2017 experiment, DA8 remained higher proline content than Malagkit Pirurutong and Kinandang Patong varieties.

#### **4.3.25.2 Effect of drought stress**

Significant variation was found for proline content on leaf of wild rice due to drought stress (Table 4.3.32). The data of our findings revealed that the higher proline content on leaf ( $0.51 \mu\text{mol g}^{-1} \text{FW}$ ) was recorded from D<sub>2</sub> treatment and the lower proline content on leaf ( $0.40 \mu\text{mol g}^{-1} \text{FW}$ ) was recorded from D<sub>1</sub> treatment. Plants have evolved a sophisticated and complex set of mechanisms to cope with environmental stresses. Overproduction of various compatible organic solutes is one of the most common stress responses of plants to environmental stresses (Serraj and Sinclair, 2002; Dien *et al.*, 2019). Osmotic adjustment is a biochemical mechanism that helps plants to acclimate to dry soil. Yue *et al.* (2006) stated that one of the best mechanism of drought tolerance through osmotic adjustment as the increased accumulation of solutes, such as proline. Proline accumulation is an early response when a plant is experiencing a water deficit, in which it decreases cell damage (Szabados and Savoure, 2010; Anjum *et al.* 2011; Maisura *et al.*, 2014). Proline was first noted to accumulate in wilted plant tissue by Kemble and MacPherson (1954) in experiments on excised perennial rye grass. Many plants and microorganisms accumulate proline as a response to osmotic stress (Hare *et al.*, 2002). Similarly, drought stress increased the accumulation of proline in groundnut varieties (Smith *et al.*, 2002; Ranganayakulu, 2015), in chickpea (Ayerb and Tenori, 1998; Mafakheri *et al.*, 2010) and in corn (Serraj and Sinclair, 2002). Hayat *et al.* (2012) reported that besides acting as an excellent osmolyte, proline plays three major roles during drought stress, *i.e.*, as a metal chelator, an antioxidative defense molecule and a signaling molecule. Proline permits osmotic adjustment, stabilizes the structure of proteins and cell membranes, acts as a protective agent for enzymes, and is a free radical scavenger and antioxidant (Sharma and Dietz, 2006; Ashraf and Foolad, 2007; Verbruggen and Hermans, 2008; Kishor and Sreenivasulu, 2014; Saha *et al.*, 2016b; Saha *et al.*, 2019). Furthermore, proline protects macromolecules from denaturation and also reduces acidity in the cell (Kishor *et al.*, 2005) and acts as an antioxidant (Vendruscolo *et al.*, 2007). According to Szabados and Savoure (2010), proline can

act as a molecular signal to modulate mitochondrial function, affect cell proliferation or cell death, and initiate certain gene expression that is important role in protecting plants from drought stress. Studies in transgenic plants have suggested that overproduction of proline enhances root biomass under drought in rice (Zhu *et al.*, 1998). Larger root systems can help plants absorb more water from the soil under drought stress conditions, and consequently more drought tolerant than other varieties. Proline accumulation does not only happen in a tolerant variety, but also on susceptible varieties. Some studies have shown that proline accumulation is generally an indicator of leaf dehydration and is associated with stress susceptibility (Hanson *et al.*, 1977). It was found that proline was highly accumulated in drought susceptible than drought resistant potato genotypes (Bansal and Nagarajan, 1986; Schafleitner *et al.*, 2007). The result of our experiment suggested that proline accumulation in rice depended not only on the severity of drought stress but also on the characteristics of varieties. In addition, higher proline accumulation ability contributed to higher drought tolerance in rice. Therefore, high proline accumulation ability might serve as an indicator for drought tolerance potential in rice. The results of our present investigation are also coinciding with the results of Pandey and Shukla (2015); Dien *et al.* (2019) and Saha *et al.* (2019) who mentioned that proline is highly accumulated under drought stress condition than control treatment.

#### **4.3.25.3 Interaction effect of species and drought stress**

Significant variation was found for proline content on leaf of wild rice due to different rice genotypes and drought stress (Table 4.3.33). The data of our findings revealed that the maximum proline content on leaf ( $0.59 \mu\text{mol g}^{-1} \text{FW}$ ) was recorded from  $V_7D_2$  treatment and the minimum proline content on leaf ( $0.36 \mu\text{mol g}^{-1} \text{FW}$ ) was recorded from both  $V_{10}D_1$  and  $V_{11}D_1$  treatment combinations.

The maximum increase of proline content (36.93%) was obtained from rice genotype FR13A (Check variety as drought tolerant) ( $V_7$ ) and the minimum increase of proline content (11.11%) was obtained from wild rice genotype *O. latifolia* ( $V_{11}$ ) (Table 4.3.37).

**Table 4.3.37 Proline content of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Increase over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 0.41                             | 0.52                  | 28.67                        |
| V <sub>2</sub>  | 0.42                             | 0.52                  | 24.00                        |
| V <sub>3</sub>  | 0.41                             | 0.54                  | 31.71                        |
| V <sub>4</sub>  | 0.43                             | 0.57                  | 33.58                        |
| V <sub>5</sub>  | 0.41                             | 0.51                  | 24.59                        |
| V <sub>6</sub>  | 0.41                             | 0.51                  | 24.39                        |
| V <sub>7</sub>  | 0.43                             | 0.59                  | 36.93                        |
| V <sub>8</sub>  | 0.40                             | 0.52                  | 30.25                        |
| V <sub>9</sub>  | 0.38                             | 0.46                  | 20.87                        |
| V <sub>10</sub> | 0.36                             | 0.42                  | 14.70                        |
| V <sub>11</sub> | 0.36                             | 0.40                  | 11.11                        |
| V <sub>12</sub> | 0.41                             | 0.50                  | 22.76                        |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### 4.3.26 Tillers hill<sup>-1</sup>

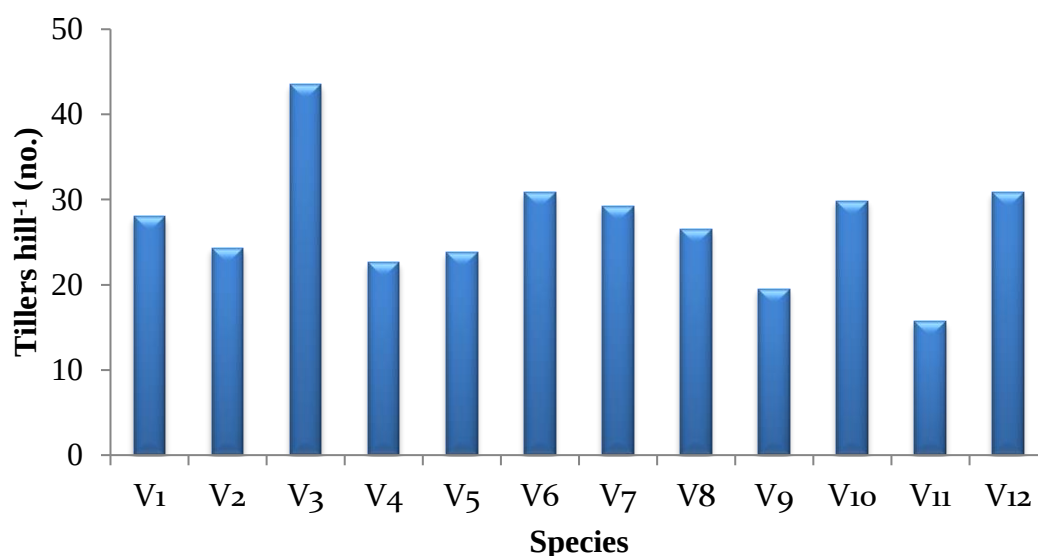
##### 4.3.26.1 Effect of species

Wild rice genotype had significant effect on tillers hill<sup>-1</sup> is depicted in figure 4.3.1. The result revealed that the maximum tillers hill<sup>-1</sup> (43.50) was obtained from *O. nivara* (V<sub>3</sub>) and the minimum tillers hill<sup>-1</sup> (15.67) was obtained from *O. latifolia* (V<sub>11</sub>). Zubaer *et al.* (2007) investigated that Binadhan 4 produced the highest tillers hill<sup>-1</sup>, Basmati and RD 2585 produced the medium and the lowest tillers hill<sup>-1</sup>, respectively. Fen *et al.* (2015) reported that rice varieties Siam and Puteh Perak showed higher tolerance against drought stress in the context of tillers hill<sup>-1</sup>.

##### 4.3.26.2 Effect of drought stress

Drought stress had significant effect on tillers hill<sup>-1</sup> is depicted in figure 4.3.2. The results revealed that the maximum tillers hill<sup>-1</sup> (28.94) was obtained from D<sub>1</sub> and the minimum tillers hill<sup>-1</sup> (25.17) was obtained from D<sub>2</sub>. Fen *et al.* (2015) conducted a research and revealed that the tiller plant<sup>-1</sup> decreased with decreasing in soil moisture content. Reduced tiller production under lower soil moisture levels might be the fact

that under water stress, plants were not able to produce enough assimilates for inhibited photosynthesis.



V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

**Figure 4.3.1 Tillers hill<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=2.03)**

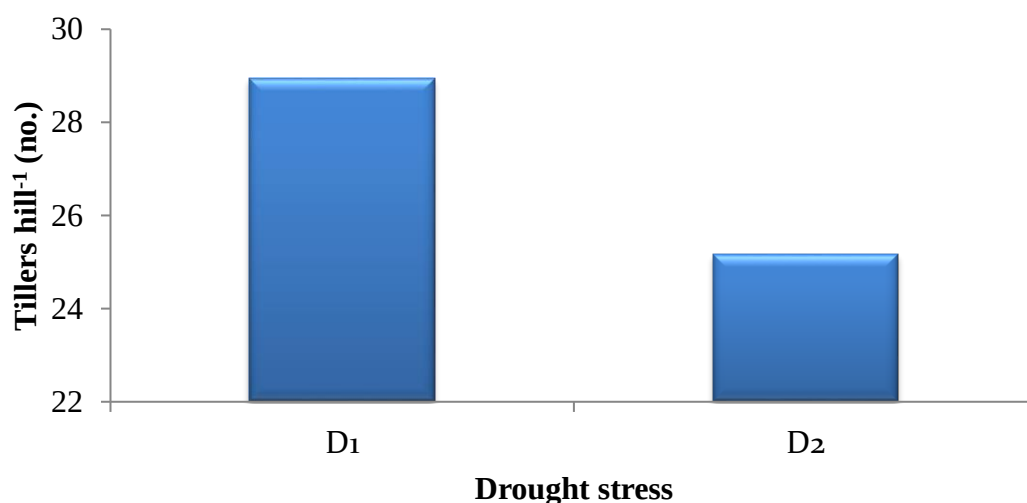
It might be also happened for less amount of water uptake to prepare sufficient food and inhibition of cell division of meristematic tissue, consequently produce lower tillers hill<sup>-1</sup>. Drought tolerance varieties have the potentials to survive under such unfavorable condition. Therefore, lower production of tiller during water stress is also a determinant of drought tolerance. Zubaer *et al.* (2007) reported that the highest number tillers hill<sup>-1</sup> was obtained from 100% FC and the lowest number of tillers hill<sup>-1</sup> was obtained from 40% FC. Our present findings are similar with those of Bunnag and Pongthai (2013); Hossain *et al.* (2020); Kartika *et al.* (2020) who reported that drought stress reduce the tillers hill<sup>-1</sup>.

#### **4.3.26.3 Interaction effect of species and drought stress**

Rice genotypes and drought stress had significant effect on tillers hill<sup>-1</sup> is presented in Table 4.3.38. The results revealed that the maximum tillers hill<sup>-1</sup> (47.00) was obtained from V<sub>3</sub>D<sub>1</sub> and the minimum tillers hill<sup>-1</sup> (14.33) was obtained from V<sub>11</sub>D<sub>2</sub> which was statistically similar with V<sub>11</sub>D<sub>1</sub>. Similar findings also reported by Zubaer *et al.* (2007) who reported that the highest number of tillers was observed from the treatment



combination of Binadhan 4 with 100% FC and the lowest one was observed from RD 2585 along with 40% FC.



D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

**Figure 4.3.2 Effect of drought stress on the tillers hill<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=1.09)**

The maximum decrease of tillers hill<sup>-1</sup> (18.68%) was observed from wild rice genotype *O. rufipogon* (V<sub>1</sub>) and the minimum decrease of tillers hill<sup>-1</sup> (9.07%) was observed from wild rice genotype *Potericia coaractata* (V<sub>10</sub>) (Table 4.3.39).

#### 4.3.27 Effective tillers hill<sup>-1</sup>

##### 4.3.27.1 Effect of species

Effective tillers hill<sup>-1</sup> was significantly influenced by different rice genotypes (Figure 4.3.3). Result showed that the maximum effective tillers hill<sup>-1</sup> (33.17) was given by *O. nivara* (V<sub>3</sub>) and the minimum effective tillers hill<sup>-1</sup> (11.00) was given by *O. latifolia* (V<sub>11</sub>). Wild rice genotype *O. nivara* attained 201.55% more effective tillers hill<sup>-1</sup> than *O. latifolia*. The results obtained in our study are in agreement with the findings of Khan *et al.* (2017) who reported that number of effective tillers hill<sup>-1</sup> was decreased in Super-7 varieties under drought stress than other tested varieties.

**Table 4.3.38 Interaction effect of species and drought stress on the yield contributing characteristics of wild species of rice**

| Treatments                     | Tillers hill <sup>-1</sup><br>(no.) | Effective tillers<br>hill <sup>-1</sup> (no.) | Non-effective<br>tillers hill <sup>-1</sup> (no.) | Panicle length<br>(cm) |
|--------------------------------|-------------------------------------|-----------------------------------------------|---------------------------------------------------|------------------------|
| V <sub>1</sub> D <sub>1</sub>  | 29.33 de                            | 20.00 c-f                                     | 9.33 c-e                                          | 29.20 cd               |
| V <sub>1</sub> D <sub>2</sub>  | 26.67 e-h                           | 18.33 f-i                                     | 8.33 ef                                           | 28.80 cd               |
| V <sub>2</sub> D <sub>1</sub>  | 26.33 f-h                           | 16.67 ij                                      | 9.67 cd                                           | 31.67 c                |
| V <sub>2</sub> D <sub>2</sub>  | 22.33 i-k                           | 14.67 kl                                      | 7.67 fg                                           | 26.40 de               |
| V <sub>3</sub> D <sub>1</sub>  | 47.00 a                             | 36.00 a                                       | 11.00 b                                           | 22.13 g-i              |
| V <sub>3</sub> D <sub>2</sub>  | 40.00 b                             | 30.33 b                                       | 9.67 cd                                           | 20.33 i                |
| V <sub>4</sub> D <sub>1</sub>  | 25.00 hi                            | 18.67 e-h                                     | 6.33 hi                                           | 25.40 ef               |
| V <sub>4</sub> D <sub>2</sub>  | 20.33 kl                            | 15.33 jk                                      | 4.97 jk                                           | 21.60 hi               |
| V <sub>5</sub> D <sub>1</sub>  | 25.67 gh                            | 17.00 h-j                                     | 8.67 d-f                                          | 25.40 ef               |
| V <sub>5</sub> D <sub>2</sub>  | 22.00 jk                            | 15.33 jk                                      | 6.67 gh                                           | 21.33 hi               |
| V <sub>6</sub> D <sub>1</sub>  | 32.67 c                             | 21.67 c                                       | 11.00 b                                           | 22.13 g-i              |
| V <sub>6</sub> D <sub>2</sub>  | 29.00 def                           | 19.67 d-g                                     | 9.33 c-e                                          | 20.93 hi               |
| V <sub>7</sub> D <sub>1</sub>  | 31.33 cd                            | 21.00 cd                                      | 10.33 bc                                          | 26.80 de               |
| V <sub>7</sub> D <sub>2</sub>  | 27.00 e-h                           | 18.33 f-i                                     | 8.67 d-f                                          | 21.00 hi               |
| V <sub>8</sub> D <sub>1</sub>  | 28.33 e-g                           | 19.00 e-g                                     | 9.33 c-e                                          | 27.33 de               |
| V <sub>8</sub> D <sub>2</sub>  | 24.67 h-j                           | 16.67 ij                                      | 8.00 f                                            | 25.13 ef               |
| V <sub>9</sub> D <sub>1</sub>  | 20.67 kl                            | 14.33 kl                                      | 6.33 hi                                           | 41.33 b                |
| V <sub>9</sub> D <sub>2</sub>  | 18.33 lm                            | 13.00 lm                                      | 5.33 ij                                           | 39.53 b                |
| V <sub>10</sub> D <sub>1</sub> | 31.33 cd                            | 21.67 c                                       | 9.67 cd                                           | 13.53 j                |
| V <sub>10</sub> D <sub>2</sub> | 28.33 e-g                           | 20.00 c-f                                     | 8.33 ef                                           | 13.07 j                |
| V <sub>11</sub> D <sub>1</sub> | 17.00 mn                            | 11.67 mn                                      | 5.33 ij                                           | 46.87 a                |
| V <sub>11</sub> D <sub>2</sub> | 14.33 n                             | 10.33 n                                       | 4.00 k                                            | 44.53 a                |
| V <sub>12</sub> D <sub>1</sub> | 32.67 c                             | 20.33 c-e                                     | 12.33 a                                           | 24.87 e-g              |
| V <sub>12</sub> D <sub>2</sub> | 29.00 def                           | 18.00 g-i                                     | 11.00 b                                           | 23.33 f-h              |
| <b>LSD<sub>(0.05)</sub></b>    | <b>2.87</b>                         | <b>1.99</b>                                   | <b>1.14</b>                                       | <b>2.93</b>            |
| <b>CV (%)</b>                  | <b>6.46</b>                         | <b>6.49</b>                                   | <b>8.28</b>                                       | <b>6.65</b>            |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*; D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

**Table 4.3.39 Tillers hill<sup>-1</sup> of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 29.33                            | 26.67                 | 9.07                         |
| V <sub>2</sub>  | 26.33                            | 22.33                 | 15.19                        |
| V <sub>3</sub>  | 47.00                            | 40.00                 | 14.89                        |
| V <sub>4</sub>  | 25.00                            | 20.33                 | 18.68                        |
| V <sub>5</sub>  | 25.67                            | 22.00                 | 14.30                        |
| V <sub>6</sub>  | 32.67                            | 29.00                 | 11.23                        |
| V <sub>7</sub>  | 31.33                            | 27.00                 | 13.82                        |
| V <sub>8</sub>  | 28.33                            | 24.67                 | 12.92                        |
| V <sub>9</sub>  | 20.67                            | 18.33                 | 11.32                        |
| V <sub>10</sub> | 31.33                            | 28.33                 | 9.58                         |
| V <sub>11</sub> | 17.00                            | 14.33                 | 15.71                        |
| V <sub>12</sub> | 32.67                            | 29.00                 | 11.23                        |

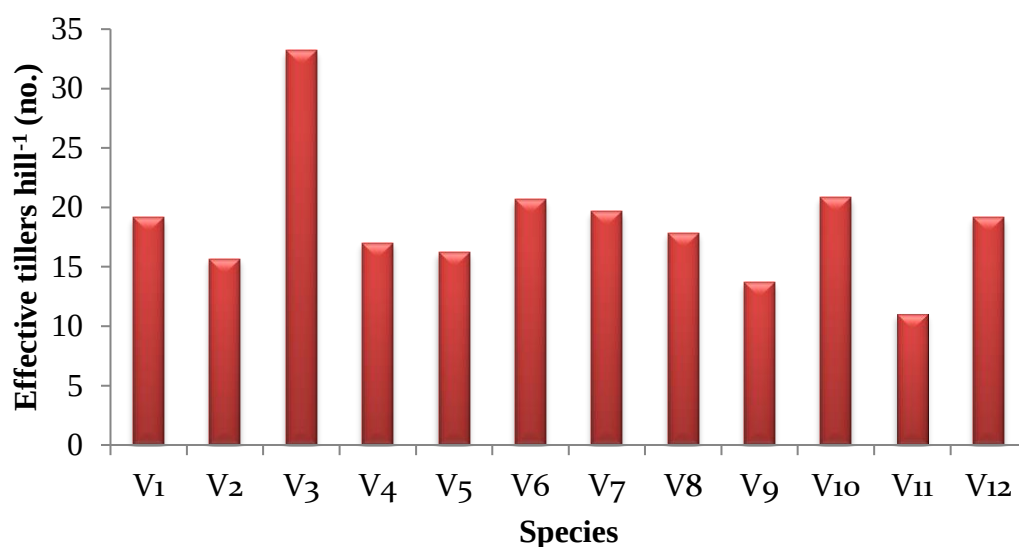
V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### 4.3.27.2 Effect of drought stress

Effective tillers hill<sup>-1</sup> was significantly influenced by different drought stress (Figure 4.3.4). Result showed that the maximum effective tillers hill<sup>-1</sup> (19.83) was given by D<sub>1</sub> treatment and the minimum effective tillers hill<sup>-1</sup> (17.50) was given by D<sub>2</sub> treatment. Control treatment (D<sub>1</sub>) attained 13.31% more effective tillers hill<sup>-1</sup> than 40-45% field capacity (D<sub>2</sub>). It was evident that drought stress before or during tillering reduces number of effective tillers hill<sup>-1</sup> (Bouman and Toungh, 2001; Kartika *et al.*, 2020). This might be due to under water scarcity condition plant could not uptake enough water from the soil, photosynthesis process hampered and there was lower accumulation of photo assimilates and finally produced lower effective tillers hill<sup>-1</sup>.

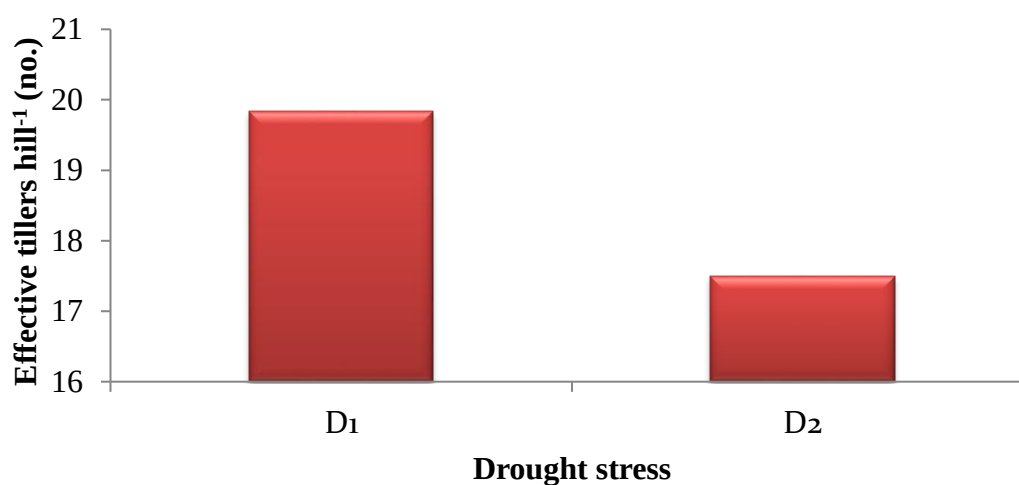
#### 4.3.27.3 Interaction effect of species and drought stress

Effective tillers hill<sup>-1</sup> was significantly influenced by the interaction effect of different genotypes and drought stress (Table 4.3.38). Result showed that the maximum effective tillers hill<sup>-1</sup> (36.00) was given by V<sub>3</sub>D<sub>1</sub> treatment combination and the minimum effective tillers hill<sup>-1</sup> (10.33) was given by V<sub>11</sub>D<sub>2</sub> treatment combination which was statistically similar with V<sub>11</sub>D<sub>1</sub>.



V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

**Figure 4.3.3 Effective tillers hill<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=1.41)**



D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

**Figure 4.3.4 Effect of drought stress on the effective tillers hill<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=0.75)**

The maximum decrease of effective tillers hill<sup>-1</sup> (17.89%) was observed from wild rice genotype *O. barthii* (V<sub>4</sub>) and the minimum decrease of effective tillers hill<sup>-1</sup> (7.71%) was observed from wild rice genotype *Potericia coaractata* (V<sub>10</sub>) (Table 4.3.40).

**Table 4.3.40 Effective tillers hill<sup>-1</sup> of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 20.00                            | 18.33                 | 8.35                         |
| V <sub>2</sub>  | 16.67                            | 14.67                 | 12.00                        |
| V <sub>3</sub>  | 36.00                            | 30.33                 | 15.75                        |
| V <sub>4</sub>  | 18.67                            | 15.33                 | 17.89                        |
| V <sub>5</sub>  | 17.00                            | 15.33                 | 9.82                         |
| V <sub>6</sub>  | 21.67                            | 19.67                 | 9.23                         |
| V <sub>7</sub>  | 21.00                            | 18.33                 | 12.71                        |
| V <sub>8</sub>  | 19.00                            | 16.67                 | 12.26                        |
| V <sub>9</sub>  | 14.33                            | 13.00                 | 9.28                         |
| V <sub>10</sub> | 21.67                            | 20.00                 | 7.71                         |
| V <sub>11</sub> | 11.67                            | 10.33                 | 11.48                        |
| V <sub>12</sub> | 20.33                            | 18.00                 | 11.46                        |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### 4.3.28 Non-effective tillers hill<sup>-1</sup>

##### 4.3.28.1 Effect of species

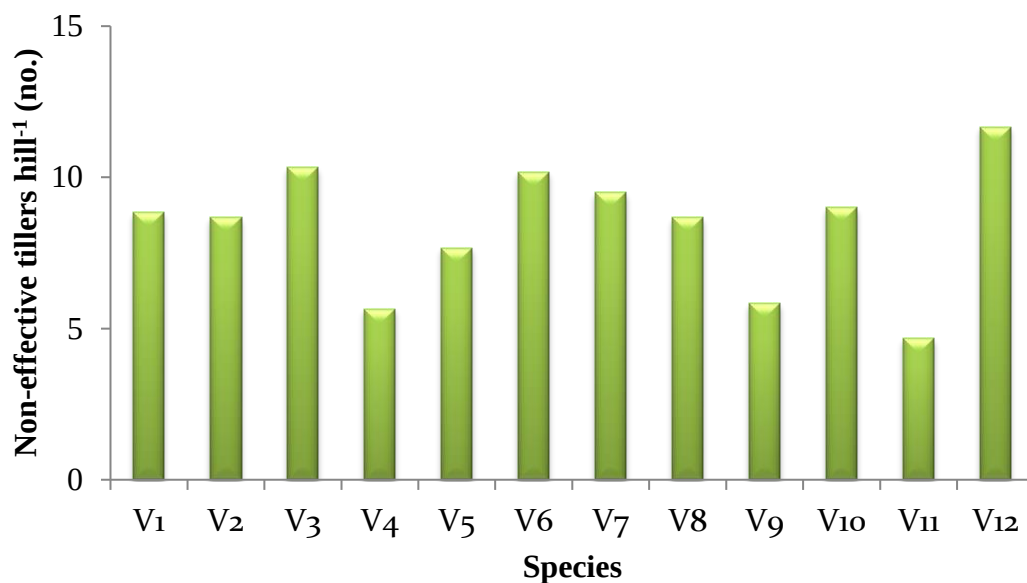
Non-effective tillers hill<sup>-1</sup> of wild rice was varied significantly for different genotypes (Figure 4.3.5). The maximum non-effective tillers hill<sup>-1</sup> (11.67) was attained by *O. officinalis* (V<sub>12</sub>) and the minimum non-effective tillers hill<sup>-1</sup> (4.67) was attained by *O. latifolia* (V<sub>11</sub>).

##### 4.3.28.2 Effect of drought stress

Non-effective tillers hill<sup>-1</sup> of wild rice varied significantly for different drought stress (Figure 4.3.6). The maximum non-effective tillers hill<sup>-1</sup> (9.11) was attained by D<sub>1</sub> and the minimum non-effective tillers hill<sup>-1</sup> (7.66) was attained by D<sub>2</sub>.

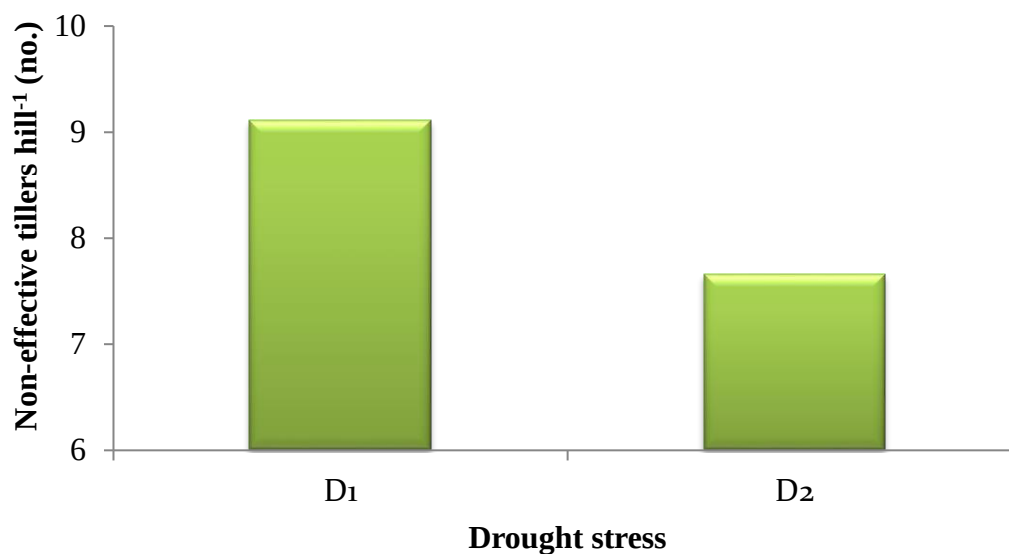
##### 4.3.28.3 Interaction effect of species and drought stress

Non-effective tillers hill<sup>-1</sup> of wild rice was varied significantly for different genotypes and drought stress (Table 4.3.38). The maximum non-effective tillers hill<sup>-1</sup> (12.33) was attained by V<sub>12</sub>D<sub>1</sub> and the minimum non-effective tillers hill<sup>-1</sup> (4.00) was attained by V<sub>11</sub>D<sub>2</sub> which was statistically similar with V<sub>4</sub>D<sub>2</sub>.



V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRR1 Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

**Figure 4.3.5 Non-effective tillers hill<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=0.81)**



D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

**Figure 4.3.6 Effect of drought stress on the non-effective tillers hill<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=0.43)**

The maximum decrease of non-effective tillers hill<sup>-1</sup> (25.00%) was observed from wild rice genotype *O. latifolia* (V<sub>11</sub>) and the minimum decrease of non-effective tillers hill<sup>-1</sup> (10.71%) was observed from wild rice genotype *O. rufipogon* (V<sub>1</sub>) (Table 4.3.41).

**Table 4.3.41 Non-effective tillers hill<sup>-1</sup> of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 9.33                             | 8.33                  | 10.71                        |
| V <sub>2</sub>  | 9.67                             | 7.67                  | 20.69                        |
| V <sub>3</sub>  | 11.00                            | 9.67                  | 12.12                        |
| V <sub>4</sub>  | 6.33                             | 4.97                  | 21.57                        |
| V <sub>5</sub>  | 8.67                             | 6.67                  | 23.08                        |
| V <sub>6</sub>  | 11.00                            | 9.33                  | 15.15                        |
| V <sub>7</sub>  | 10.33                            | 8.67                  | 16.10                        |
| V <sub>8</sub>  | 9.33                             | 8.00                  | 14.28                        |
| V <sub>9</sub>  | 6.33                             | 5.33                  | 15.79                        |
| V <sub>10</sub> | 9.67                             | 8.33                  | 13.80                        |
| V <sub>11</sub> | 5.33                             | 4.00                  | 25.00                        |
| V <sub>12</sub> | 12.33                            | 11.00                 | 10.79                        |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

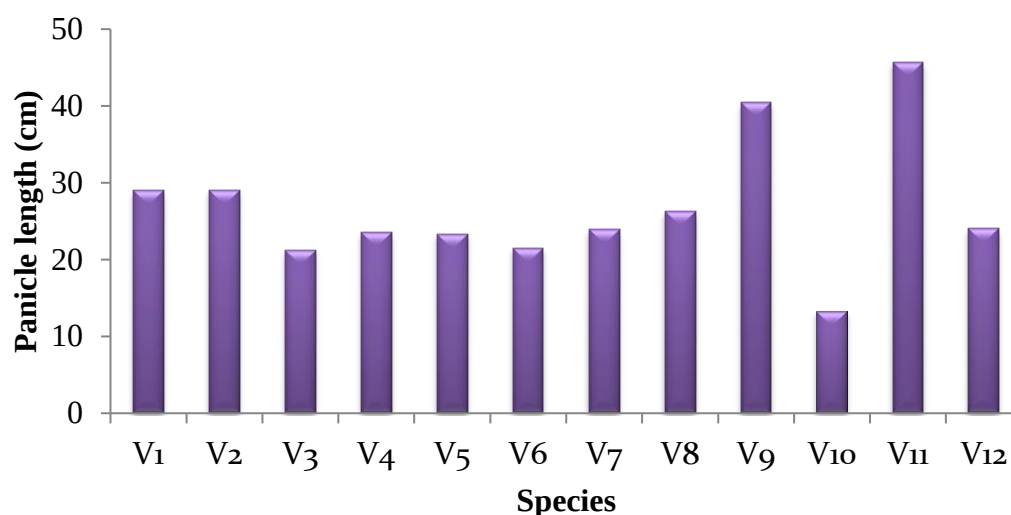
#### 4.3.29 Panicle length

##### 4.3.29.1 Effect of species

Significant difference was found on panicle length of wild rice due to species difference (Figure 4.3.7). Result exposed that the longest panicle (45.70 cm) was recorded from *O. latifolia* (V<sub>11</sub>) followed by *O. alta* (V<sub>9</sub>) (40.43 cm) and the shortest panicle (13.30 cm) was recorded from *P. coaractata* (V<sub>10</sub>). The results of our experiment are similar to the results of Ahmadikhah and Marufinia (2016) and Chaum *et al.* (2010) who reported that panicle length varied with species variation.

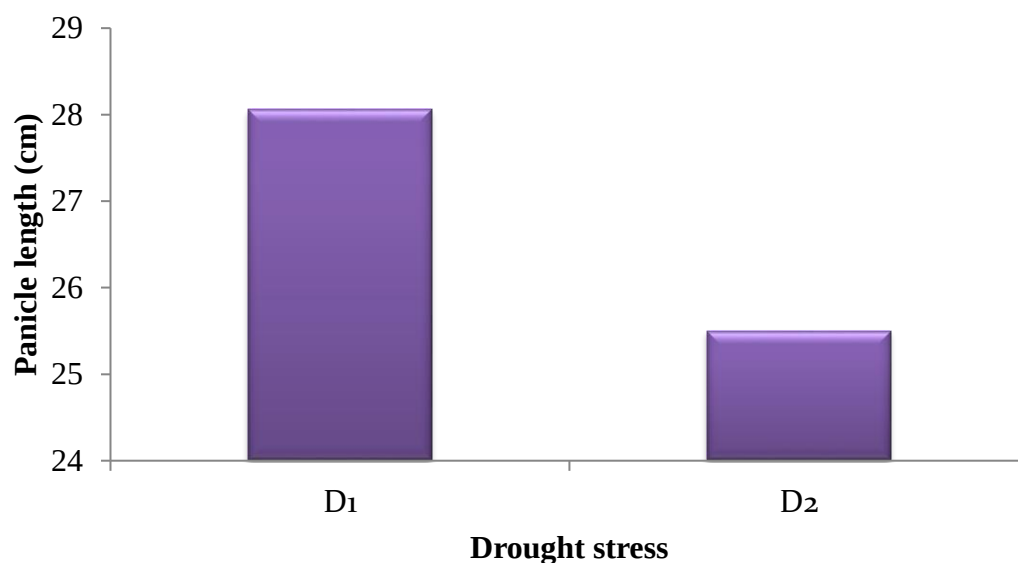
##### 4.3.29.2 Effect of drought stress

Significant difference was found on panicle length of wild rice due to drought stress (Figure 4.3.8). Result exposed that the longer panicle (28.06 cm) was recorded from D<sub>1</sub> and the shorter panicle (25.50 cm) was recorded from D<sub>2</sub> treatment.



V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potieria coarctata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

**Figure 4.3.7 Panicle length of wild species of rice (LSD<sub>0.05</sub>=2.07)**



D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

**Figure 4.3.8 Effect of drought stress on the panicle length of wild species of rice (LSD<sub>0.05</sub>=1.11)**

#### 4.3.29.3 Interaction effect of species and drought stress

Significant difference was found on panicle length of wild rice due to interaction between species and drought stress (Table 4.3.38). Result exposed that the longest panicle (46.87 cm) was recorded from V<sub>11</sub>D<sub>1</sub> which was statistically similar with



V<sub>11</sub>D<sub>2</sub> and the shortest panicle (13.07 cm) was recorded from V<sub>10</sub>D<sub>2</sub> which was statistically similar with V<sub>10</sub>D<sub>1</sub>.

The maximum decrease of panicle length (21.64%) was obtained from rice genotype FR13A (Check variety as drought tolerant) (V<sub>7</sub>) and the minimum decrease of panicle length (3.40%) was obtained from wild rice genotype *Potericia coaractata* (V<sub>10</sub>) (Table 4.3.42).

**Table 4.3.42 Panicle length of wild species of rice as influenced by drought stress**

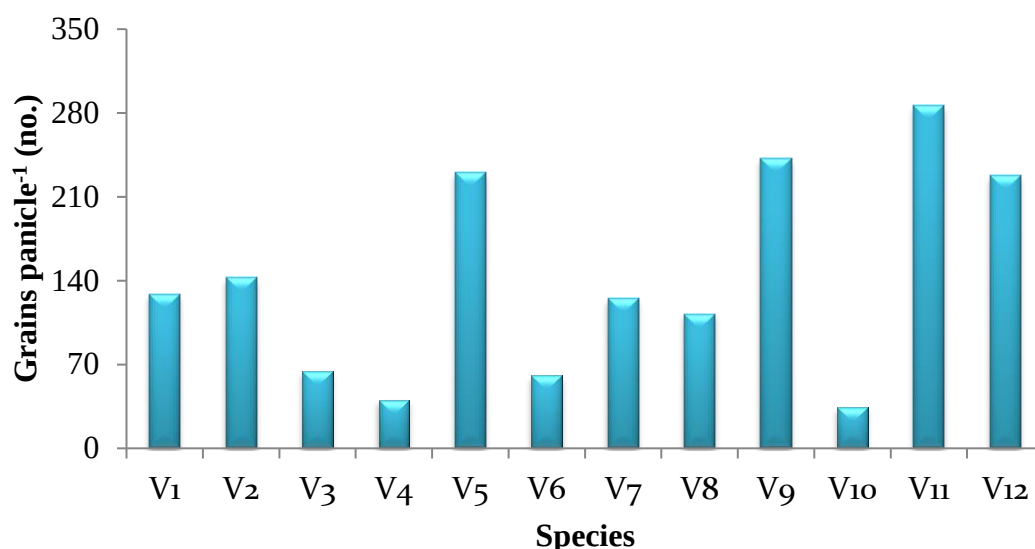
| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 29.20                            | 28.80                 | 1.37                         |
| V <sub>2</sub>  | 31.67                            | 26.40                 | 16.64                        |
| V <sub>3</sub>  | 22.13                            | 20.33                 | 8.13                         |
| V <sub>4</sub>  | 25.40                            | 21.60                 | 14.96                        |
| V <sub>5</sub>  | 25.40                            | 21.33                 | 16.02                        |
| V <sub>6</sub>  | 22.13                            | 20.93                 | 5.42                         |
| V <sub>7</sub>  | 26.80                            | 21.00                 | 21.64                        |
| V <sub>8</sub>  | 27.33                            | 25.13                 | 8.05                         |
| V <sub>9</sub>  | 41.33                            | 39.53                 | 4.36                         |
| V <sub>10</sub> | 13.53                            | 13.07                 | 3.40                         |
| V <sub>11</sub> | 46.87                            | 44.53                 | 4.99                         |
| V <sub>12</sub> | 24.87                            | 23.33                 | 6.19                         |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### 4.3.30 Grains panicle<sup>-1</sup>

##### 4.3.30.1 Effect of species

Statistical significant variation was observed on grains panicle<sup>-1</sup> of wild rice due to species difference (Figure 4.3.9). The highest grains panicle<sup>-1</sup> (286.20) was produced by *O. latifolia* (V<sub>11</sub>) and the lowest grains panicle<sup>-1</sup> (34.50) was produced by *P. coaractata* (V<sub>10</sub>) which was statistically similar with V<sub>4</sub>.



V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

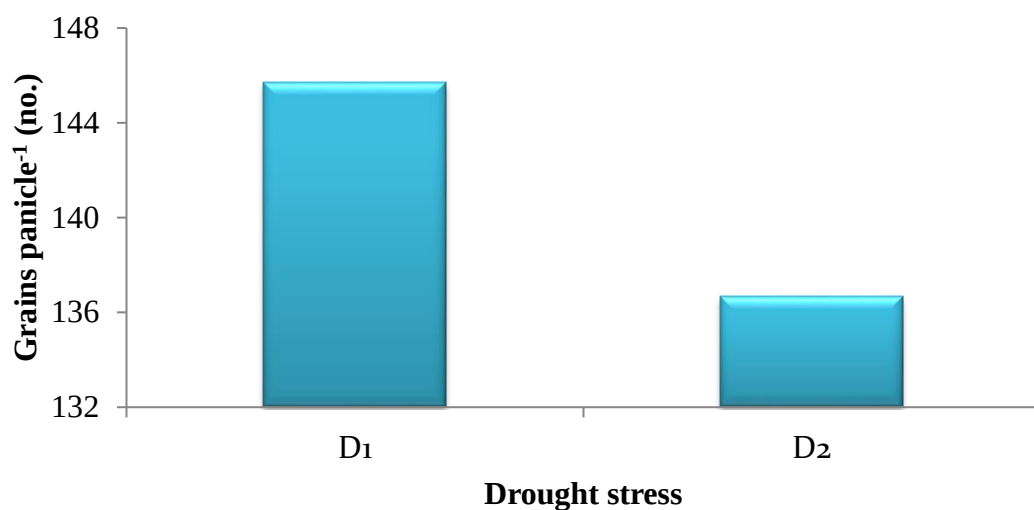
**Figure 4.3.9 Grains panicle<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=13.09)**

#### 4.3.30.2 Effect of drought stress

Statistical significant variation was observed on grains panicle<sup>-1</sup> of wild rice due to drought stress (Figure 4.3.10). The higher grains panicle<sup>-1</sup> (145.72) was produced by D<sub>1</sub> and the lower grains panicle<sup>-1</sup> (136.67) was produced by D<sub>2</sub>. Similar results are earlier reported by several researches on rice plant who explained that the grain number panicle<sup>-1</sup> decreased with increasing moisture stress (Sokoto and Muhammad, 2014; Khairi *et al.*, 2015; Zhang *et al.*, 2018; Yang, *et al.*, 2019; Hossain *et al.* 2020). In some cases, the drastic reduction of grain number (up to 50%) was also found (Sarvestani *et al.*, 2008). The reason of reduction of grain production can be narrated as; water stress reduced the starch accumulation capacity of endosperm into grain by inhibiting photosynthesis rate and nutrient uptake which affected rice yield.

#### 4.3.30.3 Interaction effect of species and drought stress

Statistical significant variation was observed on grains panicle<sup>-1</sup> of wild rice due to interaction between species and drought stress (Table 4.3.43). The highest grains panicle<sup>-1</sup> (295.00) was produced by V<sub>11</sub>D<sub>1</sub> which was statistically similar with V<sub>11</sub>D<sub>2</sub> (277.30) and the lowest grains panicle<sup>-1</sup> (33.00) was produced by V<sub>10</sub>D<sub>2</sub> which was statistically similar with V<sub>10</sub>D<sub>1</sub>, V<sub>4</sub>D<sub>2</sub> and V<sub>4</sub>D<sub>1</sub>.



D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

**Figure 4.3.10 Effect of drought stress on the grains panicle<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=7.01)**

The maximum decrease of grains panicle<sup>-1</sup> (14.61%) was obtained from wild rice genotype *O. barthii* (V<sub>4</sub>) and the minimum decrease of grains panicle<sup>-1</sup> (3.03%) was obtained from wild rice genotype *O. officinalis* (V<sub>12</sub>) (Table 4.3.44).

#### **4.3.31 Filled grains panicle<sup>-1</sup>**

##### **4.3.31.1 Effect of species**

Species had significant influence on filled grains panicle<sup>-1</sup> of rice is depicted in figure 4.3.11. The result revealed that the maximum filled grains panicle<sup>-1</sup> (129.70) was found from *O. longistaminata* (V<sub>5</sub>) and the minimum filled grains panicle<sup>-1</sup> (29.50) was found from *P. coaractata* (V<sub>10</sub>) which was statistically similar with V<sub>4</sub> and V<sub>11</sub>. *O. longistaminata* produced 339.66% more filled grain than wild rice genotype *P. coaractata*.

**Table 4.3.43 Interaction effect of species and drought stress on the grains of wild species of rice**

| Treatments                     | Grains panicle <sup>-1</sup> (no.) | Filled grains panicle <sup>-1</sup> (no.) | Unfilled grains panicle <sup>-1</sup> (no.) | Grain fertility (%) | Grain sterility (%) |
|--------------------------------|------------------------------------|-------------------------------------------|---------------------------------------------|---------------------|---------------------|
| V <sub>1</sub> D <sub>1</sub>  | 130.70 d-f                         | 86.00 i                                   | 44.67 f                                     | 65.82 ef            | 34.18 de            |
| V <sub>1</sub> D <sub>2</sub>  | 126.00 ef                          | 77.67 j                                   | 48.33 f                                     | 61.64 e-g           | 38.36 d             |
| V <sub>2</sub> D <sub>1</sub>  | 145.30 d                           | 101.30 gh                                 | 44.00 f                                     | 69.73 de            | 30.27 e             |
| V <sub>2</sub> D <sub>2</sub>  | 139.70 de                          | 86.67 i                                   | 53.00 f                                     | 62.05 efg           | 37.95 d             |
| V <sub>3</sub> D <sub>1</sub>  | 68.33 h                            | 60.67 k                                   | 7.67 g                                      | 88.77 ab            | 11.23 jk            |
| V <sub>3</sub> D <sub>2</sub>  | 60.00 hi                           | 53.67 kl                                  | 6.33 g                                      | 89.45 ab            | 10.55 jk            |
| V <sub>4</sub> D <sub>1</sub>  | 43.33 ij                           | 33.67 mn                                  | 9.67 g                                      | 77.76 cd            | 22.24 fg            |
| V <sub>4</sub> D <sub>2</sub>  | 37.00 j                            | 28.33 n                                   | 8.67 g                                      | 76.67 cd            | 23.33 f             |
| V <sub>5</sub> D <sub>1</sub>  | 235.00 bc                          | 131.00 a                                  | 104.00 e                                    | 55.74 g             | 44.26 c             |
| V <sub>5</sub> D <sub>2</sub>  | 226.00 c                           | 128.30 ab                                 | 97.67 e                                     | 56.78 fg            | 43.22 c             |
| V <sub>6</sub> D <sub>1</sub>  | 63.67 h                            | 52.00 l                                   | 11.67 g                                     | 81.60 bc            | 18.40 gh            |
| V <sub>6</sub> D <sub>2</sub>  | 58.00 hi                           | 47.33 l                                   | 10.67 g                                     | 81.59 bc            | 18.41 gh            |
| V <sub>7</sub> D <sub>1</sub>  | 129.70 d-f                         | 119.30 c-e                                | 10.33 g                                     | 92.03 a             | 7.97 k              |
| V <sub>7</sub> D <sub>2</sub>  | 120.70 fg                          | 111.30 ef                                 | 9.33 g                                      | 92.27 a             | 7.73 k              |
| V <sub>8</sub> D <sub>1</sub>  | 119.30 fg                          | 108.70 fg                                 | 10.67 g                                     | 91.05 a             | 8.95 jk             |
| V <sub>8</sub> D <sub>2</sub>  | 105.00 g                           | 95.33 h                                   | 9.67 g                                      | 90.79 a             | 9.21 jk             |
| V <sub>9</sub> D <sub>1</sub>  | 251.00 b                           | 115.00 d-f                                | 136.00 c                                    | 45.81 h             | 54.19 b             |
| V <sub>9</sub> D <sub>2</sub>  | 233.00 bc                          | 108.70 fg                                 | 124.30 d                                    | 46.63 h             | 53.37 b             |
| V <sub>10</sub> D <sub>1</sub> | 36.00 j                            | 30.33 mn                                  | 5.67 g                                      | 84.25 abc           | 15.75 hi            |
| V <sub>10</sub> D <sub>2</sub> | 33.00 j                            | 28.67 n                                   | 4.33 g                                      | 86.88 ab            | 13.12 ij            |
| V <sub>11</sub> D <sub>1</sub> | 295.00 a                           | 37.33 m                                   | 257.70 a                                    | 12.66 i             | 87.34 a             |
| V <sub>11</sub> D <sub>2</sub> | 277.30 a                           | 32.67 mn                                  | 244.70 b                                    | 11.78 i             | 88.22 a             |
| V <sub>12</sub> D <sub>1</sub> | 231.30 c                           | 126.30 a-c                                | 105.00 e                                    | 54.60 gh            | 45.40 c             |
| V <sub>12</sub> D <sub>2</sub> | 224.30 c                           | 122.30 bcd                                | 102.00 e                                    | 54.86 gh            | 45.48 c             |
| <b>LSD (0.05)</b>              | <b>18.52</b>                       | <b>8.33</b>                               | <b>9.94</b>                                 | <b>9.10</b>         | <b>4.31</b>         |
| <b>CV (%)</b>                  | <b>7.98</b>                        | <b>6.33</b>                               | <b>9.90</b>                                 | <b>8.15</b>         | <b>8.18</b>         |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*; D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

**Table 4.3.44 Grains panicle<sup>-1</sup> of wild species of rice as influenced by drought stress**

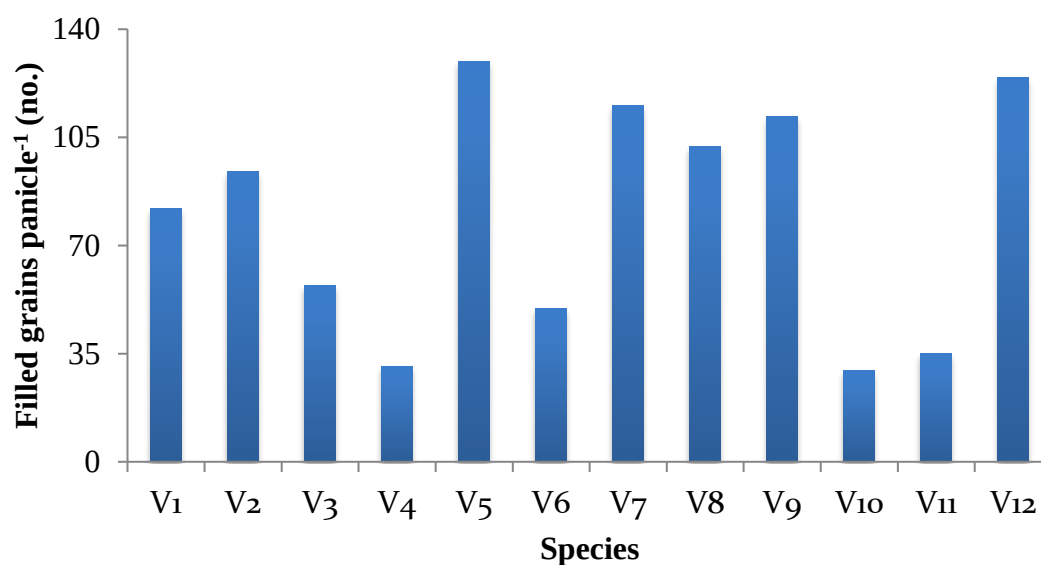
| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 130.70                           | 126.00                | 3.60                         |
| V <sub>2</sub>  | 145.30                           | 139.70                | 3.85                         |
| V <sub>3</sub>  | 68.33                            | 60.00                 | 12.19                        |
| V <sub>4</sub>  | 43.33                            | 37.00                 | 14.61                        |
| V <sub>5</sub>  | 235.00                           | 226.00                | 3.83                         |
| V <sub>6</sub>  | 63.67                            | 58.00                 | 8.91                         |
| V <sub>7</sub>  | 129.70                           | 120.70                | 6.94                         |
| V <sub>8</sub>  | 119.30                           | 105.00                | 11.99                        |
| V <sub>9</sub>  | 251.00                           | 233.00                | 7.17                         |
| V <sub>10</sub> | 36.00                            | 33.00                 | 8.33                         |
| V <sub>11</sub> | 295.00                           | 277.30                | 6.00                         |
| V <sub>12</sub> | 231.30                           | 224.30                | 3.03                         |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### 4.3.31.2 Effect of drought stress

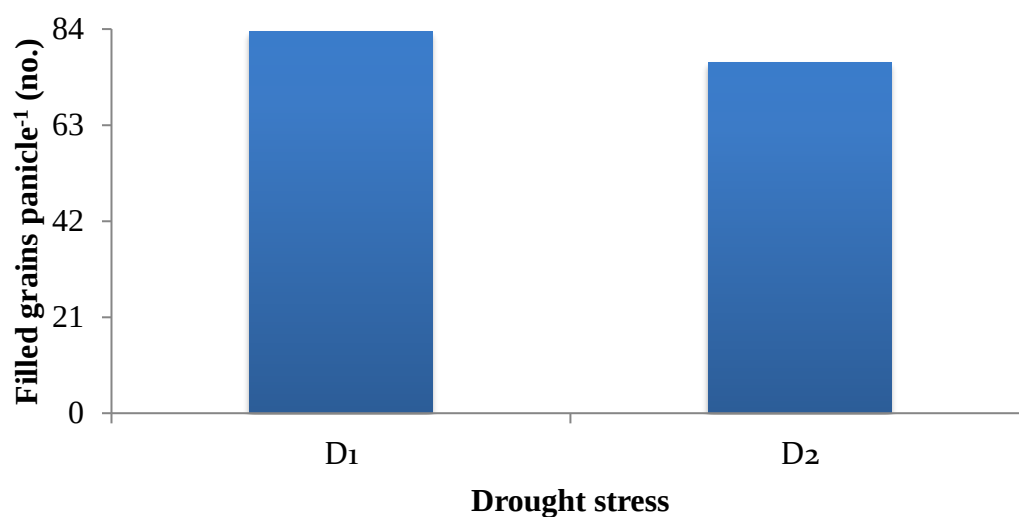
Drought stress had significant influence on filled grains panicle<sup>-1</sup> of rice is depicted in figure 4.3.12. The result revealed that the maximum filled grains panicle<sup>-1</sup> (83.47) was found from D<sub>2</sub> and the minimum filled grains panicle<sup>-1</sup> (76.75) was found from D<sub>2</sub>. Treatment D<sub>1</sub> produced 8.76% more filled grains panicle<sup>-1</sup> than treatment D<sub>2</sub>. Grain filling in rice is a process of starch biosynthesis from simple carbohydrates. It is believed that four enzymes play key roles in this process: sucrose synthase, adenosine diphosphate-glucose-pyrophosphorylase, starch synthase and starch branching enzyme (Taiz and Zeiger, 2006). In rice, on the other hand, water stress imposed during the grain-filling period enhanced remobilization of pre-stored carbon reserves to grains and accelerated grain filling (Yang *et al.*, 2001). In summary, prevailing drought reduces plant growth and development, leading to hampered flower production and grain filling and thus smaller and fewer grains. Decreased filled grains per panicle under lower soil moisture levels might also be due to inhibition of translocation of assimilate to the grains. Zubaer *et al.* (2007) review that the highest number of filled grains panicle<sup>-1</sup> was found at 100% FC followed by 70% FC and the lowest number of filled grains panicle<sup>-1</sup> was observed at 40% FC. The results obtained

in our study are in agreement with those studies of O'Toole and Moya (1981); Hossain (2001).



V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

**Figure 4.3.11 Filled grains panicle<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=5.89)**



D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

**Figure 4.3.12 Effect of drought stress on the filled grains panicle<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=3.15)**

#### 4.3.31.3 Interaction effect of species and drought stress

Species and drought stress interaction had significant influence on filled grains panicle<sup>-1</sup> of rice is presented in Table 4.3.43. The result revealed that the maximum filled grains panicle<sup>-1</sup> (131.00) was found from V<sub>5</sub>D<sub>1</sub> which was statistically similar with V<sub>5</sub>D<sub>2</sub> and V<sub>12</sub>D<sub>1</sub> and the minimum filled grains panicle<sup>-1</sup> (28.33) was found from V<sub>4</sub>D<sub>2</sub> which was statistically similar with V<sub>10</sub>D<sub>2</sub>, V<sub>10</sub>D<sub>1</sub>, V<sub>11</sub>D<sub>2</sub> and V<sub>4</sub>D<sub>1</sub>. Zubaer *et al.* (2007) reported that similar results who revealed that Binadhan 4 along with 100% FC produced the highest number of filled grains panicle<sup>-1</sup> and the lowest were obtained from the treatment combination RD2585 along with 40% FC.

The maximum decrease of filled grains panicle<sup>-1</sup> (15.86%) was obtained from wild rice genotype *O. barthii* (V<sub>4</sub>) and the minimum decrease of filled grains panicle<sup>-1</sup> (2.06%) was obtained from wild rice genotype *O. longistaminata* (V<sub>5</sub>) (Table 4.3.45).

**Table 4.3.45 Filled grains panicle<sup>-1</sup> of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 86.00                            | 77.67                 | 9.69                         |
| V <sub>2</sub>  | 101.30                           | 86.67                 | 14.44                        |
| V <sub>3</sub>  | 60.67                            | 53.67                 | 11.54                        |
| V <sub>4</sub>  | 33.67                            | 28.33                 | 15.86                        |
| V <sub>5</sub>  | 131.00                           | 128.30                | 2.06                         |
| V <sub>6</sub>  | 52.00                            | 47.33                 | 8.98                         |
| V <sub>7</sub>  | 119.30                           | 111.30                | 6.71                         |
| V <sub>8</sub>  | 108.70                           | 95.33                 | 12.30                        |
| V <sub>9</sub>  | 115.00                           | 108.70                | 5.48                         |
| V <sub>10</sub> | 30.33                            | 28.67                 | 5.47                         |
| V <sub>11</sub> | 37.33                            | 32.67                 | 12.48                        |
| V <sub>12</sub> | 126.30                           | 122.30                | 3.17                         |

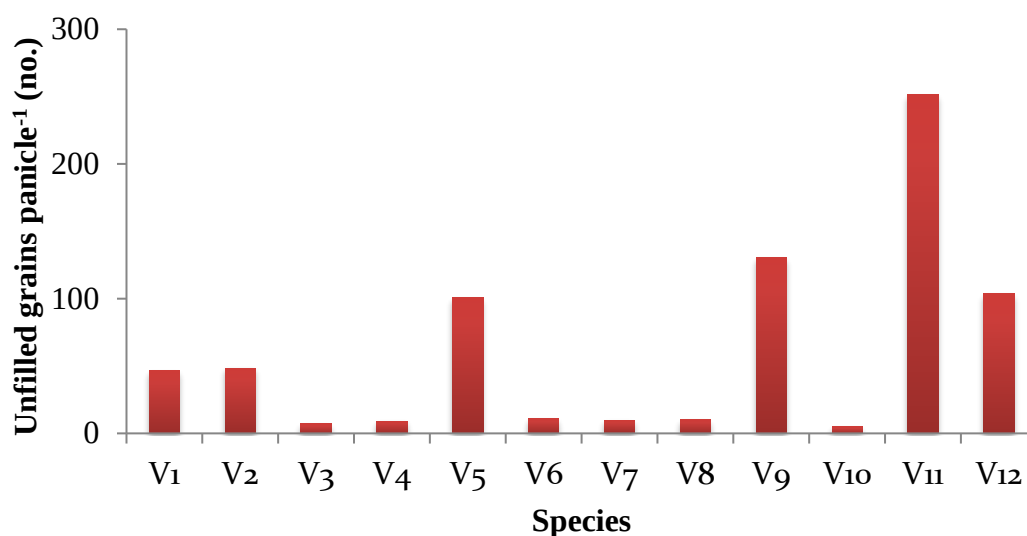
V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### 4.3.32 Unfilled grains panicle<sup>-1</sup>

##### 4.3.32.1 Effect of species

Unfilled grains panicle<sup>-1</sup> significantly varied among the wild rice genotypes (Figure 4.3.13). The maximum unfilled grains panicle<sup>-1</sup> (251.20) was received from *O.*

*latifolia* (V<sub>11</sub>) and the minimum unfilled Grains panicle<sup>-1</sup> (5.00) was received from *P. coaractata* (V<sub>10</sub>) which was statistically at par with V<sub>3</sub>, V<sub>4</sub>, V<sub>6</sub>, V<sub>7</sub> and V<sub>8</sub>.



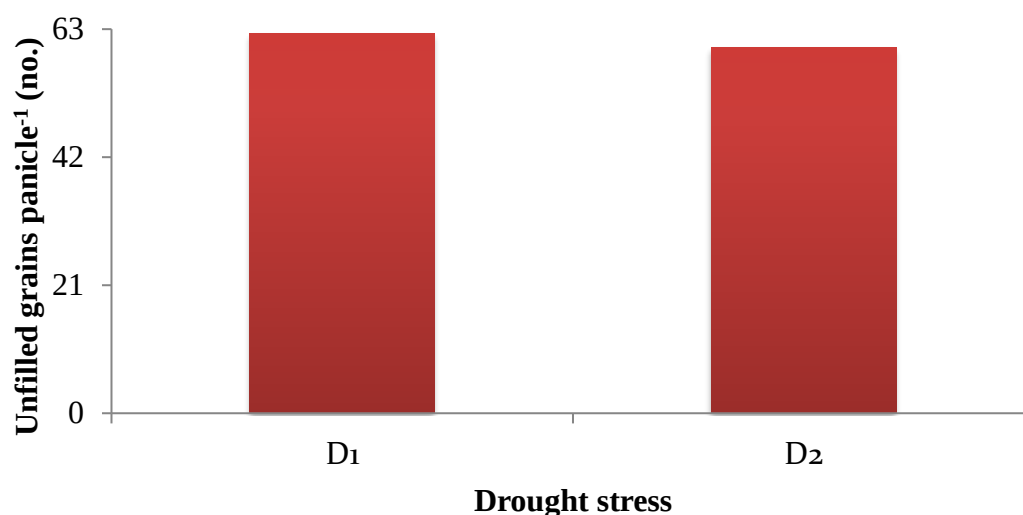
V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

**Figure 4.3.13 Unfilled grains panicle<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=7.03)**

#### 4.3.32.2 Effect of drought stress

Unfilled grains panicle<sup>-1</sup> was not significantly varied among the drought stress conditions (Figure 4.3.14). Numerically the maximum (62.25) and minimum (59.92) unfilled grains panicle<sup>-1</sup> was received from D<sub>1</sub> and D<sub>2</sub> treatments, respectively. Similar results also reported by Chelah *et al.* (2011); Jahan *et al.* (2013) who also reported that drought stress did not affect the unfilled grains panicle<sup>-1</sup>. Generally unfilled grains panicle<sup>-1</sup> increase under lower soil moisture level and it might be due to inactive pollen grain for dryness, incomplete development of pollen tube; insufficient assimilates production and its distribution to grains. Liu *et al.* (2008) reported that water stress can abort pollination for up to 67% of total grain per panicle. Our findings are not corroborates with the findings of Islam *et al.* (1994a); Hossain (2001); Zubaer *et al.* (2007).





D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

**Figure 4.3.14 Effect of drought stress on the unfilled grains panicle<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=NS)**

#### 4.3.32.3 Interaction effect of species and drought stress

Unfilled grains panicle<sup>-1</sup> was significantly varied among the wild rice genotypes and drought stress conditions (Table 4.3.43). The maximum unfilled grains panicle<sup>-1</sup> (257.70) was received from V<sub>11</sub>D<sub>1</sub> and the minimum unfilled Grains panicle<sup>-1</sup> (4.33) was received from V<sub>10</sub>D<sub>2</sub> which was statistically at par with V<sub>10</sub>D<sub>1</sub>, V<sub>8</sub>D<sub>2</sub>, V<sub>8</sub>D<sub>1</sub>, V<sub>7</sub>D<sub>2</sub>, V<sub>7</sub>D<sub>1</sub>, V<sub>6</sub>D<sub>2</sub>, V<sub>6</sub>D<sub>1</sub>, V<sub>4</sub>D<sub>2</sub>, V<sub>4</sub>D<sub>1</sub>, V<sub>3</sub>D<sub>2</sub> and V<sub>3</sub>D<sub>1</sub>. These results are in harmony with those obtained by Zubaer *et al.* (2007) who revealed that Binadhan 4 produced relatively more unfilled grain (33.13% for 70%FC and 77.21% for 40% FC) than Basmati and RD 2585 under water stressed condition.

The maximum decrease of unfilled grains panicle<sup>-1</sup> (23.54%) was obtained from wild rice genotype *Potericia coaractata* (V<sub>10</sub>) and the increase of unfilled grains panicle<sup>-1</sup> (20.45%) was obtained from wild rice genotype *O. punctata* (V<sub>2</sub>) (Table 4.3.46).

#### 4.3.33 Grain fertility percentage

##### 4.3.33.1 Effect of species

Grain fertility percentage of wild rice was significantly influenced among the rice genotypes (Figure 4.3.15). The maximum grain fertility percentage (92.15%) was attained by FR13A (V<sub>7</sub>) (Check variety as drought tolerant) which was statistically

similar with V<sub>8</sub> and V<sub>3</sub> while the minimum grain fertility percentage (12.22%) was attained by *O. latifolia* (V<sub>11</sub>). Cha-um *et al.* (2010); Ahmadikhah and Marufinia (2016) observed that when rice genotypes exposed to water deficit fertile grains in two tolerant varieties were not significantly decreased, leading to greater productivity than in two sensitive cultivars. This might be due to the differential responses of rice genotypes to water deficit.

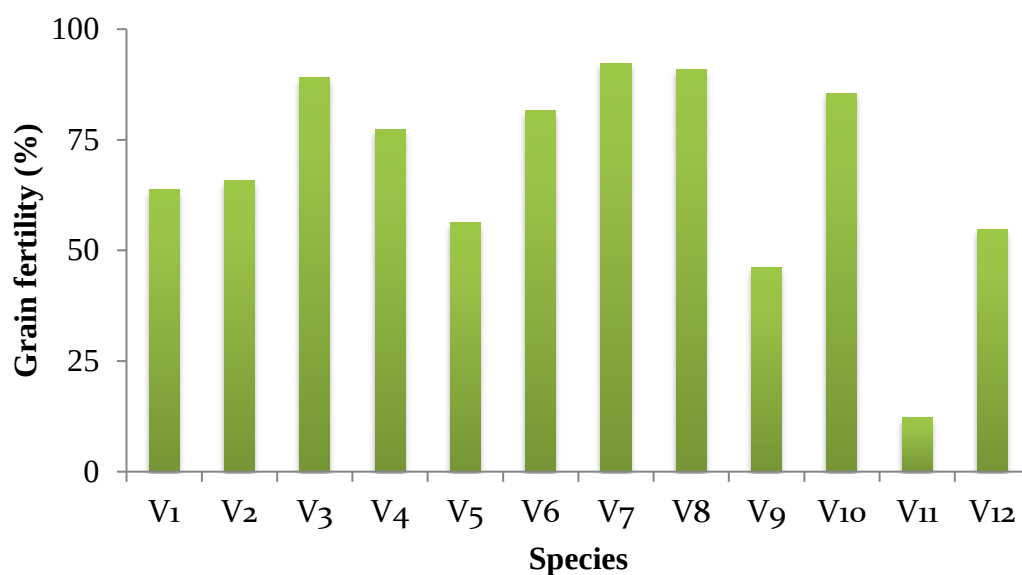
**Table 4.3.46 Unfilled grains panicle<sup>-1</sup> of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity (Control) | 40-45% field capacity | Decrease over control (%) |
|-----------------|-------------------------------|-----------------------|---------------------------|
| V <sub>1</sub>  | 44.67                         | 48.33                 | -8.19                     |
| V <sub>2</sub>  | 44.00                         | 53.00                 | -20.45                    |
| V <sub>3</sub>  | 7.67                          | 6.33                  | 17.40                     |
| V <sub>4</sub>  | 9.67                          | 8.67                  | 10.34                     |
| V <sub>5</sub>  | 104.00                        | 97.67                 | 6.09                      |
| V <sub>6</sub>  | 11.67                         | 10.67                 | 8.57                      |
| V <sub>7</sub>  | 10.33                         | 9.33                  | 9.65                      |
| V <sub>8</sub>  | 10.67                         | 9.67                  | 9.40                      |
| V <sub>9</sub>  | 136.00                        | 124.30                | 8.60                      |
| V <sub>10</sub> | 5.67                          | 4.33                  | 23.54                     |
| V <sub>11</sub> | 257.70                        | 244.70                | 5.04                      |
| V <sub>12</sub> | 105.00                        | 102.00                | 2.86                      |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potiericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

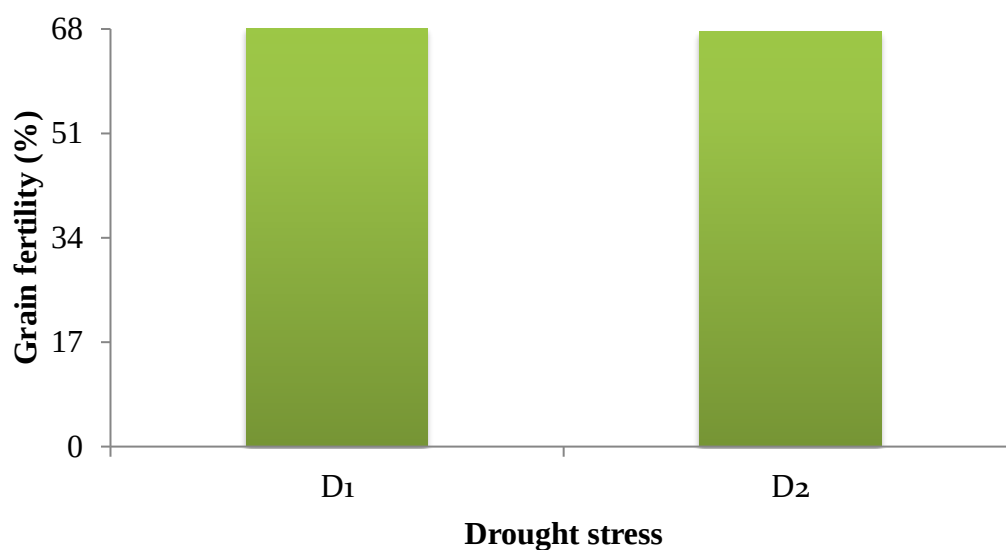
#### 4.3.33.2 Effect of drought stress

Grain fertility percentage of wild rice was not significantly influenced among the rice genotypes (Figure 4.3.16). Numerically the higher grain fertility percentage (68.32%) was attained by D<sub>1</sub> while the lower grain fertility percentage (67.61%) was attained by D<sub>2</sub>. But the grain fertility decreased with drought stress treatment. Decreased grain fertility percentage under lower soil moisture levels might also be due to dryness of pollen grain, incomplete development of pollen tube and inhibition of translocation of assimilates to the grains. The results of our experiment are not collaborated with the findings of Raman *et al.* (2012); Kumar *et al.* (2014a); Pandey and Shukla (2015) who reported that drought stress decreased the percentage of fertile grain.



V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

**Figure 4.3.15 Grain fertility percentage of wild species of rice (LSD<sub>0.05</sub>=6.44)**



D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

**Figure 4.3.16 Effect of drought stress on the grain fertility percentage of wild species of rice (LSD<sub>0.05</sub>=NS)**

#### 4.3.33.3 Interaction effect of species and drought stress

Grain fertility percentage of wild rice was significantly influenced among interaction of the rice genotypes and drought stress (Table 4.4.43). The maximum grain fertility

percentage (92.27%) was attained by V<sub>7</sub>D<sub>2</sub> which was statistically similar with V<sub>7</sub>D<sub>1</sub>, V<sub>8</sub>D<sub>1</sub>, V<sub>8</sub>D<sub>2</sub>, V<sub>10</sub>D<sub>2</sub>, V<sub>10</sub>D<sub>1</sub>, V<sub>3</sub>D<sub>1</sub> and V<sub>3</sub>D<sub>2</sub> while the minimum grain fertility percentage (11.78%) was attained by V<sub>11</sub>D<sub>2</sub> which was statistically similar with V<sub>11</sub>D<sub>1</sub>.

The maximum decrease of grain fertility percentage (11.01%) was obtained from wild rice genotype *O. punctata* (V<sub>2</sub>) and the increase of grain fertility percentage (3.12%) was obtained from wild rice genotype *Potericia coaractata* (V<sub>10</sub>) (Table 4.3.47).

**Table 4.3.47 Grain fertility percentage of wild species of rice as influenced by drought stress**

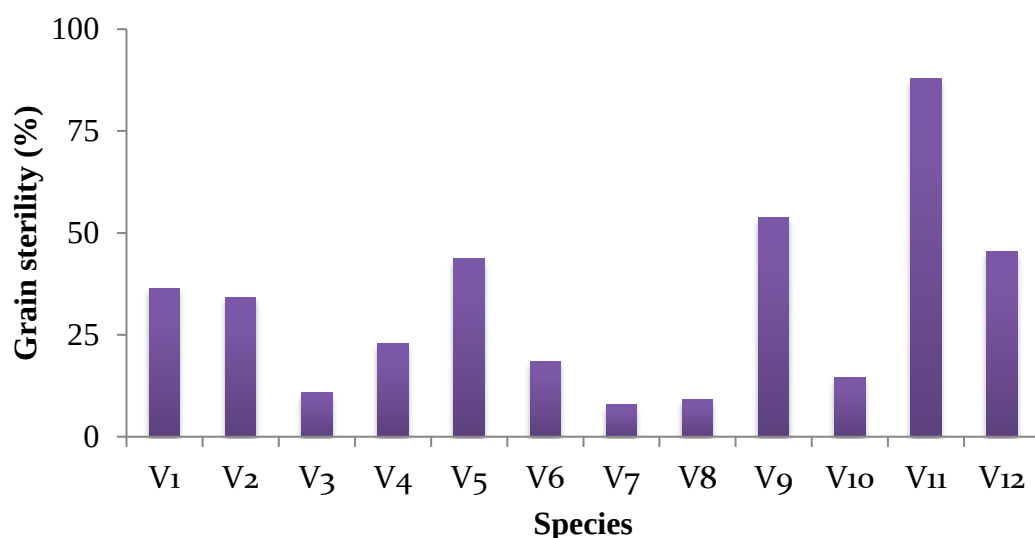
| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 65.82                            | 61.64                 | 6.35                         |
| V <sub>2</sub>  | 69.73                            | 62.05                 | 11.01                        |
| V <sub>3</sub>  | 88.77                            | 89.45                 | -0.77                        |
| V <sub>4</sub>  | 77.76                            | 76.67                 | 1.40                         |
| V <sub>5</sub>  | 55.74                            | 56.78                 | -1.87                        |
| V <sub>6</sub>  | 81.60                            | 81.59                 | 0.01                         |
| V <sub>7</sub>  | 92.03                            | 92.27                 | -0.26                        |
| V <sub>8</sub>  | 91.05                            | 90.79                 | 0.29                         |
| V <sub>9</sub>  | 45.81                            | 46.63                 | -1.79                        |
| V <sub>10</sub> | 84.25                            | 86.88                 | -3.12                        |
| V <sub>11</sub> | 12.66                            | 11.78                 | 6.95                         |
| V <sub>12</sub> | 54.60                            | 54.86                 | -0.48                        |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### 4.3.34 Grain sterility percentage

##### 4.3.34.1 Effect of species

Grain sterility percentage of wild rice was significantly varied among the rice genotypes (Figure 4.3.17). The maximum grain sterility percentage (87.78%) was attained by *O. latifolia* (V<sub>11</sub>) whereas the minimum grain sterility percentage (7.85%) was attained by FR13A (V<sub>7</sub>) (Check variety as drought tolerant) which was statistically similar with V<sub>8</sub> and V<sub>3</sub>.



V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

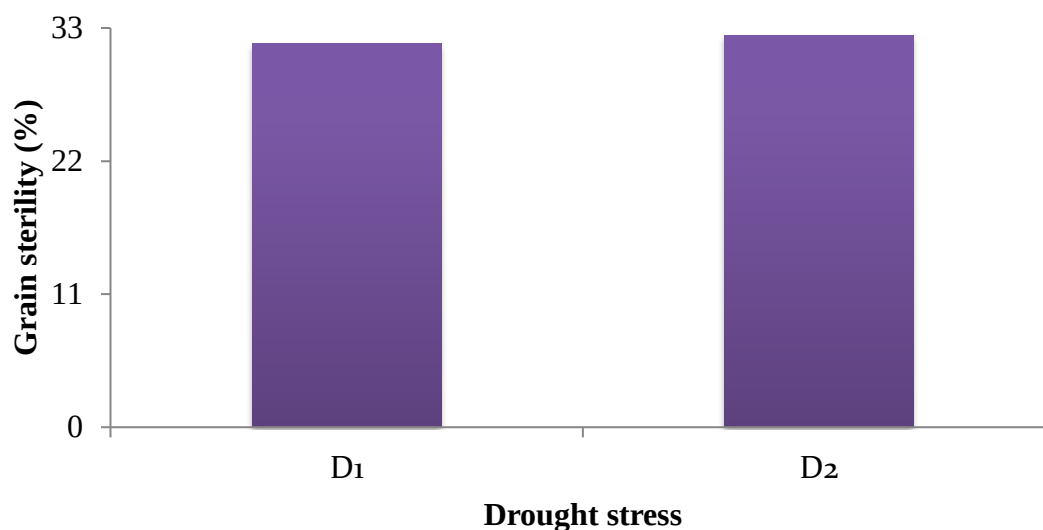
**Figure 4.3.17 Grain sterility percentage of wild species of rice (LSD<sub>0.05</sub>=3.05)**

#### 4.3.34.2 Effect of drought stress

Grain sterility percentage of wild rice was not significantly varied among the rice genotypes (Figure 4.3.18). Numerically the maximum grain sterility percentage (32.41%) was attained by D<sub>2</sub> while the minimum grain sterility percentage (31.68%) was attained by D<sub>1</sub>. Farooq *et al.* (2009b) reported that drought at flowering commonly results in barrenness. Yadav *et al.* (2004) described that one of the major reason of increased of grain sterility percentage was the reduction of assimilate flux to the developing ear below some threshold level necessary to sustain optimal grain growth. Dissimilar findings was observed of Ji *et al.* (2012); Kumar *et al.* (2014a); Pandey and Shukla (2015) who reported that drought stress significantly increased the percentage of grain sterility.

#### 4.3.34.3 Interaction effect of species and drought stress

Grain sterility percentage of wild rice was significantly varied by interaction of the rice genotypes and drought stress (Table 4.3.43). The maximum grain sterility percentage (88.22%) was attained by V<sub>11</sub>D<sub>2</sub> which was statistically similar with V<sub>11</sub>D<sub>1</sub> while the minimum grain sterility percentage (7.73%) was attained by V<sub>7</sub>D<sub>2</sub> which was statistically similar with V<sub>7</sub>D<sub>1</sub>, V<sub>8</sub>D<sub>1</sub>, V<sub>8</sub>D<sub>2</sub>, V<sub>3</sub>D<sub>1</sub> and V<sub>3</sub>D<sub>2</sub>.



D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

**Figure 4.3.18 Effect of drought stress on the grain sterility percentage of wild species of rice (LSD<sub>0.05</sub>=NS)**

The maximum increase of grain sterility percentage (25.37%) was obtained from wild rice genotype *O. punctata* (V<sub>2</sub>) and the decrease of grain sterility percentage (16.70%) was obtained from wild rice genotype *Potericia coaractata* (V<sub>10</sub>) (Table 4.3.48).

**Table 4.3.48 Grain sterility percentage of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity (Control) | 40-45% field capacity | Increase over control (%) |
|-----------------|-------------------------------|-----------------------|---------------------------|
| V <sub>1</sub>  | 34.18                         | 38.36                 | 12.23                     |
| V <sub>2</sub>  | 30.27                         | 37.95                 | 25.37                     |
| V <sub>3</sub>  | 11.23                         | 10.55                 | -6.06                     |
| V <sub>4</sub>  | 22.24                         | 23.33                 | 4.90                      |
| V <sub>5</sub>  | 44.26                         | 43.22                 | -2.35                     |
| V <sub>6</sub>  | 18.40                         | 18.41                 | 0.05                      |
| V <sub>7</sub>  | 7.97                          | 7.73                  | -2.94                     |
| V <sub>8</sub>  | 8.95                          | 9.21                  | 2.91                      |
| V <sub>9</sub>  | 54.19                         | 53.37                 | -1.51                     |
| V <sub>10</sub> | 15.75                         | 13.12                 | -16.70                    |
| V <sub>11</sub> | 87.34                         | 88.22                 | 1.01                      |
| V <sub>12</sub> | 45.40                         | 45.48                 | 0.18                      |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

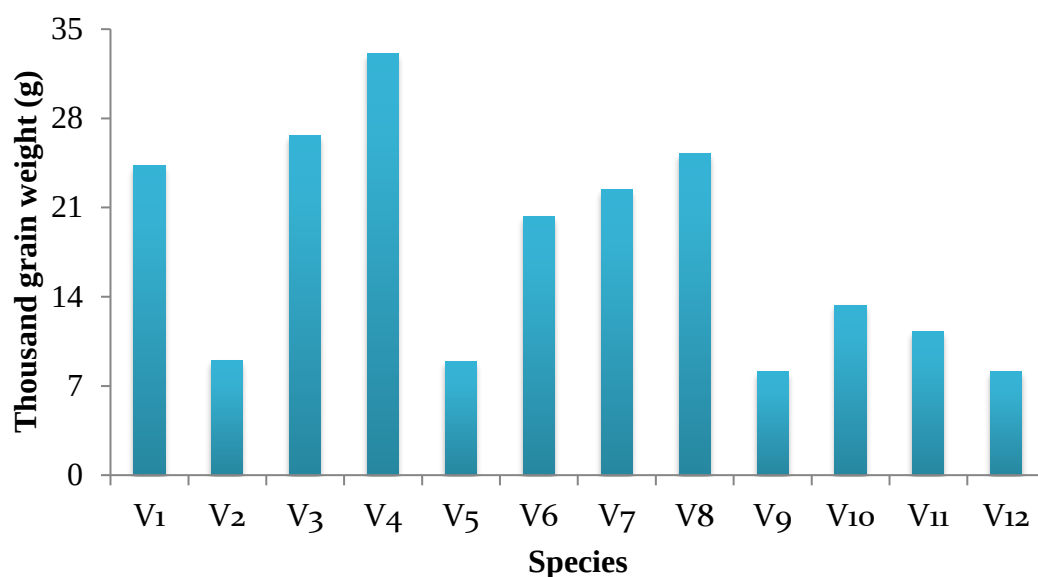
### 4.3.35 Thousand grain weight

#### 4.3.35.1 Effect of species

Thousand grain weight was significantly affected by different wild rice genotypes (Figure 4.3.19). The maximum thousand grain weight (33.08 g) was obtained from *O. barthii* (V<sub>4</sub>) and the minimum thousand grain weight (8.11 g) was obtained from *O. alta* (V<sub>9</sub>) which was statistically similar with V<sub>12</sub>, V<sub>5</sub> and V<sub>2</sub>. Wild rice genotype *O. barthii* produced 307.89% more thousand grain weight than wild rice genotype *O. alta*. Different rice genotypes were response differently for thousand grain weight under drought stress due to their genetic potentiality variation. Moonmoon *et al.* (2017) reviewed that the higher thousand grain weight was observed in genotypes Nerica (13.33) and Binadhan-13 (8.64) and lesser was observed in rest of the genotypes RM-100-16 (8.02), Kalizira (7.04), BRRI dhan-34 (6.80) and Ukunimodhu (6.59). Khan *et al.* (2017) reported that the weight of thousand grains was decreased in Super-7 varieties under drought stress. Overall grain yield reduced by 6 and 32% in PR-115 and Super-7 varieties respectively under water stress condition. Zubaer *et al.* (2007) revealed that the percent of reduction thousand grain weight was lower in Binadhan 4 (4.14 to 6.37%) than in Basmati (6.75 to 12.5%) and RD 2585 (4.57 to 14.64%). Our findings are also in line with those findings of Tsuda and Takami (1991); Islam *et al.* (1994b); RRDI (1999) who stated that water stress reduced thousand grain weight.

#### 4.3.35.2 Effect of drought stress

Thousand grain weight was not significantly affected by different wild rice genotypes (Figure 4.3.20). Numerically the higher thousand grain weight (17.60 g) was obtained from D<sub>1</sub> treatment and the lower thousand grain weight (17.52 g) was obtained from D<sub>2</sub>. Similar results also reported by Ahmadikhah and Marufinia (2016); Moonmoon *et al.* (2017); Yang *et al.* (2019) who reported that drought stress had no significant effect on thousand grain weight. But Moonmoon *et al.* (2017) reported that the reduction in thousand grain weight, due to drought stress is largely resulted from the reduction in fertile panicle and filled grain percentage. Drought stress also promoted the remobilization of stored carbon reserves and water deficit during grain-filling enhanced plant senescence and accelerated grain-filling.

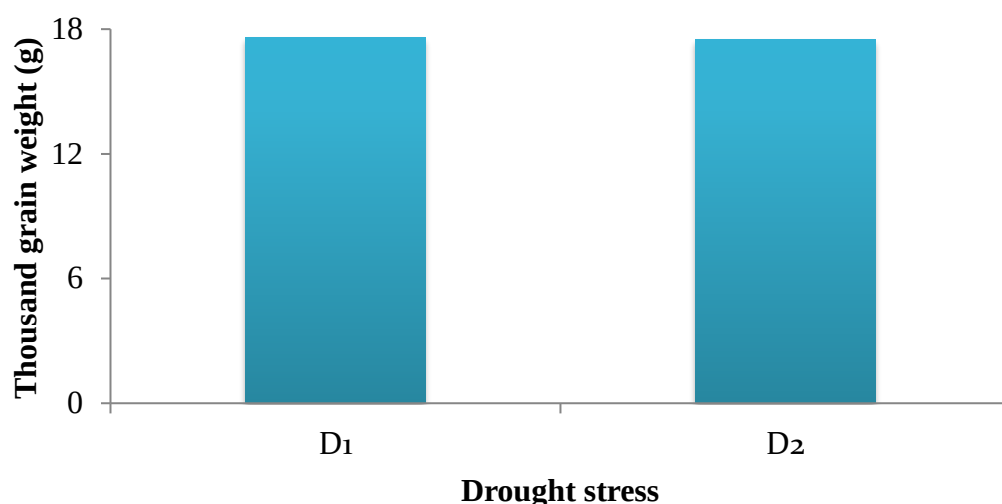


V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

**Figure 4.3.19 Thousand grain weight of wild species of rice (LSD<sub>0.05</sub>=1.10)**

Usually, senescence induced by water deficit shortens grain-filling period and can result in reduction in thousand grain weight. According to Xie *et al.* (2001) grain filling pattern had marked influence on final grain weight. The reserve mobilization and deposition to the rice endosperm was promoted in tolerant genotypes (Morita *et al.*, 2005). Due to water stress at flowering stage largely results in from the reduction in fertile panicle and filled grain percentage (Xie *et al.*, 2001). The slow grain filling and low grain weight of inferior spikelet have often been attributed to a limitation in carbohydrate supply (Tao *et al.*, 2006), thus produces the lower thousand grain weight. Zubaer *et al.* (2007) reported that the maximum thousand grain weight was found at 100% FC, followed by 70% FC, and the smallest one was found at 40% FC. The outcomes of our investigation were not similar with those of Venuprasad *et al.* (2007); Mostajeran and Eichi (2009) and Pandey and Shukla (2015) who reported that the thousand grain weight was significantly decreased under drought stress.





D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

**Figure 4.3.20 Effect of drought stress on the thousand grain weight of wild species of rice (LSD<sub>0.05</sub>=NS)**

#### 4.3.35.3 Interaction effect of species and drought stress

Thousand grain weight was significantly affected by the interaction of wild rice genotypes and drought stress (Table 4.3.49). The maximum thousand grain weight (33.13 g) was obtained from V<sub>4</sub>D<sub>1</sub> treatment which was statistically similar with V<sub>4</sub>D<sub>2</sub> and the minimum thousand grain weight (8.10 g) was obtained from V<sub>12</sub>D<sub>2</sub> which was statistically similar with V<sub>12</sub>D<sub>1</sub>, V<sub>9</sub>D<sub>2</sub>, V<sub>9</sub>D<sub>1</sub>, V<sub>5</sub>D<sub>2</sub>, V<sub>5</sub>D<sub>1</sub>, V<sub>2</sub>D<sub>2</sub> and V<sub>2</sub>D<sub>1</sub>. Hossain *et al.* (2020) reported that *Vittiatash* rice variety had the highest thousand grain weight ( $18.70 \pm 4.32$ g) at saturated condition and the lowest ( $16.19 \pm 2.73$ g) at 5 cm standing water but the values did not differ significantly from *Banglamoti* and *Atash balam*. The maximum thousand grain weight of *Banglamoti* and *Aatshbalam* was calculated in 5 cm standing water and 3 cm standing water, respectively.

The maximum decrease of thousand grain weight (4.13%) was obtained from wild rice genotype *O. punctata* (V<sub>2</sub>) and the increase of thousand grain weight (0.04%) was obtained from wild rice genotype *O. nivara* (V<sub>3</sub>) (Table 4.3.50).

**Table 4.3.49 Interaction effect of species and drought stress on the yield and yield contributing characteristics of wild species of rice**

| Treatments                     | Thousand grain weight (g) | Grain yield hill <sup>-1</sup> (g) | Biological yield hill <sup>-1</sup> (g) | Harvest index (%) |
|--------------------------------|---------------------------|------------------------------------|-----------------------------------------|-------------------|
| V <sub>1</sub> D <sub>1</sub>  | 24.32 c                   | 29.85 c                            | 113.00 cd                               | 26.39 e           |
| V <sub>1</sub> D <sub>2</sub>  | 24.28 c                   | 27.89 c                            | 102.50 ef                               | 27.21 e           |
| V <sub>2</sub> D <sub>1</sub>  | 9.19 h                    | 6.19 m                             | 56.57 h                                 | 10.96 hi          |
| V <sub>2</sub> D <sub>2</sub>  | 8.81 h                    | 5.39 mn                            | 44.35 i                                 | 12.14 h           |
| V <sub>3</sub> D <sub>1</sub>  | 26.67 b                   | 44.21 a                            | 130.90 a                                | 33.77 c           |
| V <sub>3</sub> D <sub>2</sub>  | 26.68 b                   | 41.47 b                            | 118.20 bc                               | 35.07 bc          |
| V <sub>4</sub> D <sub>1</sub>  | 33.13 a                   | 15.92 f-h                          | 57.87 h                                 | 27.50 e           |
| V <sub>4</sub> D <sub>2</sub>  | 33.02 a                   | 13.38 h-j                          | 44.65 i                                 | 29.95 d           |
| V <sub>5</sub> D <sub>1</sub>  | 8.93 h                    | 14.56 g-i                          | 100.50 ef                               | 14.50 g           |
| V <sub>5</sub> D <sub>2</sub>  | 8.89 h                    | 12.88 i-k                          | 84.34 g                                 | 15.27 g           |
| V <sub>6</sub> D <sub>1</sub>  | 20.27 e                   | 17.50 ef                           | 115.20 cd                               | 15.18 g           |
| V <sub>6</sub> D <sub>2</sub>  | 20.25 e                   | 16.28 e-g                          | 101.30 ef                               | 16.06 g           |
| V <sub>7</sub> D <sub>1</sub>  | 22.44 d                   | 45.68 a                            | 125.60 ab                               | 36.35 b           |
| V <sub>7</sub> D <sub>2</sub>  | 22.39 d                   | 40.85 b                            | 106.00 de                               | 38.56 a           |
| V <sub>8</sub> D <sub>1</sub>  | 25.28 bc                  | 22.10 d                            | 98.87 ef                                | 22.33 f           |
| V <sub>8</sub> D <sub>2</sub>  | 25.19 bc                  | 18.87 e                            | 79.63 g                                 | 23.68 f           |
| V <sub>9</sub> D <sub>1</sub>  | 8.14 h                    | 10.37 kl                           | 84.93 g                                 | 12.23 h           |
| V <sub>9</sub> D <sub>2</sub>  | 8.08 h                    | 9.14 l                             | 80.58 g                                 | 11.35 hi          |
| V <sub>10</sub> D <sub>1</sub> | 13.45 f                   | 10.93 j-l                          | 40.05 i                                 | 27.29 e           |
| V <sub>10</sub> D <sub>2</sub> | 13.23 f                   | 9.69 l                             | 35.75 i                                 | 27.07 e           |
| V <sub>11</sub> D <sub>1</sub> | 11.28 g                   | 4.42 mn                            | 106.00 de                               | 4.17 j            |
| V <sub>11</sub> D <sub>2</sub> | 11.25 g                   | 3.41 n                             | 102.80 ef                               | 3.32 j            |
| V <sub>12</sub> D <sub>1</sub> | 8.15 h                    | 11.23 j-l                          | 106.00 de                               | 10.59 hi          |
| V <sub>12</sub> D <sub>2</sub> | 8.10 h                    | 9.26 l                             | 96.05 f                                 | 9.63 i            |
| <b>LSD<sub>(0.05)</sub></b>    | <b>1.56</b>               | <b>2.62</b>                        | <b>9.28</b>                             | <b>2.18</b>       |
| <b>CV (%)</b>                  | <b>5.39</b>               | <b>8.68</b>                        | <b>6.36</b>                             | <b>6.50</b>       |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*; D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

#### 4.3.36 Grain yield hill<sup>-1</sup>

##### 4.3.36.1 Effect of species

Grain yield hill<sup>-1</sup> was significantly influenced by rice genotypes (Figure 4.3.21). The result of our investigation revealed that the highest grain yield hill<sup>-1</sup> (43.26 g) was produced by FR13A (V<sub>7</sub>) (Check variety as drought tolerant), which was statistically similar with *O. nivara* (V<sub>3</sub>) (42.84 g) whereas the lowest grain yield hill<sup>-1</sup> (3.92 g) was produced by *O. latifolia* (V<sub>11</sub>). Rice genotypes FR13A and *O. nivara* produced

1001.74% and 992.86%, respectively more grain hill<sup>-1</sup> than wild rice genotype *O. latifolia*. Foley *et al.* (2011); Pandey and Shukla (2015) made a statement that the rice variety which has the capability to with stand firmly under depleting water supply condition is regarded as drought tolerant variety. Tubur *et al.* (2012) reported that some varieties have a high tolerance to drought. Grain yield is a multigenic factor, with susceptible varieties producing high grain yield under normal conditions, but it also shows a high percent reduction over control during drought. The yield stability in tolerant varieties was due to specific adaptive feature that make them able to produce stable grain yield even under stress (Liu *et al.*, 2008; Van Heerden and Laurie, 2008). Drought is a complex mechanism involving various plant adaptive features which produce a stable yield. The highest reduction in grain yield under drought stress was recorded in Rokan variety (95.22%), followed by Menthik Wangi (82.99%), and Silugonggo (73.94%), while less reduction was noted in Jatiluhur (40.72%). Tolerant varieties (Jatiluhur) showed stable yield due to a better scavenging system, high accumulation of osmolytes during stress, and fast recovery after relief from stress (Maisura *et al.*, 2014). Pantuwan *et al.* (2002) concluded that seed yields of some rice varieties are reduced by up to 81% under drought conditions. Khan *et al.* (2017) reported that overall grain yield reduced by 6 and 32% in PR-115 and Super-7 varieties respectively under water stress condition. Keyvan (2010) revealed that in various cultivars the mean comparison of grain yield showed Chamran cultivar had highest grain yield (5118 kg h<sup>-1</sup>) and Shahryar cultivar had lowest (4536 kg h<sup>-1</sup>). Zubaer *et al.* (2007) showed that the amount of reduction of grain yield under lower moisture level was higher in Basmati (26.25 to 53.08%) and RD 2585 (32.51 to 48.84%) than that in Binadhan 4 (20.74 to 45.34%).

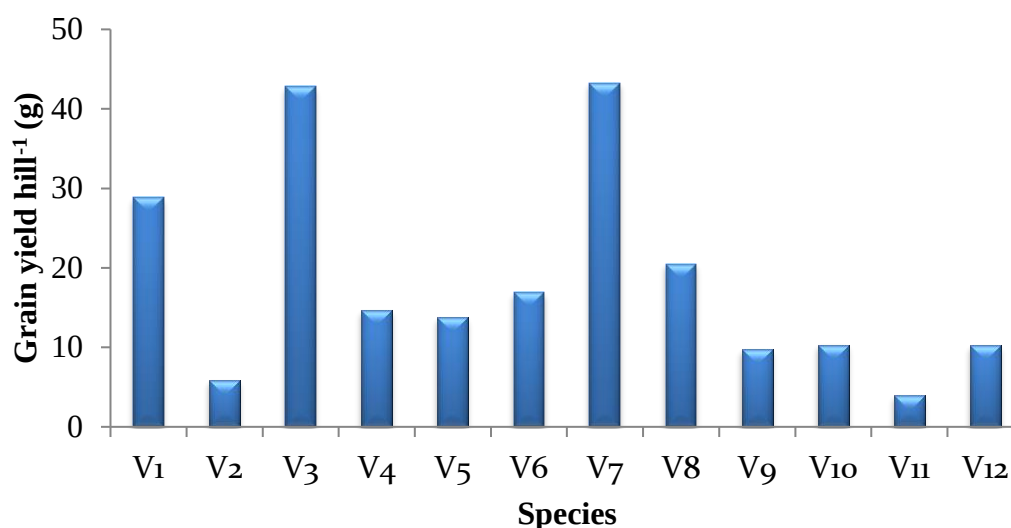
#### **4.3.36.2 Effect of drought stress**

Grain yield hill<sup>-1</sup> was significantly influenced by drought stress (Figure 4.3.22). The result of our investigation revealed that the higher grain yield hill<sup>-1</sup> (19.41 g) was produced by D<sub>1</sub> whereas the lower grain yield hill<sup>-1</sup> (17.38 g) was produced by D<sub>2</sub>. Control treatment (D<sub>1</sub>) produced 11.68% more grain than 40-45% field capacity (D<sub>2</sub>).

**Table 4.3.50 Thousand grain weight of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 24.32                            | 24.28                 | 0.16                         |
| V <sub>2</sub>  | 9.19                             | 8.81                  | 4.13                         |
| V <sub>3</sub>  | 26.67                            | 26.68                 | -0.04                        |
| V <sub>4</sub>  | 33.13                            | 33.02                 | 0.33                         |
| V <sub>5</sub>  | 8.93                             | 8.89                  | 0.41                         |
| V <sub>6</sub>  | 20.27                            | 20.25                 | 0.10                         |
| V <sub>7</sub>  | 22.44                            | 22.39                 | 0.22                         |
| V <sub>8</sub>  | 25.28                            | 25.19                 | 0.36                         |
| V <sub>9</sub>  | 8.14                             | 8.08                  | 0.74                         |
| V <sub>10</sub> | 13.45                            | 13.23                 | 1.64                         |
| V <sub>11</sub> | 11.28                            | 11.25                 | 0.27                         |
| V <sub>12</sub> | 8.15                             | 8.10                  | 0.54                         |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*



V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

**Figure 4.3.21 Grain yield hill<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=1.86)**

Drought stress in plants is characterized by the continuous water loss through transpiration of restricted water uptake due to decrease in soil moisture (Koffler *et al.*, 2014). An important physiological response of plants to drought is its ability to maintain turgor pressure by reducing osmotic potential as a tolerant mechanism

(Maisura *et al.*, 2014 and Pandey and Shukla, 2015). The decline in yield may also be due to drought induced reduction in CO<sub>2</sub> assimilation rates, reduced stomatal conductance, photosynthetic pigments, small leaf size, reduced stem extension, disturbed plant water relations, reduced WUE, reduced activities of sucrose and starch synthesis enzymes and reduced assimilate partitioning, leading to a reduction in plant growth and productivity (Anjum *et al.* 2011 and Jahan *et al.*, 2014). Photosynthesis is the main metabolic process determining crop production and is affected by drought stress. Drought induced reduction in photosynthetic rate of rice has been well documented (Lauteri *et al.*, 2014; Yang *et al.*, 2014). The major components limiting photosynthesis are the CO<sub>2</sub> diffusional limitation due to early stomatal closure reduced activity of photosynthetic enzymes, the biochemical components related to triose-phosphate formation and decreased photochemical efficiency of photosystem II (PSII). Change in any of these components alters the final photosynthesis rate. Stomatal and mesophyll conductance to CO<sub>2</sub> often decrease in response to drought (Centritto *et al.*, 2009; de Souza *et al.*, 2013). Severe drought conditions also limit photosynthesis due to a decline in Rubisco activity, which is an enzyme of the Calvin cycle (Bota *et al.*, 2004; Zhou *et al.*, 2007). However, the amount of Rubisco activase, which rescues Rubisco sites from dead end inhibition by promoting ATP-dependent conformational changes, enhances under the drought stress as a protective mechanism. The up-regulation of this enzyme might alleviate the damage on Rubisco by drought stress (Ji *et al.*, 2012). Drought causes many changes related to altered metabolic functions, and one of those is either loss of or reduced the synthesis of photosynthetic pigments. This results in declined light harvesting and generation of reducing powers, which are a source of energy for dark reactions of photosynthesis. These changes in the amounts of photosynthetic pigments are closely associated to plant biomass and yield (Jaleel *et al.*, 2009).

The generation of reactive oxygen species (ROS) is a key process in plant responsiveness to drought stress. ROS such as singlet oxygen, hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>), and superoxide anion act as important signal transduction molecules and also toxic by-products of stress metabolism, depending on their overall cellular amount (Miller *et al.*, 2010). At low to moderate concentrations, ROS may act as secondary messengers in stress signaling pathways, triggering stress-defensive or adaptive responses. However, when ROS levels reach a certain threshold, they can trigger

progressive production of superoxide radical, hydroxyl free radical, hydrogen peroxide and singlet oxygen, and causes peroxidation of lipids, denaturation of proteins, mutation of DNA, disrupt cellular homeostasis and various types of cellular oxidative damage, leading to retarded growth and eventual cell death (Hou *et al.*, 2009 and Xiong *et al.*, 2018). On the other hand, plants have evolved various mechanisms to alleviate water deficit in drought condition, including morphological, physiological, biochemical, cellular and molecular levels (Hu and Xiong, 2014 and Fang and Xiong, 2015).

As water deficit occurs, plants accumulate different types of organic and inorganic solutes in the cytosol to lower osmotic potential, thereby maintaining cell turgor (Rhodes and Samaras, 1994; Lissar *et al.*, 2012). This biochemical process is known as osmotic adjustment which strongly depends on the rate of plant water stress. This condition leads to cell enlargement reduction followed by slowing down or stopping growth and reproductive failure. Drought-tolerant types such as *O. glaberrima* had smaller size of stomata and lower stomatal density (both adaxial and abaxial surfaces) than lowland rice, making it capable to have a faster response to water deficit environment (Ouyang *et al.*, 2017). Plant cells are protected against the detrimental effects of ROS by a complex antioxidant system comprising of the non-enzymatic as well as enzymatic antioxidants. Ascorbate (AsA) and glutathione (GSH) are served as potent non-enzymatic antioxidants within the cell. The enzymatic antioxidants include superoxide dismutase (SOD), catalase (CAT), guaiacol peroxidase (GPX), enzymes of ascorbate-glutathione cycle, ascorbate peroxidase (APX), monodehydroascorbate reductase (MDHAR), dehydroascorbate reductase (DHAR) and glutathione reductase (GR) (Noctor and Foyer, 1998). These antioxidants are critical components of the ROS scavenging system in plant, and their expressions can improve drought tolerance in rice (Wang *et al.*, 2005; Miller, 2018).

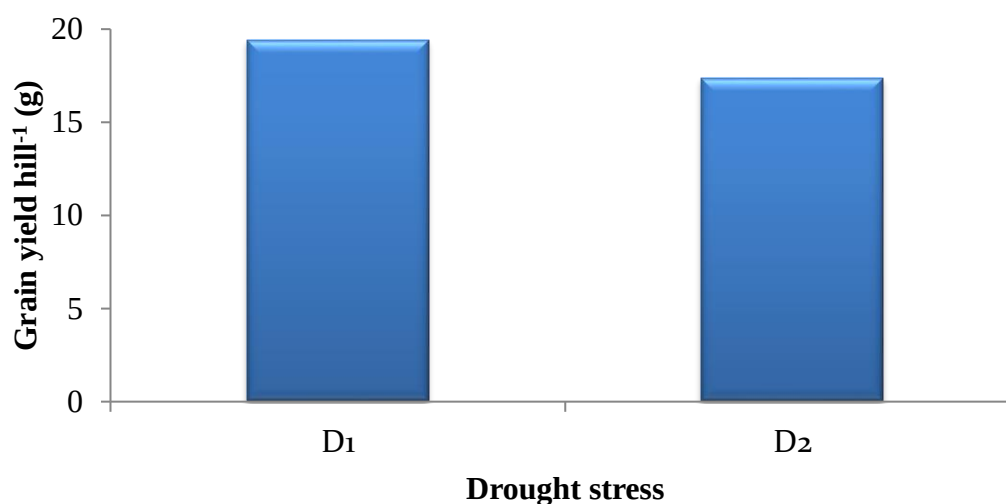
According to Kumar *et al.* (2014b) plants exposed to water stress have increased levels of phytosterols like oryzanol, which play a role in drought tolerance by strengthening the cell membrane this stabilizing property is due to its three-dimensional interactions with lipid layer of membranes and its polarity. The protective effect of oryzanol also includes scavenging of ROS produced due to oxidative stress. These functions provide tolerance to plants against water stress (Kumar *et al.*, 2014b). Fetching greater harvestable yield is the ultimate purpose of

growing crops. Reduction in seed size, weight (Venuprasad *et al.*, 2007 and Mostajeran and Eichi, 2009), seed-setting rate and thousand grain weight (Ji *et al.*, 2012) and increase in spikelet sterility (Raman *et al.*, 2012; Kumar *et al.*, 2014a) is commonly observed under drought stress. Drought stress at vegetative growth especially booting stage (Pantuwan *et al.*, 2002), flowering and terminal periods can interrupt floret initiation, causing spikelet sterility and slow seed filling, resulting in lower seed weight and ultimately poor paddy yield (Zhang *et al.*, 2018 and Yang, *et al.*, 2019). Seed dry weight is the ultimate result of seed filling. Grain filling is the final stage of growth in cereals where fertilized ovules develop into caryopses. Drought reduces grain yield probably by shortening the seed filling period (Shahryari *et al.*, 2008), disrupting leaf gas exchange properties, limiting the size of the source and sink tissues, impaired phloem loading and assimilate translocation (Farooq *et al.*, 2009a) and ultimately reduces rice yield (Kamoshita *et al.*, 2004; Botwright *et al.*, 2008). Keyvan (2010) observed that grain yield in different treatment of drought stress showed that drought stress treatment with 3663 kg h<sup>-1</sup> had highest decrease of grain yield than control treatment with 6793 kg h<sup>-1</sup>. Pantuwan *et al.* (2000); Ahmadikhah and Marufinia (2016) reported that grain yield of some rice varieties was reduced by up to 81 % under drought condition. The results obtained in our study are in agreement with those studies of Xiong *et al.* (2018); Zhang *et al.* (2018); Yang *et al.* (2019); Hossain *et al.* (2020); Kartika *et al.* (2020) who reported that rice grain yield severely reduces under drought stress but the extent of reduction is depends on whether the genotypes is tolerance or sensitive towards drought stress.

#### **4.3.36.3 Interaction effect of species and drought stress**

Grain yield hill<sup>-1</sup> was significantly influenced by rice genotypes and drought stress (Table 4.3.49). The result of our investigation revealed that the highest grain yield hill<sup>-1</sup> (45.68 g) was produced by V<sub>7</sub>D<sub>1</sub> which was statistically similar with V<sub>3</sub>D<sub>1</sub> (44.21 g) whereas the lowest grain yield hill<sup>-1</sup> (3.41 g) was produced by V<sub>11</sub>D<sub>2</sub> which was statistically similar with V<sub>11</sub>D<sub>1</sub> and V<sub>2</sub>D<sub>2</sub>.

The maximum decrease of grain yield hill<sup>-1</sup> (22.78%) was obtained from wild rice genotype *O. latifolia* (V<sub>11</sub>) and the minimum decrease of grain yield hill<sup>-1</sup> (6.20%) was obtained from wild rice genotype *O. nivara* (V<sub>3</sub>) (Table 4.3.51).



D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

**Figure 4.3.22 Effect of drought stress on the grain yield hill<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=0.99)**

**Table 4.3.51 Grain yield hill<sup>-1</sup> of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity (Control) | 40-45% field capacity | Decrease over control (%) |
|-----------------|-------------------------------|-----------------------|---------------------------|
| V <sub>1</sub>  | 29.85                         | 27.89                 | 6.57                      |
| V <sub>2</sub>  | 6.19                          | 5.39                  | 12.92                     |
| V <sub>3</sub>  | 44.21                         | 41.47                 | 6.20                      |
| V <sub>4</sub>  | 15.92                         | 13.38                 | 15.95                     |
| V <sub>5</sub>  | 14.56                         | 12.88                 | 11.54                     |
| V <sub>6</sub>  | 17.50                         | 16.28                 | 6.97                      |
| V <sub>7</sub>  | 45.68                         | 40.85                 | 10.57                     |
| V <sub>8</sub>  | 22.10                         | 18.87                 | 14.62                     |
| V <sub>9</sub>  | 10.37                         | 9.14                  | 11.86                     |
| V <sub>10</sub> | 10.93                         | 9.69                  | 11.32                     |
| V <sub>11</sub> | 4.42                          | 3.41                  | 22.78                     |
| V <sub>12</sub> | 11.23                         | 9.26                  | 17.57                     |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

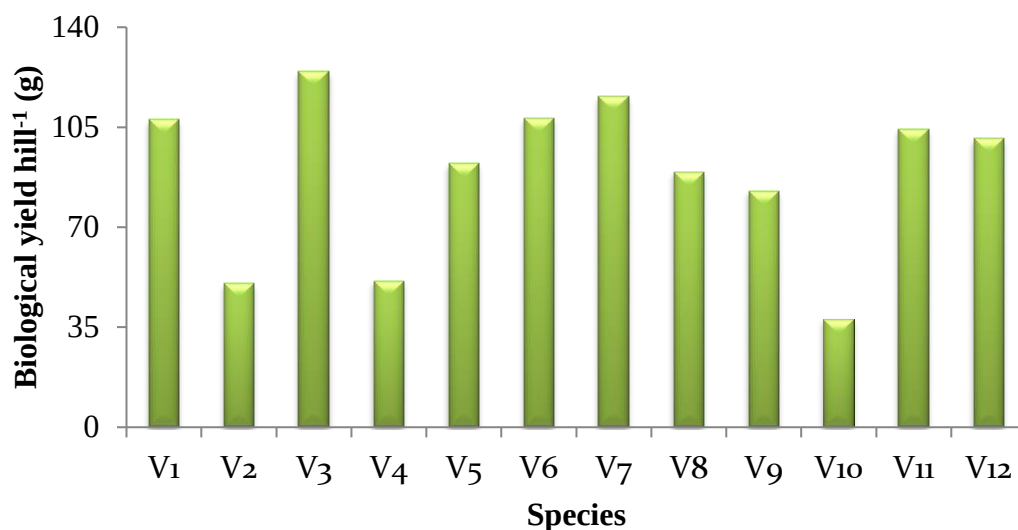
### 4.3.37 Biological yield hill<sup>-1</sup>

#### 4.3.37.1 Effect of species

Wild rice varieties exerted significant variation on biological yield hill<sup>-1</sup> (Figure 4.3.23). The maximum biological yield hill<sup>-1</sup> (124.60 g) was recorded from *O. nivara*



(V<sub>3</sub>) and the minimum biological yield hill<sup>-1</sup> (37.90 g) was recorded from *P. coaractata* (V<sub>10</sub>).



V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

**Figure 4.3.23 Biological yield hill<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=6.56)**

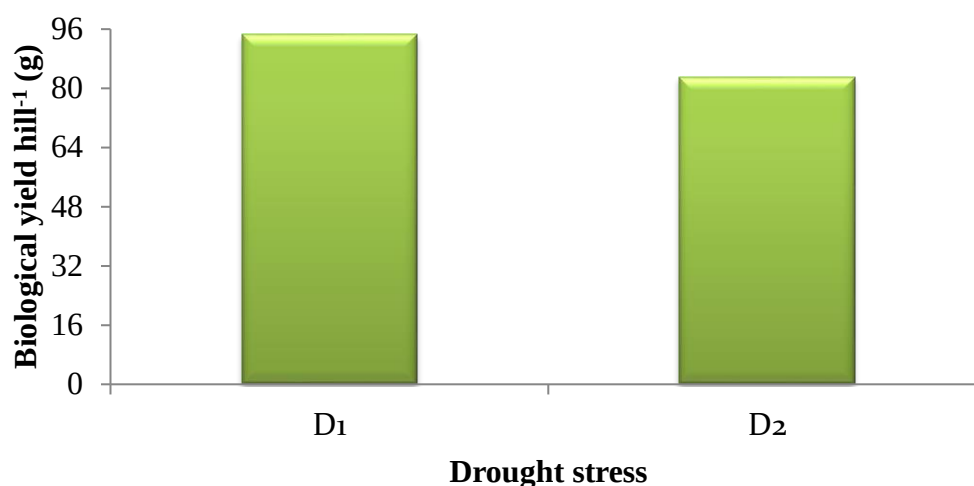
#### 4.3.37.2 Effect of drought stress

Drought stress condition exerted significant variation on biological yield hill<sup>-1</sup> (Figure 4.3.24). The higher biological yield hill<sup>-1</sup> (94.63 g) was recorded from D<sub>1</sub> and the lower biological yield hill<sup>-1</sup> (83.01 g) was recorded from D<sub>2</sub>.

#### 4.3.37.3 Interaction effect of species and drought stress

Interaction effect of wild rice varieties and drought stress exerted significant variation on biological yield hill<sup>-1</sup> (Table 4.3.40). The maximum biological yield hill<sup>-1</sup> (130.90 g) was recorded from V<sub>3</sub>D<sub>1</sub> which was statistically similar with V<sub>7</sub>D<sub>1</sub> and the minimum biological yield hill<sup>-1</sup> (35.75 g) was recorded from V<sub>10</sub>D<sub>2</sub> which was statistically similar with V<sub>10</sub>D<sub>1</sub>, V<sub>4</sub>D<sub>2</sub> and V<sub>2</sub>D<sub>2</sub>.

The maximum decrease of biological yield hill<sup>-1</sup> (22.84%) was obtained from wild rice genotype *O. barthii* (V<sub>4</sub>) and the minimum decrease of biological yield hill<sup>-1</sup> (3.02%) was obtained from wild rice genotype *O. latifolia* (V<sub>11</sub>) (Table 4.3.52).



D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

**Figure 4.3.24 Effect of drought stress on the biological yield hill<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=3.51)**

**Table 4.3.52 Biological yield hill<sup>-1</sup> of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity (Control) | 40-45% field capacity | Decrease over control (%) |
|-----------------|-------------------------------|-----------------------|---------------------------|
| V <sub>1</sub>  | 113.00                        | 102.50                | 9.29                      |
| V <sub>2</sub>  | 56.57                         | 44.35                 | 21.60                     |
| V <sub>3</sub>  | 130.90                        | 118.20                | 9.70                      |
| V <sub>4</sub>  | 57.87                         | 44.65                 | 22.84                     |
| V <sub>5</sub>  | 100.50                        | 84.34                 | 16.08                     |
| V <sub>6</sub>  | 115.20                        | 101.30                | 12.07                     |
| V <sub>7</sub>  | 125.60                        | 106.00                | 15.61                     |
| V <sub>8</sub>  | 98.87                         | 79.63                 | 19.46                     |
| V <sub>9</sub>  | 84.93                         | 80.58                 | 5.12                      |
| V <sub>10</sub> | 40.05                         | 35.75                 | 10.74                     |
| V <sub>11</sub> | 106.00                        | 102.80                | 3.02                      |
| V <sub>12</sub> | 106.00                        | 96.05                 | 9.39                      |

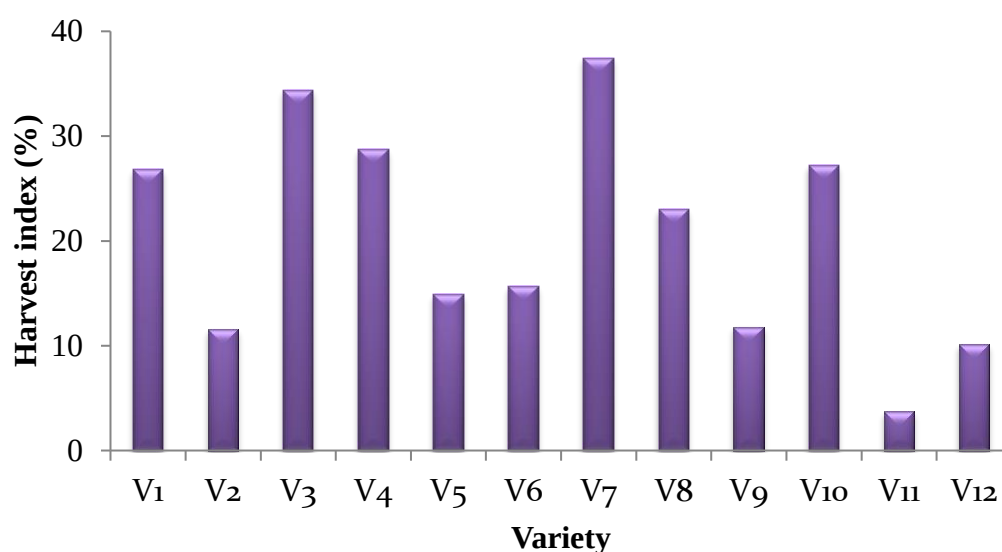
V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

### 4.3.38 Harvest index

#### 4.3.38.1 Effect of species

Harvest index (HI) of wild rice genotypes was significantly varied by species variation (Figure 4.3.25). Result showed that the maximum harvest index (37.45%)

was received from FR13A (V<sub>7</sub>) and the minimum harvest index (3.75%) was received from *O. latifolia* (V<sub>11</sub>). Similar results were also reported by Zubaer *et al.* (2007) who informed that harvest index of all rice genotypes was reduced with reduced moisture level. It might be due to the fact that drought stress affects the translocation of photosynthates towards the grain. But the degree of reduction in HI value under lower moisture level was different in different genotypes. It was higher in Basmati (13.15 to 36.84%) and RD2585 (12.5 to 28.12%) than that in Binadhan 4(11.11 to 20.0 %).



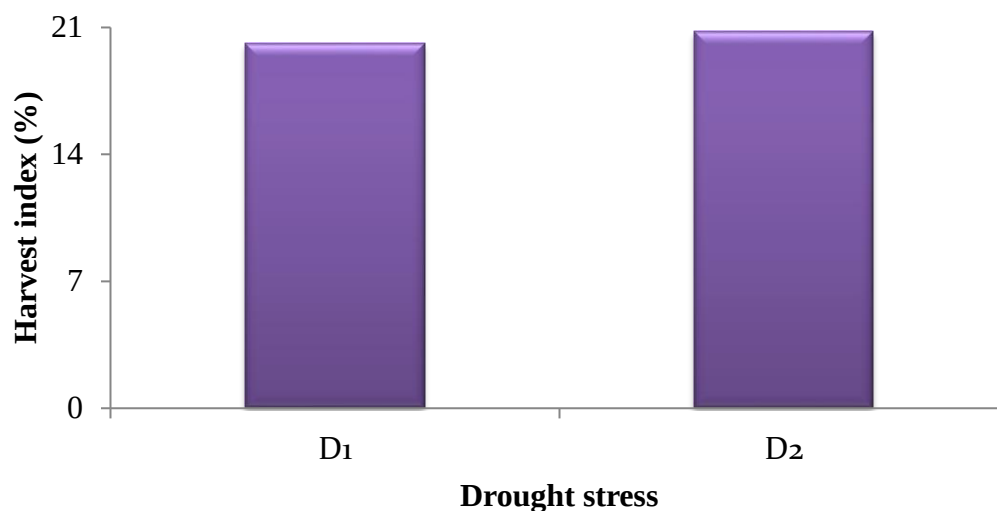
V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

**Figure 4.3.25 Harvest index of wild species of rice (LSD<sub>0.05</sub>=1.54)**

#### 4.3.38.2 Effect of drought stress

Harvest index of wild rice genotypes was not significantly affected by drought stress (Figure 4.3.26). Result showed that numerically the maximum (20.78%) and minimum (20.11%) harvest index was received from D<sub>2</sub> and D<sub>1</sub>, respectively. Though harvest index in our investigation was not significantly varied but it is one of the most important characters for the assessment of drought tolerant rice genotypes. Hossain *et al.* (2020) reported that the harvest index value is a very important indicator of production efficiency which indicates the proper translocation of sufficient assimilates to the grain. The reason of decrease in HI value could be explained as water stress inhibit nutrient supply and increase the yield of empty grain. The result was in agreement with the findings of Zubaer *et al.* (2007); Khairi *et al.* (2015) who observed

that HI decreased with increasing the water stress. They also stated that, the rate of reduction of HI largely influenced by the tolerance level of rice genotypes and soil moisture level.



D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity

**Figure 4.3.26 Effect of drought stress on the harvest index of wild species of rice (LSD<sub>0.05</sub>=NS)**

#### 4.3.38.3 Interaction effect of species and drought stress

Harvest index of wild rice genotypes was significantly varied by the interaction of species and drought stress (Table 4.3.49). Result showed that the maximum harvest index (38.56%) was received from V<sub>7</sub>D<sub>2</sub> followed by V<sub>7</sub>D<sub>1</sub> (36.35%) and the minimum harvest index (3.32%) was received from V<sub>11</sub>D<sub>2</sub> which was similar with V<sub>11</sub>D<sub>1</sub>. Hossain *et al.* (2020) reported that among the rice varieties studied, the *Vittiatash* rice showed the highest HI (0.50 ±0.06) than the other varieties of rice with 5 cm standing water and *Atash balam* was in the lowest position in all the treatments.

The maximum decrease of harvest index (20.25%) was obtained from wild rice genotype *O. latifolia* (V<sub>11</sub>) and the increase of harvest index (10.77%) was obtained from wild rice genotype *O. punctata* (V<sub>2</sub>) (Table 4.3.53).

**Table 4.3.53 Harvest index of wild species of rice as influenced by drought stress**

| Treatments      | 100% field capacity<br>(Control) | 40-45% field capacity | Decrease over<br>control (%) |
|-----------------|----------------------------------|-----------------------|------------------------------|
| V <sub>1</sub>  | 26.39                            | 27.21                 | -3.11                        |
| V <sub>2</sub>  | 10.96                            | 12.14                 | -10.77                       |
| V <sub>3</sub>  | 33.77                            | 35.07                 | -3.85                        |
| V <sub>4</sub>  | 27.50                            | 29.95                 | -8.91                        |
| V <sub>5</sub>  | 14.50                            | 15.27                 | -5.31                        |
| V <sub>6</sub>  | 15.18                            | 16.06                 | -5.80                        |
| V <sub>7</sub>  | 36.35                            | 38.56                 | -6.08                        |
| V <sub>8</sub>  | 22.33                            | 23.68                 | -6.05                        |
| V <sub>9</sub>  | 12.23                            | 11.35                 | 7.20                         |
| V <sub>10</sub> | 27.29                            | 27.07                 | 0.81                         |
| V <sub>11</sub> | 4.17                             | 3.32                  | 20.25                        |
| V <sub>12</sub> | 10.59                            | 9.63                  | 9.07                         |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Check variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis*

#### **4.4 Experiment 4: Growth and yield performance of selected rice genotypes as affected by salinity stress**

In this experiment the germination and vigourity test were performed. The tested genotypes germination value were viz.,  $V_1 = 70\%$ ,  $V_2 = 6\%$ ,  $V_3 = 80\%$ ,  $V_4 = 21\%$ ,  $V_5 = 6\%$ ,  $V_6 = 67\%$ ,  $V_7 = 52\%$ ,  $V_8 = 5\%$ ,  $V_9 = 22\%$  and  $V_{10} = 35\%$  and the tested genotypes vigor index were viz.,  $V_1 = 820.40$ ,  $V_2 = 78.78$ ,  $V_3 = 1702.40$ ,  $V_4 = 146.58$ ,  $V_5 = 85.08$ ,  $V_6 = 1900.12$ ,  $V_7 = 804.96$ ,  $V_8 = 72.50$ ,  $V_9 = 250.36$  and  $V_{10} = 436.10$ .

##### **4.4.1 Plant height**

###### **4.4.1.1 Effect of species**

The data on plant height shows that there was significant difference for the plant height among the genotypes of wild rice (Table 4.4.1). The results of our study revealed that the tallest plant (186.50 cm) was distinctly observed from *O. latifolia* ( $V_4$ ) and the shortest plant (36.07 cm) was distinctly observed from BRRI Dhan 29 ( $V_{12}$ ) (check variety as salt sensitive). The results of our experiment might be due to genetic differences of wild genotypes of rice. The findings of our study are also supported by Shalhevet (1995); Islam and Mia (2007); Hasamuzzaman *et al.* (2009) who reported that plant elongation of different varieties were different and which might be due to genetic potentiality of the varieties.

###### **4.4.1.2 Effect of salinity level**

Plant height of wild rice significantly varied due to salinity level variations which are presented in Table 4.4.1. Data revealed that the magnitude of reduction of plant height increased with the increase of salinity level. The tallest plant (136.30 cm) was observed when the pot was not treated with salt ( $S_1$ ) and the shortest plant (55.48 cm) was observed when the pot was treated with 100 mM NaCl ( $S_3$ ). Netondo *et al.*, (2004); Radi *et al.*, (2013); Rahman *et al.* (2016) explained that plant height represents the growing nature of the plants, which plays an important role in assessing the growth performance of the plant. Reduction in plant height due to salt stress may be attributed to the effects of salts in retarding the processes of cell division and cell expansion upon which growth depends on. Mazher *et al.* (2007); Khanam *et al.* (2018) reported that the salt induced reduction in plant height could be due to the

negative effect of this salt on the rate of photosynthesis, the changes in enzyme activity (that subsequently affects protein synthesis) and also the decrease in the level of carbohydrates and growth hormones. An imbalance of salts contents in plants affects the physiological processes in plant body. It alters the conductance of CO<sub>2</sub> through mesophyll and stomata, consequently inhabiting photosynthetic activity due to limitation of CO<sub>2</sub> availability and due to impairment of photosynthesis plant became shortening on growth (Flexas *et al.*, 2007; Channa *et al.*, 2019). Le Rudulier (2005); Datir *et al.* (2018) also reported that the reduction of plant height is mainly due to the fact that under salinity stress condition Na<sup>+</sup> and Cl<sup>-</sup> sequestered in the vacuole could decrease the internal osmotic potential and cause partial dehydration of cytoplasm. As a result, dehydration hampers the cellular metabolism and ultimately reduced the growth of the rice plant. Again Polash *et al.* (2018) reported that the high concentration of salt in the root zone makes it harder for root to uptake water. Water is essential for all metabolic processes; lack of water may collapse all the metabolic processes of salt treated plant and finally retardant the growth of plant. The results what we found are conforming to the results of Baque *et al.* (2018); Datir *et al.* (2018); Khanam *et al.* (2018); Polash *et al.* (2018); Channa *et al.* (2019); Malumpong *et al.* (2019).

#### **4.4.1.3 Interaction effect of species and salinity level**

Statistically significant variation was found on plant height of wild rice due to the interaction of species and salinity levels are depicted in Table 4.4.2. Data revealed that the tallest plant (188.50 cm) was observed in *O. latifolia* (V<sub>4</sub>) when the pot was not treated with any salt (S<sub>1</sub>) which was statistically similar with V<sub>4</sub>S<sub>2</sub> and V<sub>4</sub>S<sub>3</sub> treatment combinations. On the other hand in case of V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub> treatment combinations the plant did not survive so the numerical value was (0.00 cm) for those treatment combinations.

**Table 4.4.1 Effect of species and salinity level on the morphological characteristics of wild rice**

| Treatments                      | Plant height<br>(cm) | Leaves<br>plant <sup>-1</sup> (no) | Nodes<br>plant <sup>-1</sup> (no.) | Days to 1 <sup>st</sup><br>flowering | Growth<br>duration (day) |
|---------------------------------|----------------------|------------------------------------|------------------------------------|--------------------------------------|--------------------------|
| <b>Effect of species</b>        |                      |                                    |                                    |                                      |                          |
| V <sub>1</sub>                  | 76.57 f              | 4.64 e                             | 3.82 cd                            | 129.90 de                            | 176.10 b                 |
| V <sub>2</sub>                  | 44.00 h              | 2.84 h                             | 2.33 f                             | 67.78 i                              | 78.33 h                  |
| V <sub>3</sub>                  | 68.49 g              | 4.13 f                             | 3.11 e                             | 124.10 ef                            | 171.00 c                 |
| V <sub>4</sub>                  | 186.50 a             | 6.27 b                             | 5.24 b                             | 107.70 g                             | 145.00 e                 |
| V <sub>5</sub>                  | 109.10 c             | 6.79 a                             | 6.59 a                             | 118.60 f                             | 150.00 d                 |
| V <sub>6</sub>                  | 42.78 h              | 2.60 h                             | 1.80 g                             | 72.44 i                              | 88.33 g                  |
| V <sub>7</sub>                  | 92.61 e              | 5.09 d                             | 4.00 c                             | 131.40 d                             | 230.00 a                 |
| V <sub>8</sub>                  | 114.50 c             | 6.43 b                             | 5.08 b                             | 176.30 b                             | 229.80 a                 |
| V <sub>9</sub>                  | 99.24 d              | 5.91 c                             | 5.02 b                             | 158.20 c                             | 230.40 a                 |
| V <sub>10</sub>                 | 168.90 b             | 5.33 d                             | 3.22 e                             | 200.20 a                             | 145.00 e                 |
| V <sub>11</sub>                 | 71.03 fg             | 3.56 g                             | 3.58 d                             | 95.67 h                              | 110.00 f                 |
| V <sub>12</sub>                 | 36.07 i              | 1.84 i                             | 1.73 g                             | 47.11 j                              | 56.67 i                  |
| <b>LSD<sub>(0.05)</sub></b>     | <b>5.65</b>          | <b>0.35</b>                        | <b>0.30</b>                        | <b>6.62</b>                          | <b>2.45</b>              |
| <b>CV (%)</b>                   | <b>6.49</b>          | <b>7.98</b>                        | <b>8.41</b>                        | <b>5.91</b>                          | <b>1.72</b>              |
| <b>Effect of salinity level</b> |                      |                                    |                                    |                                      |                          |
| S <sub>1</sub>                  | 136.30 a             | 7.28 a                             | 6.11 a                             | 181.80 a                             | 206.80 a                 |
| S <sub>2</sub>                  | 85.63 b              | 4.18 b                             | 3.39 b                             | 112.50 b                             | 151.80 b                 |
| S <sub>3</sub>                  | 55.48 c              | 2.41 c                             | 1.88 c                             | 63.14 c                              | 94.08 c                  |
| <b>LSD<sub>(0.05)</sub></b>     | <b>2.82</b>          | <b>0.17</b>                        | <b>0.15</b>                        | <b>3.31</b>                          | <b>1.22</b>              |
| <b>CV (%)</b>                   | <b>6.49</b>          | <b>7.98</b>                        | <b>8.41</b>                        | <b>5.91</b>                          | <b>1.72</b>              |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant)and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive); S<sub>1</sub>= 0 mM NaCl (Control), S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl

At 50 mM NaCl concentration it was observed that rice genotypes *O. barthii* (V<sub>2</sub>), *O. glaberrima* (V<sub>6</sub>) and BRRI Dhan 29 (Check variety as salt sensitive) (V<sub>12</sub>) did not survive and at 100 mM NaCl concentration *O. rufipogon* (V<sub>1</sub>), *O. barthii* (V<sub>2</sub>), *O. nivara* (V<sub>3</sub>), *O. glaberrima* (V<sub>6</sub>), Pokkali (Check variety as salt tolerant)(V<sub>11</sub>) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive) (V<sub>12</sub>) did not survive. Among survival genotypes at 50 mM NaCl concentration the maximum decrease of plant height (41.56%) was observed in *O. nivara* (V<sub>3</sub>) and minimum decrease of plant height (1.06 %) was observed in *O. latifolia* (V<sub>4</sub>) (Table 1). Again at 100 mM NaCl concentration the maximum decrease of plant height (69.24%) was observed in *O. punctata* (V<sub>9</sub>) and minimum decrease of plant height (2.12%) was observed in *O. latifolia* (V<sub>4</sub>) (Table 4.4.3).



**Table 4.4.2 Interaction effect of species and salinity level on the morphological characteristics of wild rice**

| Treatments                     | Plant height<br>(cm) | Leaves<br>plant <sup>-1</sup> (no) | Nodes<br>plant <sup>-1</sup> (no.) | Days to 1 <sup>st</sup><br>flowering | Growth duration<br>(day) |
|--------------------------------|----------------------|------------------------------------|------------------------------------|--------------------------------------|--------------------------|
| V <sub>1</sub> S <sub>1</sub>  | 138.30 cd            | 8.73 a                             | 7.27 a                             | 233.30 a                             | 265.00 a                 |
| V <sub>1</sub> S <sub>2</sub>  | 91.43 g              | 5.20 jk                            | 4.20 h                             | 156.30 d                             | 263.30 a                 |
| V <sub>1</sub> S <sub>3</sub>  | 0.00 j               | 0.00 o                             | 0.00 k                             | 0.00 k                               | 0.00 i                   |
| V <sub>2</sub> S <sub>1</sub>  | 132.00 de            | 8.53 ab                            | 7.00 a                             | 203.30 c                             | 235.00 c                 |
| V <sub>2</sub> S <sub>2</sub>  | 0.00 j               | 0.00 o                             | 0.00 k                             | 0.00 k                               | 0.00 i                   |
| V <sub>2</sub> S <sub>3</sub>  | 0.00 j               | 0.00 o                             | 0.00 k                             | 0.00 k                               | 0.00 i                   |
| V <sub>3</sub> S <sub>1</sub>  | 129.70 de            | 7.80 c-e                           | 6.40 bc                            | 220.00 b                             | 251.70 b                 |
| V <sub>3</sub> S <sub>2</sub>  | 75.80 h              | 4.60 k-m                           | 2.93 i                             | 152.30 de                            | 261.30 a                 |
| V <sub>3</sub> S <sub>3</sub>  | 0.00 j               | 0.00 o                             | 0.00 k                             | 0.00 k                               | 0.00 i                   |
| V <sub>4</sub> S <sub>1</sub>  | 188.50 a             | 6.53 gh                            | 5.67 de                            | 108.70 hi                            | 145.00 h                 |
| V <sub>4</sub> S <sub>2</sub>  | 186.50 a             | 6.27 gh                            | 5.27 e-g                           | 107.30 i                             | 145.00 h                 |
| V <sub>4</sub> S <sub>3</sub>  | 184.50 a             | 6.00 hi                            | 4.80 g                             | 107.00 i                             | 145.00 h                 |
| V <sub>5</sub> S <sub>1</sub>  | 110.50 f             | 7.20 ef                            | 7.00 a                             | 117.30 hi                            | 150.00 g                 |
| V <sub>5</sub> S <sub>2</sub>  | 109.00 f             | 6.73 fg                            | 6.47 bc                            | 119.00 h                             | 150.00 g                 |
| V <sub>5</sub> S <sub>3</sub>  | 107.70 f             | 6.43 gh                            | 6.30 c                             | 119.30 h                             | 150.00 g                 |
| V <sub>6</sub> S <sub>1</sub>  | 128.30 e             | 7.80 c-e                           | 5.40 ef                            | 217.30 b                             | 265.00 a                 |
| V <sub>6</sub> S <sub>2</sub>  | 0.00 j               | 0.00 o                             | 0.00 k                             | 0.00 k                               | 0.00 i                   |
| V <sub>6</sub> S <sub>3</sub>  | 0.00 j               | 0.00 o                             | 0.00 k                             | 0.00 k                               | 0.00 i                   |
| V <sub>7</sub> S <sub>1</sub>  | 143.80 c             | 8.27 a-c                           | 6.87 ab                            | 197.30 c                             | 230.00 d                 |
| V <sub>7</sub> S <sub>2</sub>  | 45.00 i              | 2.47 n                             | 2.07 j                             | 66.00 j                              | 231.70 cd                |
| V <sub>7</sub> S <sub>3</sub>  | 89.03 g              | 4.53 lm                            | 3.07 i                             | 131.00 g                             | 228.30 d                 |
| V <sub>8</sub> S <sub>1</sub>  | 141.90 c             | 8.03 b-d                           | 6.43 bc                            | 197.00 c                             | 230.00 d                 |
| V <sub>8</sub> S <sub>2</sub>  | 123.00 e             | 6.87 fg                            | 5.40 ef                            | 200.00 c                             | 230.00 d                 |
| V <sub>8</sub> S <sub>3</sub>  | 78.60 h              | 4.40 m                             | 3.40 i                             | 132.00 fg                            | 229.30 d                 |
| V <sub>9</sub> S <sub>1</sub>  | 132.00 de            | 7.80 c-e                           | 7.07 a                             | 203.30 c                             | 230.00 d                 |
| V <sub>9</sub> S <sub>2</sub>  | 125.10 e             | 7.53 de                            | 6.07 cd                            | 203.30 c                             | 230.00 d                 |
| V <sub>9</sub> S <sub>3</sub>  | 40.60 i              | 2.40 n                             | 1.93 j                             | 68.00 j                              | 231.30 cd                |
| V <sub>10</sub> S <sub>1</sub> | 173.90 b             | 5.60 ij                            | 3.43 i                             | 199.30 c                             | 145.00 h                 |
| V <sub>10</sub> S <sub>2</sub> | 167.40 b             | 5.30 j                             | 3.17 i                             | 201.00 c                             | 145.00 h                 |
| V <sub>10</sub> S <sub>3</sub> | 165.40 b             | 5.10 j-l                           | 3.07 i                             | 200.30 c                             | 145.00 h                 |
| V <sub>11</sub> S <sub>1</sub> | 108.90 f             | 5.47 ij                            | 5.60 d-f                           | 142.70 ef                            | 165.00 f                 |
| V <sub>11</sub> S <sub>2</sub> | 104.20 f             | 5.20 jk                            | 5.13 fg                            | 144.30 e                             | 165.00 f                 |
| V <sub>11</sub> S <sub>3</sub> | 0.00 j               | 0.00 o                             | 0.00 k                             | 0.00 k                               | 0.00 i                   |
| V <sub>12</sub> S <sub>1</sub> | 108.20 f             | 5.53 ij                            | 5.20 e-g                           | 141.30 e-g                           | 170.00 e                 |
| V <sub>12</sub> S <sub>2</sub> | 0.00 j               | 0.00 o                             | 0.00 k                             | 0.00 k                               | 0.00 i                   |
| V <sub>12</sub> S <sub>3</sub> | 0.00 j               | 0.00 o                             | 0.00 k                             | 0.00 k                               | 0.00 i                   |
| <b>LSD (0.05)</b>              | <b>9.78</b>          | <b>0.60</b>                        | <b>0.52</b>                        | <b>11.47</b>                         | <b>4.24</b>              |
| <b>CV (%)</b>                  | <b>6.49</b>          | <b>7.98</b>                        | <b>8.41</b>                        | <b>5.91</b>                          | <b>1.72</b>              |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant)and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive); S<sub>1</sub>= 0 mM NaCl (Control), S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl

**Table 4.4.3 Plant height of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 138.30    | 91.43      | 33.89                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 132.00    | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 129.70    | 75.80      | 41.56                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 188.50    | 186.50     | 1.06                      | 184.50      | 2.12                      |
| V <sub>5</sub>  | 110.50    | 109.00     | 1.36                      | 107.70      | 2.53                      |
| V <sub>6</sub>  | 128.30    | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 143.80    | 89.03      | 38.09                     | 45.00       | 68.71                     |
| V <sub>8</sub>  | 141.90    | 123.00     | 13.32                     | 78.60       | 44.61                     |
| V <sub>9</sub>  | 132.00    | 125.10     | 5.23                      | 40.60       | 69.24                     |
| V <sub>10</sub> | 173.90    | 167.40     | 3.74                      | 165.40      | 4.89                      |
| V <sub>11</sub> | 108.90    | 104.20     | 4.32                      | 0.00        | 100.00                    |
| V <sub>12</sub> | 108.20    | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.2 Leaves plant<sup>-1</sup>

##### 4.4.2.1 Effect of species

The size of photosynthetic surface in terms of leaves plant<sup>-1</sup> was found significantly different in all genotypes of wild rice (Table 4.4.1). The maximum leaves plant<sup>-1</sup> (6.79) was found from species *Potericia coaractata* (V<sub>5</sub>) and the minimum leaves plant<sup>-1</sup> (1.84) was found from variety BRRI Dhan 29 (V<sub>12</sub>) (Check variety as salt sensitive). Leaves production is a genetic trait and it varied with different genetic variability of wild rice accession.

##### 4.4.2.2 Effect of salinity level

The size of photosynthetic surface in terms of leaves plant<sup>-1</sup> was found significantly different due to different levels of salinity (Table 4.4.1). The leaves plant<sup>-1</sup> decreased with the increasing of salinity level. The maximum leaves plant<sup>-1</sup> (7.28) was found with no salt treated pot (S<sub>1</sub>) and the minimum leaves plant<sup>-1</sup> (2.41) was found when the pot treated with 100 mM NaCl (S<sub>3</sub>). Inhibition of the formation of leaf primordia under salinity stress could be the probable reason for the reduction in leaf number (Alamgir and Ali, 2006). The decrease in leaf number may further be carried over due to the accumulation of sodium chloride in the cell walls and cytoplasm of the

older leaves. At the same time, their vacuole saps cannot accumulate more salt and, thereby increases the concentration of salt inside the cells, which ultimately leads to their quick death (Munns, 2002). Munns and Tester (2008) also stated that the ion-specific phase of plant response to salinity stress starts when salt accumulates to toxic level in the old leaves and they die and cause a decrease in the leaf number. This result is supported by Rahman *et al.* (2016); Khanam *et al.* (2018); Channa *et al.* (2019).

#### 4.4.2.3 Interaction effect of species and salinity level

Interaction effect of species and salinity level exerted significant variations on the leaves plant<sup>-1</sup> of wild rice are presented in Table 4.4.2. Data exposed that the maximum leaves plant<sup>-1</sup> (8.73) was found with the V<sub>1</sub>S<sub>1</sub> treatment combination which was statistically similar with V<sub>2</sub>S<sub>1</sub> and V<sub>7</sub>S<sub>1</sub> treatment combinations. No leaves plant<sup>-1</sup> (0.00) was found with the V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub> treatment combinations as the plant was not survived with these combinations.

The maximum and minimum leaves plant<sup>-1</sup> of wild rice decrease (45.20 and 3.42%) were found from *O. longistaminata* (V<sub>7</sub>) and *O. punctata* (V<sub>9</sub>), respectively at 50 mM NaCl. At 100 mM NaCl concentration the maximum and minimum leaves plant<sup>-1</sup> of wild rice decrease (69.23 and 8.16%) were found from *O. punctata* (V<sub>9</sub>) and *O. latifolia* (V<sub>4</sub>), respectively (Table 4.4.4).

**Table 4.4.4 Leaves plant<sup>-1</sup> of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 8.73      | 5.20       | 40.46                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 8.53      | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 7.80      | 4.60       | 41.03                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 6.53      | 6.27       | 4.07                      | 6.00        | 8.16                      |
| V <sub>5</sub>  | 7.20      | 6.73       | 6.49                      | 6.43        | 10.65                     |
| V <sub>6</sub>  | 7.80      | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 8.27      | 4.53       | 45.20                     | 2.47        | 70.12                     |
| V <sub>8</sub>  | 8.03      | 6.87       | 14.52                     | 4.40        | 45.23                     |
| V <sub>9</sub>  | 7.80      | 7.53       | 3.42                      | 2.40        | 69.23                     |
| V <sub>10</sub> | 5.60      | 5.30       | 5.36                      | 5.10        | 8.93                      |
| V <sub>11</sub> | 5.47      | 5.20       | 4.88                      | 0.00        | 100.00                    |
| V <sub>12</sub> | 5.53      | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

### 4.4.3 Nodes plant<sup>-1</sup>

#### 4.4.3.1 Effect of species

Data presented in Table 4.4.1 showed that the nodes plant<sup>-1</sup> of wild rice was significantly varied by different species. The maximum nodes plant<sup>-1</sup> (6.59) was recorded from *P. coaractata* (V<sub>5</sub>) and the minimum nodes plant<sup>-1</sup> (1.73) was recorded from BRRI Dhan 29 (V<sub>12</sub>) (Check variety as salt sensitive).

#### 4.4.3.2 Effect of salinity level

Data presented in Table 4.4.1 showed that the nodes plant<sup>-1</sup> of wild rice was significantly varied by different salinity levels. There was a promising decrease of nodes plant<sup>-1</sup> was observed with the increasing of the salinity level. Data showed that the maximum nodes plant<sup>-1</sup> (6.11) was recorded from S<sub>1</sub> treatment and the minimum nodes plant<sup>-1</sup> (1.88) was recorded from S<sub>3</sub> treatment.

#### 4.4.3.3 Interaction effect of species and salinity level

Data presented in Table 4.4.2 showed that the nodes plant<sup>-1</sup> of wild rice was significantly varied by the interaction of different species and salinity levels. That the maximum nodes plant<sup>-1</sup> (7.27) was recorded from V<sub>1</sub>S<sub>1</sub> treatment which was statistically similar with V<sub>2</sub>S<sub>1</sub>, V<sub>5</sub>S<sub>1</sub>, V<sub>9</sub>S<sub>1</sub> and V<sub>7</sub>S<sub>1</sub> treatment combinations and No nodes plant<sup>-1</sup> (0.00) was recorded from V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub> treatment combinations.

The nodes plant<sup>-1</sup> of wild rice was decreased with increasing the salt concentration. At 50 mM NaCl concentration the maximum nodes plant<sup>-1</sup> decrease (55.29%) was recorded from *O. longistaminata* (V<sub>7</sub>) and the minimum decrease (7.06%) was recorded from *O. latifolia* (V<sub>4</sub>). At 100 mM NaCl concentration the maximum nodes plant<sup>-1</sup> decrease (69.86%) was recorded from *O. longistaminata* (V<sub>7</sub>) and the minimum decrease (10.00%) was recorded from *Potericia coaractata* (V<sub>5</sub>) (Table 4.4.5).

**Table 4.4.5 Nodes plant<sup>-1</sup> of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 7.27      | 4.20       | 42.20                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 7.00      | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 6.40      | 2.93       | 54.22                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 5.67      | 5.27       | 7.06                      | 4.80        | 15.30                     |
| V <sub>5</sub>  | 7.00      | 6.47       | 7.61                      | 6.30        | 10.00                     |
| V <sub>6</sub>  | 5.40      | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 6.87      | 3.07       | 55.29                     | 2.07        | 69.86                     |
| V <sub>8</sub>  | 6.43      | 5.40       | 16.06                     | 3.40        | 47.15                     |
| V <sub>9</sub>  | 7.07      | 6.07       | 14.15                     | 1.93        | 72.69                     |
| V <sub>10</sub> | 3.43      | 3.17       | 7.75                      | 3.07        | 10.66                     |
| V <sub>11</sub> | 5.60      | 5.13       | 8.34                      | 0.00        | 100.00                    |
| V <sub>12</sub> | 5.20      | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.4 Days to 1<sup>st</sup> flowering

##### 4.4.4.1 Effect of species

Days to 1<sup>st</sup> flowering was significantly varied due to species variation of wild rice (Table 4.4.1). Data revealed that the earliest 1<sup>st</sup> flowering (47.11 days) was obtained from BRRI Dhan 29 (V<sub>12</sub>) (Check variety as salt sensitive) and the delayed 1<sup>st</sup> flowering (200.20 days) was obtained from *O. alta* (V<sub>10</sub>). This might be due to the variability in genetic potentiality of the rice genotypes.

##### 4.4.4.2 Effect of salinity level

Days to 1<sup>st</sup> flowering was significantly varied due to different salinity level (Table 4.4.1). Data revealed that the earliest 1<sup>st</sup> flowering (63.14 days) was obtained from S<sub>3</sub> treatment and the delayed 1<sup>st</sup> flowering (181.80 days) was obtained from S<sub>1</sub> treatment.

##### 4.4.4.3 Interaction effect of species and salinity level

Days to 1<sup>st</sup> flowering was significantly varied due to interaction effect of species and salinity level (Table 4.4.2). Data revealed that the earliest 1<sup>st</sup> flowering (66.00 days) was obtained from V<sub>7</sub>S<sub>2</sub> treatment combination which was statistically similar with

V<sub>9</sub>S<sub>3</sub> treatment combination and the delayed 1<sup>st</sup> flowering (233.30 days) was obtained from V<sub>1</sub>S<sub>1</sub> treatment combination.

*O. longistaminata* (V<sub>7</sub>) rice genotype required (33.60%) less days to 1<sup>st</sup> flowering compare to control treatment (no salt stress) where *O. officinalis* (V<sub>8</sub>)rice genotype required (1.52%) more days to 1<sup>st</sup> flowering compare to control treatment (no salt stress) at 50 mM NaCl concentration. *O. longistaminata* (V<sub>7</sub>) and *O. punctata* (V<sub>9</sub>)rice genotypes required (66.55%) less days to 1<sup>st</sup> flowering compare to control treatment (no salt stress) where *Potericia coaractata* (V<sub>5</sub>) rice genotype required (1.71%) more days to 1<sup>st</sup> flowering compare to control treatment (no salt stress) at 100 mM NaCl concentration (Table 4.4.6).

**Table 4.4.6 Days required to 1<sup>st</sup> flowering of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 233.30    | 156.30     | 33.00                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 203.30    | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 220.00    | 152.30     | 30.77                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 108.70    | 107.30     | 1.29                      | 107.00      | 1.56                      |
| V <sub>5</sub>  | 117.30    | 119.00     | -1.45                     | 119.30      | -1.71                     |
| V <sub>6</sub>  | 217.30    | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 197.30    | 131.00     | 33.60                     | 66.00       | 66.55                     |
| V <sub>8</sub>  | 197.00    | 200.00     | -1.52                     | 132.00      | 32.99                     |
| V <sub>9</sub>  | 203.30    | 203.30     | 0.00                      | 68.00       | 66.55                     |
| V <sub>10</sub> | 199.30    | 201.00     | -0.85                     | 200.30      | -0.50                     |
| V <sub>11</sub> | 142.70    | 144.30     | -1.12                     | 0.00        | 100.00                    |
| V <sub>12</sub> | 141.30    | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.5 Growth duration

##### 4.4.5.1 Effect of species

Growth duration of wild rice was significantly influenced by different species (Table 4.4.1). The longest growth duration (230.40 days) was observed from *O. punctata* (V<sub>9</sub>) which was statistically at par with V<sub>7</sub> and V<sub>8</sub> varieties. On the other hand the shortest growth duration (56.67 days) was observed from BRRI Dhan 29 (V<sub>12</sub>). The

life cycle of a plant mostly depend on the genetic potentiality and in our study it also varied due to the genetic potentiality of different rice genotypes.

#### **4.4.5.2 Effect of salinity level**

Growth duration of wild rice was significantly influenced by salinity level (Table 4.4.1). The longest growth duration (206.80 days) was observed from S<sub>1</sub> treatment and the shortest growth duration (94.08 days) was observed from S<sub>3</sub> treatment.

#### **4.4.5.3 Interaction effect of species and salinity level**

Growth duration of wild rice was significantly influenced by combined effect of species and salinity level (Table 4.4.2). The longest growth duration (265.00 days) was observed from both V<sub>1</sub>S<sub>1</sub> and V<sub>6</sub>S<sub>1</sub> treatment combinations which were statistically similar with V<sub>1</sub>S<sub>2</sub> and V<sub>3</sub>S<sub>2</sub> treatment combinations and the shortest growth duration (145.00 days) was observed from V<sub>4</sub>S<sub>1</sub>, V<sub>4</sub>S<sub>2</sub>, V<sub>4</sub>S<sub>3</sub>, V<sub>10</sub>S<sub>1</sub>, V<sub>10</sub>S<sub>2</sub> and V<sub>10</sub>S<sub>3</sub> treatment combinations. In case of V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub> treatment combinations the plants was not survived under these circumstances.

*O. rufipogon* (V<sub>1</sub>) rice genotype required (0.64%) less days to complete its life cycle comparing to control treatment (no salt stress) and *O. nivara* (V<sub>3</sub>) rice genotype required (3.81%) more days to complete its life cycle that control treatment (no salt stress) at 50 mM NaCl concentration. Again, *O. longistaminata* (V<sub>7</sub>)rice genotype required (0.74%) less days to complete its life cycle comparing to control treatment (no salt stress) and *O. punctata* (V<sub>9</sub>)rice genotype required (0.57%) more days to complete its life cycle comparing to control treatment (no salt stress) at 100 mM NaCl concentration (Table 4.4.7).

#### **4.4.6 Normal leaf length**

##### **4.4.6.1 Effect of species**

Data on normal leaf length in rice genotypes are presented in table 4.4.8. From the data it can be concluded that there was significant difference among the wild rice genotypes for normal leaf length was observed and the longest normal leaf (52.88 cm)

was achieved from *O. latifolia* (V<sub>4</sub>) and the shortest one (5.38 cm) was achieved from BRRI Dhan 29 (V<sub>12</sub>) (Check variety as salt sensitive).

**Table 4.4.7 Growth duration of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 265.00    | 263.30     | 0.64                      | 0.00        | 100.00                    |
| V <sub>2</sub>  | 235.00    | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 251.70    | 261.30     | -3.81                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 145.00    | 145.00     | 0.00                      | 145.00      | 0.00                      |
| V <sub>5</sub>  | 150.00    | 150.00     | 0.00                      | 150.00      | 0.00                      |
| V <sub>6</sub>  | 265.00    | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 230.00    | 231.70     | -0.74                     | 228.30      | 0.74                      |
| V <sub>8</sub>  | 230.00    | 230.00     | 0.00                      | 229.30      | 0.30                      |
| V <sub>9</sub>  | 230.00    | 230.00     | 0.00                      | 231.30      | -0.57                     |
| V <sub>10</sub> | 145.00    | 145.00     | 0.00                      | 145.00      | 0.00                      |
| V <sub>11</sub> | 165.00    | 165.00     | 0.00                      | 0.00        | 100.00                    |
| V <sub>12</sub> | 170.00    | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.6.2 Effect of salinity level

Data on normal leaf length in rice genotypes are presented in table 4.4.8. From the data it can be concluded that there was significant difference among the salinity levels for normal leaf length of wild rice was noticed. There was a marked reduction of normal leaf length was observed with the advancement of salt density. Data revealed that the longest normal leaf (28.10 cm) was achieved from S<sub>1</sub> treatment and the shortest normal leaf (11.54 cm) was achieved from S<sub>3</sub> treatment. Under salinity stress condition division and elongation of cell was hampered and more over photosynthesis process was retarded, consequently the growth of leaf was slower and leaf length was shorten. These results of our investigation are similar to the results of Abbas *et al.* (2013); Channa *et al.* (2019); Malumpong *et al.* (2019) who reported that higher salinity levels caused significant reduction in leaf length of a plant.



**Table 4.4.8 Effect of species and salinity level on normal leaf characteristics of wild species of rice**

| Treatments                      | Normal leaf length (cm) | Normal leaf breadth (cm) | Normal leaf length breadthratio | Normal leaf area (cm <sup>2</sup> ) |
|---------------------------------|-------------------------|--------------------------|---------------------------------|-------------------------------------|
| <b>Effect of species</b>        |                         |                          |                                 |                                     |
| V <sub>1</sub>                  | 17.05 e                 | 0.65 f                   | 13.78 c                         | 19.35 e                             |
| V <sub>2</sub>                  | 11.92 g                 | 0.51 g                   | 4.34 g                          | 14.62 f                             |
| V <sub>3</sub>                  | 14.07 f                 | 0.71 ef                  | 8.01 f                          | 18.52 e                             |
| V <sub>4</sub>                  | 52.88 a                 | 2.68 a                   | 17.06 a                         | 108.3 a                             |
| V <sub>5</sub>                  | 12.66 g                 | 0.73 e                   | 15.27 b                         | 7.46 g                              |
| V <sub>6</sub>                  | 9.74 h                  | 0.53 g                   | 4.40 g                          | 13.98 f                             |
| V <sub>7</sub>                  | 22.54 c                 | 1.16 d                   | 14.01 c                         | 31.17 c                             |
| V <sub>8</sub>                  | 18.09 de                | 1.47 c                   | 12.06 d                         | 29.14 d                             |
| V <sub>9</sub>                  | 18.82 d                 | 1.47 c                   | 9.31 e                          | 32.85 c                             |
| V <sub>10</sub>                 | 30.01 b                 | 2.16 b                   | 8.37 f                          | 49.28 b                             |
| V <sub>11</sub>                 | 14.04 f                 | 1.20 d                   | 8.12 f                          | 19.23 e                             |
| V <sub>12</sub>                 | 5.38 i                  | 0.65 f                   | 2.57 h                          | 7.35 g                              |
| <b>LSD<sub>(0.05)</sub></b>     | <b>1.20</b>             | <b>0.08</b>              | <b>0.92</b>                     | <b>1.80</b>                         |
| <b>CV (%)</b>                   | <b>6.74</b>             | <b>7.12</b>              | <b>9.97</b>                     | <b>6.54</b>                         |
| <b>Effect of salinity level</b> |                         |                          |                                 |                                     |
| S <sub>1</sub>                  | 28.10 a                 | 1.74 a                   | 14.81 a                         | 42.45 a                             |
| S <sub>2</sub>                  | 17.16 b                 | 1.09 b                   | 9.17 b                          | 27.22 b                             |
| S <sub>3</sub>                  | 11.54 c                 | 0.66 c                   | 5.35 c                          | 18.15 c                             |
| <b>LSD<sub>(0.05)</sub></b>     | <b>0.60</b>             | <b>0.04</b>              | <b>0.46</b>                     | <b>0.90</b>                         |
| <b>CV (%)</b>                   | <b>6.74</b>             | <b>7.12</b>              | <b>9.97</b>                     | <b>6.54</b>                         |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive); S<sub>1</sub>= 0 mM NaCl (Control), S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl

#### 4.4.6.3 Interaction effect of species and salinity level

Data on normal leaf length in rice genotypes are presented in table 4.4.9. From the data it can be concluded that there was significant difference among the species and salinity level for normal leaf length of wild rice was identified. Data revealed that the longest normal leaf (54.18 cm) was achieved from the interaction of V<sub>4</sub> along with S<sub>1</sub> treatment which was statistically similar with V<sub>4</sub>S<sub>2</sub> where as no normal leaf data was received from V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub> treatment combinations.

**Table 4.4.9 Interaction effect of species and salinity level on the morphological characteristics of wild rice**

| Treatments                     | Normal leaf length (cm) | Normal leaf breadth (cm) | Normal leaf length breadth ratio | Normal leaf area (cm <sup>2</sup> ) |
|--------------------------------|-------------------------|--------------------------|----------------------------------|-------------------------------------|
| V <sub>1</sub> S <sub>1</sub>  | 31.03 d                 | 1.20 k                   | 26.18 a                          | 35.80 h                             |
| V <sub>1</sub> S <sub>2</sub>  | 20.11 i                 | 0.76 mn                  | 15.17 f                          | 22.25 l                             |
| V <sub>1</sub> S <sub>3</sub>  | 0.00 n                  | 0.00 p                   | 0.00 o                           | 0.00 o                              |
| V <sub>2</sub> S <sub>1</sub>  | 35.77 c                 | 1.54 i                   | 13.01 hi                         | 43.85 fg                            |
| V <sub>2</sub> S <sub>2</sub>  | 0.00 n                  | 0.00 p                   | 0.00 o                           | 0.00 o                              |
| V <sub>2</sub> S <sub>3</sub>  | 0.00 n                  | 0.00 p                   | 0.00 o                           | 0.00 o                              |
| V <sub>3</sub> S <sub>1</sub>  | 27.20 f                 | 1.34 j                   | 15.17 f                          | 35.44 hi                            |
| V <sub>3</sub> S <sub>2</sub>  | 15.00 jk                | 0.80 m                   | 8.87 kl                          | 20.13 l                             |
| V <sub>3</sub> S <sub>3</sub>  | 0.00 n                  | 0.00 p                   | 0.00 o                           | 0.00 o                              |
| V <sub>4</sub> S <sub>1</sub>  | 54.18 a                 | 2.90 a                   | 18.58 c                          | 121.40 a                            |
| V <sub>4</sub> S <sub>2</sub>  | 53.18 ab                | 2.80 a                   | 17.25 cd                         | 104.80 b                            |
| V <sub>4</sub> S <sub>3</sub>  | 51.28 b                 | 2.34 b                   | 15.35 ef                         | 98.78 c                             |
| V <sub>5</sub> S <sub>1</sub>  | 12.98 kl                | 0.75 mn                  | 16.80 de                         | 7.56 n                              |
| V <sub>5</sub> S <sub>2</sub>  | 12.62 lm                | 0.72 mn                  | 14.75 fg                         | 7.43 n                              |
| V <sub>5</sub> S <sub>3</sub>  | 12.39 lm                | 0.72 mn                  | 14.26 f-h                        | 7.39 n                              |
| V <sub>6</sub> S <sub>1</sub>  | 29.21 d-f               | 1.60 i                   | 13.19 g-i                        | 41.94 g                             |
| V <sub>6</sub> S <sub>2</sub>  | 0.00 n                  | 0.00 p                   | 0.00 o                           | 0.00 o                              |
| V <sub>6</sub> S <sub>3</sub>  | 0.00 n                  | 0.00 p                   | 0.00 o                           | 0.00 o                              |
| V <sub>7</sub> S <sub>1</sub>  | 34.36 c                 | 1.83 fg                  | 22.09 b                          | 48.02 e                             |
| V <sub>7</sub> S <sub>2</sub>  | 11.14 lm                | 0.58 o                   | 6.89 m                           | 15.49 m                             |
| V <sub>7</sub> S <sub>3</sub>  | 22.13 g-i               | 1.08 kl                  | 13.04 hi                         | 29.99 jk                            |
| V <sub>8</sub> S <sub>1</sub>  | 20.95 hi                | 1.76 gh                  | 11.21 j                          | 34.31 hi                            |
| V <sub>8</sub> S <sub>2</sub>  | 20.23 i                 | 1.63 hi                  | 15.42 ef                         | 32.55 ij                            |
| V <sub>8</sub> S <sub>3</sub>  | 13.10 kl                | 1.02 l                   | 9.56 k                           | 20.55 l                             |
| V <sub>9</sub> S <sub>1</sub>  | 23.30 g                 | 1.91 f                   | 12.28 ij                         | 35.97 h                             |
| V <sub>9</sub> S <sub>2</sub>  | 22.50 gh                | 1.88 fg                  | 11.91 ij                         | 48.39 e                             |
| V <sub>9</sub> S <sub>3</sub>  | 10.65 m                 | 0.63 no                  | 3.75 n                           | 14.18 m                             |
| V <sub>10</sub> S <sub>1</sub> | 30.76 de                | 2.27 bc                  | 8.77 kl                          | 53.49 d                             |
| V <sub>10</sub> S <sub>2</sub> | 30.35 de                | 2.14 cd                  | 8.13 k-m                         | 47.49 e                             |
| V <sub>10</sub> S <sub>3</sub> | 28.92 ef                | 2.08 de                  | 8.20 k-m                         | 46.86 ef                            |
| V <sub>11</sub> S <sub>1</sub> | 21.34 g-i               | 1.85 fg                  | 12.74 h-j                        | 29.53 jk                            |
| V <sub>11</sub> S <sub>2</sub> | 20.77 hi                | 1.75 gh                  | 11.62 ij                         | 28.17 k                             |
| V <sub>11</sub> S <sub>3</sub> | 0.00 n                  | 0.00 p                   | 0.00 o                           | 0.00 o                              |
| V <sub>12</sub> S <sub>1</sub> | 16.13 j                 | 1.95 ef                  | 7.71 lm                          | 22.04 l                             |
| V <sub>12</sub> S <sub>2</sub> | 0.00 n                  | 0.00 p                   | 0.00 o                           | 0.00 o                              |
| V <sub>12</sub> S <sub>3</sub> | 0.00 n                  | 0.00 p                   | 0.00 o                           | 0.00 o                              |
| <b>LSD<sub>(0.05)</sub></b>    | <b>2.08</b>             | <b>0.14</b>              | <b>1.59</b>                      | <b>3.12</b>                         |
| <b>CV (%)</b>                  | <b>6.74</b>             | <b>7.12</b>              | <b>9.97</b>                      | <b>6.54</b>                         |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali

(Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive); S<sub>1</sub>= 0 mM NaCl (Control), S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl

The magnitude of reduction of normal leaf length was increased with increasing the salt concentration. At 50 mM NaCl the maximum (44.85%) decrease of normal leaf length was attained by wild rice genotype *O. nivara* (V<sub>3</sub>) compare to the no salt stress condition and the minimum (1.33%) decrease of leaf normal length was attained by wild rice genotype *O. alta* (V<sub>10</sub>) compare to the no salt stress condition. At 100 mM NaCl the maximum (67.58%) decrease of normal leaf length was attained by wild rice genotype *O. longistaminata* (V<sub>7</sub>)compare to the no salt stress condition and the minimum (4.55%) decrease of normal leaf length was attained by wild rice genotype *Potericia coaractata* (V<sub>5</sub>) compare to the no salt stress condition (Table 4.4.10).

**Table 4.4.10 Normal leaf length of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 31.03     | 20.11      | 35.19                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 35.77     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 27.20     | 15.00      | 44.85                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 54.18     | 53.18      | 1.85                      | 51.28       | 5.35                      |
| V <sub>5</sub>  | 12.98     | 12.62      | 2.77                      | 12.39       | 4.55                      |
| V <sub>6</sub>  | 29.21     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 34.36     | 22.13      | 35.59                     | 11.14       | 67.58                     |
| V <sub>8</sub>  | 20.95     | 20.23      | 3.44                      | 13.10       | 37.47                     |
| V <sub>9</sub>  | 23.30     | 22.50      | 3.43                      | 10.65       | 54.29                     |
| V <sub>10</sub> | 30.76     | 30.35      | 1.33                      | 28.92       | 5.98                      |
| V <sub>11</sub> | 21.34     | 20.77      | 2.67                      | 0.00        | 100.00                    |
| V <sub>12</sub> | 16.13     | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.7 Normal leaf breadth

##### 4.4.7.1 Effect of species

There was significant variations for normal leaf breadth among the tested genotypes of wild rice are depicted in Table 4.4.8. Data exposed that the widest normal leaf (2.68 cm) was produced by *O. latifolia* (V<sub>4</sub>) and the narrowest normal leaf (0.51 cm) was produced by *O. barthii* (V<sub>2</sub>) which was statistically similar with V<sub>6</sub> treatment.

#### 4.4.7.2 Effect of salinity level

There was significant variation for normal leaf breadth among the salinity levels are depicted in Table 4.4.8. Data exposed that the widest normal leaf (1.74 cm) was produced by S<sub>1</sub> treatment and the narrowest normal leaf (0.66 cm) was produced by S<sub>3</sub>.

#### 4.4.7.3 Interaction effect of species and salinity level

There was significant variation for normal leaf breadth due to the interaction between wild rice species and salinity levels are depicted in Table 4.4.9. Data exposed that the widest normal leaf (2.90 cm) was produced by V<sub>4</sub>S<sub>1</sub> treatment combination which was statistically similar with V<sub>4</sub>S<sub>2</sub> and no normal leaf breadth values were produced by V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub> treatment combinations.

At 50 mM NaCl the maximum decrease of normal leaf breadth (40.89%) observed in *O. longistaminata* (V<sub>7</sub>) and minimum decrease of normal leaf breadth (1.73%) observed in *O. punctata* (V<sub>9</sub>) while at 100 mM NaCl the maximum decrease of normal leaf breadth (68.25%) observed in *O. longistaminata* (V<sub>7</sub>) and minimum decrease of normal leaf breadth (4.42%) observed in *Potericia coaractata* (V<sub>5</sub>) (Table 4.4.11).

**Table 4.4.11 Normal leaf breadth of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 1.20      | 0.76       | 36.67                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 1.54      | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 1.34      | 0.80       | 40.30                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 2.90      | 2.80       | 3.44                      | 2.34        | 19.50                     |
| V <sub>5</sub>  | 0.75      | 0.72       | 3.98                      | 0.72        | 4.42                      |
| V <sub>6</sub>  | 1.60      | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 1.83      | 1.08       | 40.89                     | 0.58        | 68.25                     |
| V <sub>8</sub>  | 1.76      | 1.63       | 7.06                      | 1.02        | 41.95                     |
| V <sub>9</sub>  | 1.91      | 1.88       | 1.73                      | 0.63        | 67.07                     |
| V <sub>10</sub> | 2.27      | 2.14       | 5.73                      | 2.08        | 8.38                      |
| V <sub>11</sub> | 1.85      | 1.75       | 5.41                      | 0.00        | 100.00                    |
| V <sub>12</sub> | 1.95      | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### **4.4.8 Normal leaf length breadth ratio**

##### **4.4.8.1 Effect of species**

Normal leaf length breadth ratio showed significant variation among the rice genotypes are presented in table 4.4.8. The maximum (17.06) and minimum (2.57) normal leaf length breadth ratio were recorded from *O. latifolia* (V<sub>4</sub>) and BRRI Dhan 29 (V<sub>12</sub>), respectively. The rest of the treatment scored the intermediate values for normal leaf ratio.

##### **4.4.8.2 Effect of salinity level**

Normal leaf length breadth ratio showed significant variation among the salinity levels are presented in table 4.4.8. There was a decreasing trend of normal leaf ratio was noticed with the increasing of salt concentration. The maximum (14.81) and minimum (5.35) normal leaf length breadth ratio were recorded from S<sub>1</sub> and S<sub>3</sub>, respectively.

##### **4.4.8.3 Interaction effect of species and salinity level**

Normal leaf length breadth ratio showed significant variation between the wild rice species and salinity levels are presented in table 4.4.9. Data showed that the maximum normal leaf length breadth ratio (26.18) was noticed from treatment combination V<sub>1</sub>S<sub>1</sub> and no normal leaf length breadth ratio values scored by V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub> treatment combinations.

At 50 mM NaCl the maximum decrease of normal leaf ratio (42.06%) observed in *O. rufipogon* (V<sub>1</sub>) and increase of normal leaf ratio (37.65%) observed in *O. officinalis* (V<sub>8</sub>) while at 100 mM NaCl the maximum decrease of normal leaf ratio (69.46%) observed in *O. punctata* (V<sub>9</sub>) and minimum decrease of normal leaf ratio (6.53%) observed in *O. alta* (V<sub>10</sub>) (Table 4.4.12).

#### **4.4.9 Normal leaf area**

##### **4.4.9.1 Effect of species**

Normal leaf area showed significant variation among the wild rice varieties (Table 4.4.8). The highest normal leaf area (108.30 cm<sup>2</sup>) was obtained from *O. latifolia* (V<sub>4</sub>)

and the lowest normal leaf area (7.35 cm<sup>2</sup>) was obtained from BRRI Dhan 29 (V<sub>12</sub>) (Check variety as salt sensitive). The potentiality of the expansion of the leaf is markedly depends on the genetic potentiality of a plant and it varied with genotypic variation.

**Table 4.4.12 Normal leaf ratio of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 26.18     | 15.17      | 42.06                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 13.01     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 15.17     | 8.87       | 41.53                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 18.58     | 17.25      | 7.16                      | 15.35       | 17.38                     |
| V <sub>5</sub>  | 16.80     | 14.75      | 12.20                     | 14.26       | 15.12                     |
| V <sub>6</sub>  | 13.19     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 22.09     | 13.04      | 40.97                     | 6.89        | 68.81                     |
| V <sub>8</sub>  | 11.21     | 15.42      | -37.56                    | 9.56        | 14.72                     |
| V <sub>9</sub>  | 12.28     | 11.91      | 3.01                      | 3.75        | 69.46                     |
| V <sub>10</sub> | 8.77      | 8.13       | 7.26                      | 8.20        | 6.53                      |
| V <sub>11</sub> | 12.74     | 11.62      | 8.79                      | 0.00        | 100.00                    |
| V <sub>12</sub> | 7.71      | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.9.2 Effect of salinity level

Normal leaf area showed significant variation among the salinity levels (Table 4.4.8). With the advancement of the salt concentration the magnitude of the reduction normal leaf area was increased. The results of our investigation revealed that the highest normal leaf area (42.45 cm<sup>2</sup>) was obtained from S<sub>1</sub> treatment and the lowest normal leaf area (18.15 cm<sup>2</sup>) was obtained from S<sub>3</sub> treatment. Netondo *et al.* (2004); Hasamuzzaman *et al.* (2009) reported that the decrease in leaf area might have been due to decrease in leaf expansion in salinity stress condition. The decrease in leaf area could be explained by the negative effect of salt on photosynthesis that leads to the reduction of leaf growth. This result corroborates with the founding of Gupta and Huang (2014); Hussain *et al.* (2017); Khanam *et al.* (2018); Channa *et al.* (2019); Malumpong *et al.* (2019) who reported that the salinity stress tremendously affect the leaf expansion of plant and ultimately reduce the leaf surface area.

#### 4.4.9.3 Interaction effect of species and salinity level

Normal leaf area showed significant variation between the interaction of wild rice species and salinity levels (Table 4.4.9). The results of our investigation revealed that the highest normal leaf area (121.40 cm<sup>2</sup>) was obtained from V<sub>4</sub>S<sub>1</sub> treatment combination and V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub> treatment combinations scored no value for normal leaf area.

At 50 mM NaCl the maximum decrease of normal leaf area (43.20%) observed in *O. nivara* (V<sub>3</sub>) and increase of normal leaf area (34.53%) observed in *O. punctata* (V<sub>9</sub>) while at 100 mM NaCl the maximum decrease of normal leaf area (67.74%) observed in *O. longistaminata* (V<sub>7</sub>) and minimum decrease of normal leaf area (2.17%) observed in *Potericia coaractata* (V<sub>5</sub>) (Table 4.4.13).

**Table 4.4.13 Normal leaf area of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 35.80     | 22.25      | 37.85                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 43.85     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 35.44     | 20.13      | 43.20                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 121.40    | 104.80     | 13.67                     | 98.78       | 18.63                     |
| V <sub>5</sub>  | 7.56      | 7.43       | 1.68                      | 7.39        | 2.17                      |
| V <sub>6</sub>  | 41.94     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 48.02     | 29.99      | 37.55                     | 15.49       | 67.74                     |
| V <sub>8</sub>  | 34.31     | 32.55      | 5.13                      | 20.55       | 40.10                     |
| V <sub>9</sub>  | 35.97     | 48.39      | -34.53                    | 14.18       | 60.58                     |
| V <sub>10</sub> | 53.49     | 47.49      | 11.22                     | 46.86       | 12.39                     |
| V <sub>11</sub> | 29.53     | 28.17      | 4.61                      | 0.00        | 100.00                    |
| V <sub>12</sub> | 22.04     | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.10 Flag leaf length

##### 4.4.10.1 Effect of species

Data on flag leaf length in rice genotypes are presented in table 4.4.14. From the data it can be concluded that there was significant difference among the wild rice genotypes for flag leaf length was observed and the longest flag leaf (43.97 cm) was

scored by *O. latifolia* (V<sub>4</sub>) and the shortest one (3.91 cm) was scored by *O. barthii* (V<sub>2</sub>) which was statistically similar with V<sub>6</sub> and V<sub>12</sub>. The result of our experiment also coincided by the findings of Malumpong *et al.* (2019) who revealed that under salt stress condition the reduction of the length of flag leaf was higher in sensitive cultivars (IR29 and JHN) compare to that of tolerance cultivars (Pokkali, FL496, FL530).

#### 4.4.10.2 Effect of salinity level

Data on flag leaf length in rice genotypes are presented in table 4.4.14. From the data it can be concluded that there was significant difference among the salinity levels for flag leaf length of wild rice was noticed. There was a marked reduction of flag leaf length was observed with the advancement of salt density. Data revealed that the longest flag leaf (16.48 cm) was achieved from S<sub>1</sub> treatment and the shortest flag leaf (7.24 cm) was achieved from S<sub>3</sub> treatment.

**Table 4.4.14 Effect of species and salinity level on the morphological characteristics of wild rice**

| Treatments                      | Flag leaf length (cm) | Flag leaf breadth (cm) | Flag leaf length breadth ratio | Flag leaf area (cm <sup>2</sup> ) |
|---------------------------------|-----------------------|------------------------|--------------------------------|-----------------------------------|
| <b>Effect of species</b>        |                       |                        |                                |                                   |
| V <sub>1</sub>                  | 9.68 d                | 0.66 f                 | 7.56 c                         | 11.63 g                           |
| V <sub>2</sub>                  | 3.91 g                | 0.54 g                 | 2.41 gh                        | 5.24 j                            |
| V <sub>3</sub>                  | 6.79 f                | 0.80 e                 | 4.14 ef                        | 9.41 h                            |
| V <sub>4</sub>                  | 43.97 a               | 2.79 b                 | 13.11 a                        | 95.63 a                           |
| V <sub>5</sub>                  | 8.07 e                | 0.66 f                 | 11.51 b                        | 3.61 k                            |
| V <sub>6</sub>                  | 4.54 g                | 0.55 g                 | 2.58 g                         | 6.51 i                            |
| V <sub>7</sub>                  | 9.47 d                | 1.48 c                 | 6.10 d                         | 15.54 e                           |
| V <sub>8</sub>                  | 13.98 b               | 1.49 c                 | 7.82 c                         | 20.16 c                           |
| V <sub>9</sub>                  | 12.69 c               | 1.26 d                 | 5.97 d                         | 16.83 d                           |
| V <sub>10</sub>                 | 13.38 bc              | 3.08 a                 | 3.85 f                         | 31.31 b                           |
| V <sub>11</sub>                 | 9.69 d                | 1.27 d                 | 4.35 e                         | 13.73 f                           |
| V <sub>12</sub>                 | 4.13 g                | 0.65 f                 | 2.03 h                         | 5.23 j                            |
| <b>LSD<sub>(0.05)</sub></b>     | <b>0.84</b>           | <b>0.08</b>            | <b>0.46</b>                    | <b>1.16</b>                       |
| <b>CV (%)</b>                   | <b>7.62</b>           | <b>6.90</b>            | <b>8.19</b>                    | <b>6.32</b>                       |
| <b>Effect of salinity level</b> |                       |                        |                                |                                   |
| S <sub>1</sub>                  | 16.48 a               | 1.92 a                 | 8.86 a                         | 26.71 a                           |
| S <sub>2</sub>                  | 11.35 b               | 1.15 b                 | 5.57 b                         | 18.69 b                           |
| S <sub>3</sub>                  | 7.24 c                | 0.74 c                 | 3.43 c                         | 13.30 c                           |
| <b>LSD<sub>(0.05)</sub></b>     | <b>0.42</b>           | <b>0.04</b>            | <b>0.23</b>                    | <b>0.58</b>                       |
| <b>CV (%)</b>                   | <b>7.62</b>           | <b>6.90</b>            | <b>8.19</b>                    | <b>6.32</b>                       |



V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive); S<sub>1</sub>= 0 mM NaCl (Control), S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl

#### 4.4.10.3 Interaction effect of species and salinity level

Data on flag leaf length in rice genotypes are presented in table 4.4.15. From the data it can be concluded that there was significant difference among the species and salinity level for flag leaf length of wild rice was identified. Data revealed that the longest flag leaf (45.32 cm) was achieved from the interaction of V<sub>4</sub> along with S<sub>1</sub> treatment followed by V<sub>4</sub>S<sub>2</sub> (44.65 cm) where as no flag leaf data was received from V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub> treatment combinations.

At 50 mM NaCl the maximum decrease of flag leaf length (36.80%) observed in *O. rufipogon* (V<sub>1</sub>) and minimum decrease of flag leaf length (1.48%) observed in *O. latifolia* (V<sub>4</sub>) while at 100 mM NaCl the maximum decrease of flag leaf length (68.31%) observed in *O. punctata* (V<sub>9</sub>) and minimum decrease of flag leaf length (7.02%) observed in *Potericia coaractata* (V<sub>5</sub>) (Table 4.4.16).

#### 4.4.11 Flag leaf breadth

##### 4.4.11.1 Effect of species

There was significant variations for flag leaf breadth among the tested genotypes of wild rice are depicted in Table 4.4.14. Data exposed that the widest flag leaf (3.08 cm) was attained by *O. alta* (V<sub>10</sub>) and the narrowest flag leaf (0.54 cm) was attained by *O. barthii* (V<sub>2</sub>) treatment which was statistically similar with V<sub>6</sub> treatment.

##### 4.4.11.2 Effect of salinity level

There was significant variation for flag leaf breadth among the salinity levels are depicted in Table 4.4.14. Data exposed that the widest flag leaf (1.92 cm) was attained by S<sub>1</sub> treatment and the narrowest flag leaf (0.74 cm) was attained by S<sub>3</sub>.

**Table 4.4.15 Interaction effect of species and salinity level on the morphological characteristics of wild rice**

| Treatments                     | Flag leaf length (cm) | Flag leaf breadth (cm) | Flag leaf length breadth ratio | Flag leaf area (cm <sup>2</sup> ) |
|--------------------------------|-----------------------|------------------------|--------------------------------|-----------------------------------|
| V <sub>1</sub> S <sub>1</sub>  | 17.80 c               | 1.30 g                 | 14.09 a                        | 21.24 g-i                         |
| V <sub>1</sub> S <sub>2</sub>  | 11.25 j               | 0.67 i                 | 8.60 ef                        | 13.65 l                           |
| V <sub>1</sub> S <sub>3</sub>  | 0.00 o                | 0.00 k                 | 0.00 o                         | 0.00 p                            |
| V <sub>2</sub> S <sub>1</sub>  | 11.72 ij              | 1.63 f                 | 7.23 gh                        | 15.71 jk                          |
| V <sub>2</sub> S <sub>2</sub>  | 0.00 o                | 0.00 k                 | 0.00 o                         | 0.00 p                            |
| V <sub>2</sub> S <sub>3</sub>  | 0.00 o                | 0.00 k                 | 0.00 o                         | 0.00 p                            |
| V <sub>3</sub> S <sub>1</sub>  | 12.29 h-j             | 1.57 f                 | 7.68 g                         | 17.34 j                           |
| V <sub>3</sub> S <sub>2</sub>  | 8.07 lm               | 0.84 h                 | 4.75 k                         | 10.90 m                           |
| V <sub>3</sub> S <sub>3</sub>  | 0.00 o                | 0.00 k                 | 0.00 o                         | 0.00 p                            |
| V <sub>4</sub> S <sub>1</sub>  | 45.32 a               | 3.00 b                 | 14.22 a                        | 103.1 a                           |
| V <sub>4</sub> S <sub>2</sub>  | 44.65 a               | 2.80 c                 | 12.89 b                        | 93.47 b                           |
| V <sub>4</sub> S <sub>3</sub>  | 41.94 b               | 2.56 d                 | 12.22 b                        | 90.28 c                           |
| V <sub>5</sub> S <sub>1</sub>  | 8.36 k-m              | 0.67 i                 | 12.26 b                        | 3.65 o                            |
| V <sub>5</sub> S <sub>2</sub>  | 8.07 lm               | 0.67 i                 | 10.92 c                        | 3.62 o                            |
| V <sub>5</sub> S <sub>3</sub>  | 7.77 m                | 0.64 ij                | 11.33 c                        | 3.57 o                            |
| V <sub>6</sub> S <sub>1</sub>  | 13.63 f-h             | 1.66 f                 | 7.73 g                         | 19.54 i                           |
| V <sub>6</sub> S <sub>2</sub>  | 0.00 o                | 0.00 k                 | 0.00 o                         | 0.00 p                            |
| V <sub>6</sub> S <sub>3</sub>  | 0.00 o                | 0.00 k                 | 0.00 o                         | 0.00 p                            |
| V <sub>7</sub> S <sub>1</sub>  | 14.24 e-g             | 2.64 d                 | 9.49 d                         | 24.01 ef                          |
| V <sub>7</sub> S <sub>2</sub>  | 4.76 n                | 0.62 ij                | 3.05 mn                        | 7.63 n                            |
| V <sub>7</sub> S <sub>3</sub>  | 9.42 kl               | 1.19 g                 | 5.76 j                         | 14.99 kl                          |
| V <sub>8</sub> S <sub>1</sub>  | 16.83 cd              | 1.83 e                 | 9.04 de                        | 24.85 e                           |
| V <sub>8</sub> S <sub>2</sub>  | 15.46 de              | 1.69 f                 | 8.78 de                        | 22.21 f-h                         |
| V <sub>8</sub> S <sub>3</sub>  | 9.66 k                | 0.95 h                 | 5.65 j                         | 13.42 l                           |
| V <sub>9</sub> S <sub>1</sub>  | 16.60 cd              | 1.68 f                 | 7.81 fg                        | 22.54 fg                          |
| V <sub>9</sub> S <sub>2</sub>  | 16.19 d               | 1.60 f                 | 7.61 g                         | 21.22 g-i                         |
| V <sub>9</sub> S <sub>3</sub>  | 5.26 n                | 0.51 j                 | 2.49 n                         | 6.73 n                            |
| V <sub>10</sub> S <sub>1</sub> | 13.96 fg              | 3.22 a                 | 4.00 kl                        | 32.12 d                           |
| V <sub>10</sub> S <sub>2</sub> | 13.38 f-h             | 3.05 b                 | 3.81 lm                        | 31.19 d                           |
| V <sub>10</sub> S <sub>3</sub> | 12.81 g-i             | 2.97 b                 | 3.73 lm                        | 30.61 d                           |
| V <sub>11</sub> S <sub>1</sub> | 14.67 ef              | 1.92 e                 | 6.68 hi                        | 20.75 g-i                         |
| V <sub>11</sub> S <sub>2</sub> | 14.41 ef              | 1.90 e                 | 6.39 ij                        | 20.44 hi                          |
| V <sub>11</sub> S <sub>3</sub> | 0.00 o                | 0.00 k                 | 0.00 o                         | 0.00 p                            |
| V <sub>12</sub> S <sub>1</sub> | 12.38 h-j             | 1.95 e                 | 6.08 ij                        | 15.68 jk                          |
| V <sub>12</sub> S <sub>2</sub> | 0.00 o                | 0.00 k                 | 0.00 o                         | 0.00 p                            |
| V <sub>12</sub> S <sub>3</sub> | 0.00 o                | 0.00 k                 | 0.00 o                         | 0.00 p                            |
| <b>LSD<sub>(0.05)</sub></b>    | <b>1.45</b>           | <b>0.15</b>            | <b>0.79</b>                    | <b>2.02</b>                       |
| <b>CV (%)</b>                  | <b>7.62</b>           | <b>6.90</b>            | <b>8.19</b>                    | <b>6.32</b>                       |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali

(Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive); S<sub>1</sub>= 0 mM NaCl (Control), S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl

**Table 4.4.16 Flag leaf length of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 17.80     | 11.25      | 36.80                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 11.72     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 12.29     | 8.07       | 34.34                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 45.32     | 44.65      | 1.48                      | 41.94       | 7.46                      |
| V <sub>5</sub>  | 8.36      | 8.07       | 3.43                      | 7.77        | 7.02                      |
| V <sub>6</sub>  | 13.63     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 14.24     | 9.42       | 33.85                     | 4.76        | 66.57                     |
| V <sub>8</sub>  | 16.83     | 15.46      | 8.14                      | 9.66        | 42.60                     |
| V <sub>9</sub>  | 16.60     | 16.19      | 2.47                      | 5.26        | 68.31                     |
| V <sub>10</sub> | 13.96     | 13.38      | 4.15                      | 12.81       | 8.24                      |
| V <sub>11</sub> | 14.67     | 14.41      | 1.77                      | 0.00        | 100.00                    |
| V <sub>12</sub> | 12.38     | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.11.3 Interaction effect of species and salinity level

There was significant variation for flag leaf breadth among the wild rice varieties and salinity levels are depicted in Table 4.4.15. Data exposed that the widest flag leaf (3.22 cm) was attained by V<sub>10</sub>S<sub>1</sub> treatment combination and no flag leaf breadth values were found from V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub> treatment combinations.

At 50 mM NaCl the maximum decrease of flag leaf breadth (54.87%) found from *O. longistaminata* (V<sub>7</sub>) and no decrease offlag leaf breadth (0.00%) found from *Potericia coaractata* (V<sub>5</sub>) while at 100 mM NaCl the maximum decrease of flag leaf breadth (76.49%) found from *O. longistaminata* (V<sub>7</sub>) and minimum decrease of flag leaf breadth (5.44%) found from *Potericia coaractata* (V<sub>5</sub>) (Table 4.4.17).

**Table 4.4.17 Flag leaf breadth of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 1.30      | 0.67       | 48.58                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 1.63      | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 1.57      | 0.84       | 46.50                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 3.00      | 2.80       | 6.66                      | 2.56        | 14.65                     |
| V <sub>5</sub>  | 0.67      | 0.67       | 0.00                      | 0.64        | 5.44                      |
| V <sub>6</sub>  | 1.66      | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 2.64      | 1.19       | 54.87                     | 0.62        | 76.49                     |
| V <sub>8</sub>  | 1.83      | 1.69       | 7.97                      | 0.95        | 48.17                     |
| V <sub>9</sub>  | 1.68      | 1.60       | 4.76                      | 0.51        | 69.64                     |
| V <sub>10</sub> | 3.22      | 3.05       | 5.19                      | 2.97        | 7.77                      |
| V <sub>11</sub> | 1.92      | 1.90       | 1.20                      | 0.00        | 100.00                    |
| V <sub>12</sub> | 1.95      | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potiericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.12 Flag leaf length breadth ratio

##### 4.4.12.1 Effect of species

Flag leaf length breadth ratio showed significant variation among the rice genotypes are presented in Table 4.4.14. The maximum flag leaf length breadth ratio (13.11) was recorded from *O. latifolia* (V<sub>4</sub>) followed by *P. coaractata* (V<sub>5</sub>)(11.51) and the minimum flag leaf length breadth ratio (2.03) was recorded from BRRI Dhan 29 (V<sub>12</sub>) (Check variety as salt sensitive) which was statistically similar with V<sub>2</sub> treatment.

##### 4.4.12.2 Effect of salinity level

Flag leaf length breadth ratio showed significant variation among the salinity levels are presented in Table 4.4.14. There was a decreasing trend of flag leaf length breadth ratio was noticed with the increasing of salt concentration. The maximum (8.86) and minimum (3.43) flag leaf length breadth ratio were recorded from S<sub>1</sub> and S<sub>3</sub>, respectively.

##### 4.4.12.3 Interaction effect of species and salinity level

Flag leaf length breadth ratio showed significant variation between the interaction of wild rice genotypes and salinity levels are presented in Table 4.4.15. Data showed that

the maximum flag leaf length breadth ratio (14.22) was recorded from treatment combination V<sub>4</sub>S<sub>1</sub> which was statistically similar with V<sub>1</sub>S<sub>1</sub> and no flag leaf length breadth ratio values scored by V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub> treatment combinations.

At 50 mM NaCl the maximum decrease of flag leaf ratio (39.29%) found from *O. longistaminata* (V<sub>7</sub>) and minimum decrease of flag leaf ratio (2.60%) found from *O. punctata* (V<sub>9</sub>) while at 100 mM NaCl the maximum decrease of flag leaf ratio (68.13%) found from *O. punctata* (V<sub>9</sub>) and minimum decrease of flag leaf ratio (6.75%) found from *O. alta* (V<sub>10</sub>) (Table 4.4.18).

**Table 4.4.18 Flag leaf ratio of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 14.09     | 8.60       | 38.96                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 7.23      | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 7.68      | 4.75       | 38.15                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 14.22     | 12.89      | 9.35                      | 12.22       | 14.06                     |
| V <sub>5</sub>  | 12.26     | 11.33      | 7.59                      | 10.92       | 10.93                     |
| V <sub>6</sub>  | 7.73      | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 9.49      | 5.76       | 39.29                     | 3.05        | 67.85                     |
| V <sub>8</sub>  | 9.04      | 8.78       | 2.88                      | 5.65        | 37.50                     |
| V <sub>9</sub>  | 7.81      | 7.61       | 2.60                      | 2.49        | 68.13                     |
| V <sub>10</sub> | 4.00      | 3.81       | 4.83                      | 3.73        | 6.75                      |
| V <sub>11</sub> | 6.68      | 6.39       | 4.34                      | 0.00        | 100.00                    |
| V <sub>12</sub> | 6.08      | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potrericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.13 Flag leaf area

##### 4.4.13.1 Effect of species

Flag leaf area showed significant variation among the wild rice varieties (Table 4.4.14). The highest flag leaf area (95.63 cm<sup>2</sup>) was obtained from *O. latifolia* (V<sub>4</sub>) and the lowest flag leaf area (3.61 cm<sup>2</sup>) was obtained from *P. coaractata* (V<sub>5</sub>).

#### 4.4.13.2 Effect of salinity level

Flag leaf area showed significant variation among the salinity levels (Table 4.4.14). With the advancement of the salt concentration the magnitude of the reduction flag leaf area was increased. The results of our investigation revealed that the highest flag leaf area (26.71 cm<sup>2</sup>) was obtained from S<sub>1</sub> treatment and the lowest flag leaf area (13.30 cm<sup>2</sup>) was obtained from S<sub>3</sub> treatment.

#### 4.4.13.3 Interaction effect of species and salinity level

Flag leaf area significant variation among the wild rice varieties and salinity levels (Table 4.4.15). The results of our investigation revealed that the highest flag leaf area (103.10 cm<sup>2</sup>) was obtained from V<sub>4</sub>S<sub>1</sub> treatment combination and V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub> treatment combinations scored no value for flag leaf area.

At 50 mM NaCl the maximum decrease of flag leaf area (37.57%) found from *O. longistaminata* (V<sub>7</sub>) and minimum decrease offlag leaf area (1.49%) found from Pokkali (Check variety as salt tolerant) (V<sub>11</sub>) while at 100 mM NaCl the maximum decrease of flag leaf area (70.14%) found from *O. punctata* (V<sub>9</sub>) and minimum decrease of flag leaf area (2.27%) found from *Potericia coaractata* (V<sub>5</sub>) (Table 4.4.19).

**Table 4.4.19 Flag leaf area of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 21.24     | 13.65      | 35.73                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 15.71     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 17.34     | 10.90      | 37.14                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 103.10    | 93.47      | 9.34                      | 90.28       | 12.43                     |
| V <sub>5</sub>  | 3.65      | 3.62       | 0.90                      | 3.57        | 2.27                      |
| V <sub>6</sub>  | 19.54     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 24.01     | 14.99      | 37.57                     | 7.63        | 68.22                     |
| V <sub>8</sub>  | 24.85     | 22.21      | 10.62                     | 13.42       | 46.00                     |
| V <sub>9</sub>  | 22.54     | 21.22      | 5.86                      | 6.73        | 70.14                     |
| V <sub>10</sub> | 32.12     | 31.19      | 2.90                      | 30.61       | 4.70                      |
| V <sub>11</sub> | 20.75     | 20.44      | 1.49                      | 0.00        | 100.00                    |
| V <sub>12</sub> | 15.68     | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### **4.4.14 Root length**

##### **4.4.14.1 Effect of species**

The results of our study revealed that the significant variation was found among the wild rice genotypes for root length (Table 4.4.20). The longest root (46.68 cm) was attained by *O. latifolia* (V<sub>4</sub>) and the shortest root (4.58 cm) was attained by *O. glaberrima* (V<sub>6</sub>).

##### **4.4.14.2 Effect of salinity level**

The results of our study revealed that the significant difference was found among the salinity levels (Table 4.4.20). The longest root (26.22 cm) was attained by S<sub>1</sub> and the shortest root (11.30 cm) was attained by S<sub>3</sub>. Root has direct contact with the biotic and abiotic factors in the soil environment and the rest of the plant (Smet *et al.*, 2012; Hussain *et al.*, 2017). H<sub>2</sub>O and solutes enter by the roots through a combination of different pathways such as symplastic, apoplastic, and transcellular, however, transport of water and solutes *via* apoplastic transpiration pathway is very important in rice (Ochiai and Matoh, 2002; Kronzucker and Britto, 2011). Mostly, Na<sup>+</sup> passages in shoots of rice through the apoplastic pathway where Na<sup>+</sup> transports *via* apoplast through solvent drag and Casparian bands (Ranathunge *et al.* 2005; Gong *et al.* 2006). Jamil *et al.* (2006) and Jiang *et al.* (2010) reported that significant reduction in mean root length and mean root numbers per plant occurred under increased salt stress. Thus, root length is one of the important indicators of rice plant response to salt stress. Rice plant root cell division and cell elongation are seriously affected by salt stress, which lead to reduction of root length (Munns, 2002). Baque *et al.* (2018) also reported that root length of wheat adversely affected by salt stress and as a consequence there was a rapid reduction observed for salinity sensitive genotypes compare to the tolerance one. It has been found that, under salt stress condition photosynthetic rate is markedly reduced, lost huge energy in salt removal mechanism, reduced transportation of compatible nutrient, arrested cell division and enlargement, for consequence there was a marked reduction of root length. These finding are consistent with those of Baque *et al.* (2018); Datir *et al.* (2018); Channa *et al.* (2019);

Malumpong *et al.* (2019) who reported that root length was reduced by increasing the levels of salt concentration.

**Table 4.4.20 Effect of species and salinity level on the morphological characteristics of wild rice**

| Treatments                      | Root length<br>(cm) | Shoot dry<br>weight hill <sup>-1</sup> (g) | Root dry<br>weight hill <sup>-1</sup> (g) | Total dry weight<br>hill <sup>-1</sup> (g) |
|---------------------------------|---------------------|--------------------------------------------|-------------------------------------------|--------------------------------------------|
| <b>Effect of species</b>        |                     |                                            |                                           |                                            |
| V <sub>1</sub>                  | 10.82 f             | 95.93 e                                    | 94.41 f                                   | 190.10 f                                   |
| V <sub>2</sub>                  | 7.11 h              | 17.34 k                                    | 9.36 k                                    | 39.74 k                                    |
| V <sub>3</sub>                  | 9.70 fg             | 78.85 g                                    | 69.32 g                                   | 152.60 g                                   |
| V <sub>4</sub>                  | 46.68 a             | 181.30 a                                   | 165.70 a                                  | 347.50 a                                   |
| V <sub>5</sub>                  | 18.81 d             | 43.66 i                                    | 33.73 h                                   | 78.19 i                                    |
| V <sub>6</sub>                  | 4.58 i              | 30.70 j                                    | 27.05 i                                   | 115.20 h                                   |
| V <sub>7</sub>                  | 16.63 e             | 109.30 d                                   | 108.40 e                                  | 221.80 e                                   |
| V <sub>8</sub>                  | 21.57 c             | 147.00 c                                   | 136.80 c                                  | 300.70 b                                   |
| V <sub>9</sub>                  | 18.80 d             | 90.04 f                                    | 144.30 b                                  | 231.90 d                                   |
| V <sub>10</sub>                 | 38.13 b             | 166.40 b                                   | 120.10 d                                  | 284.60 c                                   |
| V <sub>11</sub>                 | 17.24 e             | 40.27 i                                    | 22.46 j                                   | 66.96 j                                    |
| V <sub>12</sub>                 | 8.66 g              | 51.99 h                                    | 31.37 h                                   | 83.36 i                                    |
| <b>LSD<sub>(0.05)</sub></b>     | <b>1.17</b>         | <b>4.16</b>                                | <b>4.29</b>                               | <b>9.98</b>                                |
| <b>CV (%)</b>                   | <b>6.82</b>         | <b>5.04</b>                                | <b>5.69</b>                               | <b>6.03</b>                                |
| <b>Effect of salinity level</b> |                     |                                            |                                           |                                            |
| S <sub>1</sub>                  | 26.22 a             | 131.20 a                                   | 117.40 a                                  | 266.60 a                                   |
| S <sub>2</sub>                  | 17.16 b             | 81.86 b                                    | 76.79 b                                   | 163.40 b                                   |
| S <sub>3</sub>                  | 11.30 c             | 50.19 c                                    | 46.60 c                                   | 98.15 c                                    |
| <b>LSD<sub>(0.05)</sub></b>     | <b>0.58</b>         | <b>2.08</b>                                | <b>2.15</b>                               | <b>4.99</b>                                |
| <b>CV (%)</b>                   | <b>6.82</b>         | <b>5.04</b>                                | <b>5.69</b>                               | <b>6.03</b>                                |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive); S<sub>1</sub>= 0 mM NaCl (Control), S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl

#### 4.4.14.3 Interaction effect of species and salinity level

The results of our study revealed that the significant difference was found among the rice varieties and salinity levels (Table 4.4.21). The longest root (49.53 cm) was attained by treatment combination V<sub>4</sub>S<sub>1</sub> but treatment combinations V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub> did not attain any root length.

At 50 mM NaCl the maximum decrease of root length (46.60%) attained by wild rice genotype *O. nivara* (V<sub>3</sub>) and minimum decrease of root length (2.75%) attained by wild rice genotype *Potericia coaractata* (V<sub>5</sub>) while at 100 mM NaCl the maximum decrease of root length (70.27%) attained by wild rice genotype *O. punctata* (V<sub>9</sub>) and



minimum decrease of root length (4.82%) attained by wild rice genotype *Potericia coaractata* (V<sub>5</sub>) (Table 4.4.22).

**Table 4.4.21 Interaction effect of species and salinity level on the morphological characteristics of wild rice**

| Treatments                     | Root length<br>(cm) | Shoot dry<br>weight hill <sup>-1</sup> (g) | Root dry weight<br>hill <sup>-1</sup> (g) | Total dry<br>weight hill <sup>-1</sup> (g) |
|--------------------------------|---------------------|--------------------------------------------|-------------------------------------------|--------------------------------------------|
| V <sub>1</sub> S <sub>1</sub>  | 19.80 jk            | 178.90 a-d                                 | 176.70 bc                                 | 355.10 ab                                  |
| V <sub>1</sub> S <sub>2</sub>  | 12.67 m             | 108.80 i                                   | 106.60 jk                                 | 215.40 i                                   |
| V <sub>1</sub> S <sub>3</sub>  | 0.00 p              | 0.00 q                                     | 0.00 q                                    | 0.00 p                                     |
| V <sub>2</sub> S <sub>1</sub>  | 21.33 j             | 52.03 mn                                   | 28.09 p                                   | 119.20 k                                   |
| V <sub>2</sub> S <sub>2</sub>  | 0.00 p              | 0.00 q                                     | 0.00 q                                    | 0.00 p                                     |
| V <sub>2</sub> S <sub>3</sub>  | 0.00 p              | 0.00 q                                     | 0.00 q                                    | 0.00 p                                     |
| V <sub>3</sub> S <sub>1</sub>  | 18.97 k             | 140.70 g                                   | 123.30 gh                                 | 277.40 fg                                  |
| V <sub>3</sub> S <sub>2</sub>  | 10.13 n             | 95.81 jk                                   | 84.64 m                                   | 180.20 j                                   |
| V <sub>3</sub> S <sub>3</sub>  | 0.00 p              | 0.00 q                                     | 0.00 q                                    | 0.00 p                                     |
| V <sub>4</sub> S <sub>1</sub>  | 49.53 a             | 186.00 a                                   | 171.00 cd                                 | 359.40 a                                   |
| V <sub>4</sub> S <sub>2</sub>  | 46.20 b             | 182.00 a-c                                 | 167.70 d                                  | 349.40 a-c                                 |
| V <sub>4</sub> S <sub>3</sub>  | 44.30 b             | 176.00 b-d                                 | 158.40 e                                  | 333.60 c                                   |
| V <sub>5</sub> S <sub>1</sub>  | 19.30 k             | 46.68 mn                                   | 36.35 o                                   | 82.42 m-o                                  |
| V <sub>5</sub> S <sub>2</sub>  | 18.77 k             | 45.44 no                                   | 33.11 op                                  | 77.22 no                                   |
| V <sub>5</sub> S <sub>3</sub>  | 18.37 k             | 38.87 op                                   | 31.72 op                                  | 74.92 o                                    |
| V <sub>6</sub> S <sub>1</sub>  | 13.73 m             | 92.10 k                                    | 81.15 m                                   | 345.60 a-c                                 |
| V <sub>6</sub> S <sub>2</sub>  | 0.00 p              | 0.00 q                                     | 0.00 q                                    | 0.00 p                                     |
| V <sub>6</sub> S <sub>3</sub>  | 0.00 p              | 0.00 q                                     | 0.00 q                                    | 0.00 p                                     |
| V <sub>7</sub> S <sub>1</sub>  | 25.97 f-h           | 174.50 d                                   | 169.60 cd                                 | 342.10 bc                                  |
| V <sub>7</sub> S <sub>2</sub>  | 8.10 o              | 53.66 m                                    | 53.40 n                                   | 110.70 kl                                  |
| V <sub>7</sub> S <sub>3</sub>  | 15.82 l             | 99.81 j                                    | 102.20 k                                  | 212.50 i                                   |
| V <sub>8</sub> S <sub>1</sub>  | 26.23 fg            | 182.80 ab                                  | 175.80 c                                  | 358.90 ab                                  |
| V <sub>8</sub> S <sub>2</sub>  | 24.07 hi            | 164.40 e                                   | 141.20 f                                  | 348.30 a-c                                 |
| V <sub>8</sub> S <sub>3</sub>  | 14.40 lm            | 93.92 jk                                   | 93.26 l                                   | 195.00 j                                   |
| V <sub>9</sub> S <sub>1</sub>  | 25.33 f-i           | 121.10 h                                   | 189.20 a                                  | 303.60 d                                   |
| V <sub>9</sub> S <sub>2</sub>  | 23.53 i             | 114.00 hi                                  | 183.70 ab                                 | 297.60 de                                  |
| V <sub>9</sub> S <sub>3</sub>  | 7.53 o              | 34.97 p                                    | 60.15 n                                   | 94.49 l-n                                  |
| V <sub>10</sub> S <sub>1</sub> | 41.20 c             | 175.10 cd                                  | 127.30 g                                  | 302.10 d                                   |
| V <sub>10</sub> S <sub>2</sub> | 38.00 d             | 165.30 e                                   | 119.60 hi                                 | 284.60 ef                                  |
| V <sub>10</sub> S <sub>3</sub> | 35.20 e             | 158.60 ef                                  | 113.40 ij                                 | 267.30 gh                                  |
| V <sub>11</sub> S <sub>1</sub> | 27.23 f             | 68.09 l                                    | 35.86 o                                   | 103.90 kl                                  |
| V <sub>11</sub> S <sub>2</sub> | 24.50 g-i           | 52.73 m                                    | 31.53 op                                  | 96.93 lm                                   |
| V <sub>11</sub> S <sub>3</sub> | 0.00 p              | 0.00 q                                     | 0.00 q                                    | 0.00 p                                     |
| V <sub>12</sub> S <sub>1</sub> | 25.97 f-h           | 156.00 f                                   | 94.11 l                                   | 250.10 h                                   |
| V <sub>12</sub> S <sub>2</sub> | 0.00 p              | 0.00 q                                     | 0.00 q                                    | 0.00 p                                     |
| V <sub>12</sub> S <sub>3</sub> | 0.00 p              | 0.00 q                                     | 0.00 q                                    | 0.00 p                                     |
| <b>LSD<sub>(0.05)</sub></b>    | <b>2.02</b>         | <b>7.21</b>                                | <b>7.43</b>                               | <b>17.29</b>                               |
| <b>CV (%)</b>                  | <b>6.82</b>         | <b>5.04</b>                                | <b>5.69</b>                               | <b>6.03</b>                                |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive); S<sub>1</sub>= 0 mM NaCl (Control), S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl

**Table 4.4.22 Root length of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 19.80     | 12.67      | 36.01                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 21.33     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 18.97     | 10.13      | 46.60                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 49.53     | 46.20      | 6.72                      | 44.30       | 10.56                     |
| V <sub>5</sub>  | 19.30     | 18.77      | 2.75                      | 18.37       | 4.82                      |
| V <sub>6</sub>  | 13.73     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 25.97     | 15.82      | 39.08                     | 8.10        | 68.81                     |
| V <sub>8</sub>  | 26.23     | 24.07      | 8.23                      | 14.40       | 45.10                     |
| V <sub>9</sub>  | 25.33     | 23.53      | 7.11                      | 7.53        | 70.27                     |
| V <sub>10</sub> | 41.20     | 38.00      | 7.77                      | 35.20       | 14.56                     |
| V <sub>11</sub> | 27.23     | 24.50      | 10.03                     | 0.00        | 100.00                    |
| V <sub>12</sub> | 25.97     | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.15 Shoot dry weight hill<sup>-1</sup>

##### 4.4.15.1 Effect of species

It was observed that shoot dry weight hill<sup>-1</sup> was significantly differed for all wild rice genotypes (Table 4.4.20). Rice species *O. latifolia* (V<sub>4</sub>) produced the maximum shoot dry weight hill<sup>-1</sup> (181.30 g) whereas *O. barthii* (V<sub>2</sub>) produced the minimum shoot dry weight hill<sup>-1</sup> (17.34 g). Similar findings was also reported by Channa *et al.* (2019) who revealed that there was an average 9.04 % reduction in shoot dry mass in all rice genotypes at (EC 6.0 dS m<sup>-1</sup>).

##### 4.4.15.2 Effect of salinity level

It was observed that shoot dry weight hill<sup>-1</sup> was significantly differed for different salinity levels (Table 4.4.20). Data showed that S<sub>1</sub> treatment produced the maximum shoot dry weight hill<sup>-1</sup> (131.20 g) whereas, treatment S<sub>3</sub> produced the minimum shoot dry weight hill<sup>-1</sup> (50.19 g). Akbar and Yabuno (1974); Basra *et al.* (2006) reported that shoot growth was acutely restrained by salt stress at 10 dS m<sup>-1</sup> because osmotic pressure of medium was increased by high salt concentration. As the plant could not

absorb water and nutrient from the soil and growth and development of shoot become restricted, moreover even survival in this hard condition become difficult. So, the dry mass of shoot becomes reduced under higher salinity state. In this respect, Chopart *et al.* (2008) stated that evaluation of shoot and root density and distribution could be considered as a key factor for water and nutrient uptake by a plant from the soil. Rahman *et al.* (2016) observed that the shoot density epitomizes dry mass production per unit of shoot length. The reduction in both density and distribution of rice in this study may reflect the effect of salinity on decreasing shoot dry weight. These results were in harmony with those obtained by Aref (2013); Gupta and Huang (2014); Rahman *et al.* (2016); Malumpong *et al.* (2019) on rice cultivars; Seckin *et al.* (2010) on barley cultivars and Ali (2009) on wheat cultivars who stated that the higher salinity levels caused significant reduction in shoot dry weight.

#### **4.4.15.3 Interaction effect of species and salinity level**

It was observed that shoot dry weight hill<sup>-1</sup> was significantly differed for different rice varieties and salinity levels (Table 4.4.21). Data showed that V<sub>4</sub>S<sub>1</sub> treatment combination produced the maximum shoot dry weight hill<sup>-1</sup> (186.00 g) which was statistically similar with V<sub>8</sub>S<sub>1</sub>, V<sub>4</sub>S<sub>2</sub> and V<sub>1</sub>S<sub>1</sub> whereas treatment combinations V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub> did not produce any shoot dry weight hill<sup>-1</sup> (0.00 g).

At 50 mM NaCl the maximum decrease of shoot dry weight hill<sup>-1</sup> (42.80%) attained by wild rice genotype *O. longistaminata* (V<sub>7</sub>) and minimum decrease of shoot dry weight hill<sup>-1</sup> (2.15%) attained by wild rice genotype *O. latifolia* (V<sub>4</sub>) while at 100 mM NaCl the maximum decrease of shoot dry weight hill<sup>-1</sup> (71.12%) attained by wild rice genotype *O. punctata* (V<sub>9</sub>) and minimum decrease of shoot dry weight hill<sup>-1</sup> (5.38%) attained by wild rice genotype *O. latifolia* (V<sub>4</sub>) (Table 4.4.23).

#### **4.4.16 Root dry weight hill<sup>-1</sup>**

##### **4.4.16.1 Effect of species**

Root dry weight hill<sup>-1</sup> was significantly influenced by different wild rice varieties (Table 4.4.20). Result revealed that the maximum root dry weight hill<sup>-1</sup> (165.70 g)

was recorded from *O. latifolia* (V<sub>4</sub>) and the minimum root dry weight hill<sup>-1</sup> (9.36 g) was recorded from *O. barthii* (V<sub>2</sub>).

**Table 4.4.23 Shoot dry weight hill<sup>-1</sup> of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 178.90    | 108.80     | 39.18                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 52.03     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 140.70    | 95.81      | 31.90                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 186.00    | 182.00     | 2.15                      | 176.00      | 5.38                      |
| V <sub>5</sub>  | 46.68     | 45.44      | 2.66                      | 38.87       | 16.73                     |
| V <sub>6</sub>  | 92.10     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 174.50    | 99.81      | 42.80                     | 53.66       | 69.25                     |
| V <sub>8</sub>  | 182.80    | 164.40     | 10.07                     | 93.92       | 48.62                     |
| V <sub>9</sub>  | 121.10    | 114.00     | 5.86                      | 34.97       | 71.12                     |
| V <sub>10</sub> | 175.10    | 165.30     | 5.60                      | 158.60      | 9.42                      |
| V <sub>11</sub> | 68.09     | 52.73      | 22.56                     | 0.00        | 100.00                    |
| V <sub>12</sub> | 156.00    | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.16.2 Effect of salinity level

Root dry weight hill<sup>-1</sup> was significantly influenced by different salinity levels (Table 4.4.20). The magnitude of the reduction of root dry weight hill<sup>-1</sup> was increased along with the increasing concentration of salt. Result revealed that the maximum root dry weight hill<sup>-1</sup> (117.40 g) was recorded from S<sub>1</sub> treatment and the minimum root dry weight hill<sup>-1</sup> (46.60 g) was recorded from S<sub>3</sub> treatment. As we know from the findings of Rahman *et al.* (2016) that root density represents dry mass production per unit of root length. The reduction of root length may reflect the effect of salinity on decreasing root dry weight. The evaluation of root density and distribution could be considered as a key factor for water and nutrient uptake by a plant from the soil (Chopart *et al.*, 2008). The results of our present findings are supported by Ashraf (2009); Hakim *et al.* (2010); Joseph *et al.* (2010); Malumpong *et al.* (2019) on rice; Seckin *et al.* (2010) on barley cultivars and Ali (2009) on wheat cultivars who observed that under salinity stress showed a remarkable reduction in root dry weight.

#### 4.4.16.3 Interaction effect of species and salinity level

Root dry weight hill<sup>-1</sup> was significantly influenced by different rice varieties and salinity levels (Table 4.4.21). Result revealed that the maximum root dry weight hill<sup>-1</sup> (189.20 g) was recorded from treatment combination V<sub>9</sub>S<sub>1</sub> which was statistically similar with V<sub>9</sub>S<sub>2</sub> and the minimum root dry weight hill<sup>-1</sup> (0.00 g) was recorded from treatment combinations V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub>.

At 50 mM NaCl the maximum decrease of root dry weight hill<sup>-1</sup>(39.74%) attained by wild rice genotype *O. longistaminata* (V<sub>7</sub>)and minimum decrease of root dry weight hill<sup>-1</sup>(1.93%) attained by wild rice genotype *O. latifolia* (V<sub>4</sub>) while at 100 mM NaCl the maximum decrease of root dry weight hill<sup>-1</sup>(68.51%) attained by wild rice genotype *O. longistaminata* (V<sub>7</sub>)and minimum decrease of root dry weight hill<sup>-1</sup>(7.37%) attained by wild rice genotype *O. latifolia* (V<sub>4</sub>) (Table 4.4.24).

**Table 4.4.24 Root dry weight hill<sup>-1</sup> of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 176.70    | 106.60     | 39.67                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 28.09     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 123.30    | 84.64      | 31.35                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 171.00    | 167.70     | 1.93                      | 158.40      | 7.37                      |
| V <sub>5</sub>  | 36.35     | 33.11      | 8.91                      | 31.72       | 12.74                     |
| V <sub>6</sub>  | 81.15     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 169.60    | 102.20     | 39.74                     | 53.40       | 68.51                     |
| V <sub>8</sub>  | 175.80    | 141.20     | 19.68                     | 93.26       | 46.95                     |
| V <sub>9</sub>  | 189.20    | 183.70     | 2.91                      | 60.15       | 68.21                     |
| V <sub>10</sub> | 127.30    | 119.60     | 6.05                      | 113.40      | 10.92                     |
| V <sub>11</sub> | 35.86     | 31.53      | 12.07                     | 0.00        | 100.00                    |
| V <sub>12</sub> | 94.11     | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant)and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.17 Total dry weight hill<sup>-1</sup>

##### 4.4.17.1 Effect of species

Different varieties of wild rice exerted significant variation on total dry weight hill<sup>-1</sup> (Table4.4.20). The maximum total dry weight hill<sup>-1</sup> (347.50 g) was produced by *O.*

*latifolia* (V<sub>4</sub>) and the minimum total dry weight hill<sup>-1</sup> (39.74 g) was produced by *O. barthii* (V<sub>2</sub>). Asch *et al.* (1999); Rubel *et al.* (2014) worked with 8 rice cultivars and found that the cultivars were differed in their salt uptake and tolerant cultivars had lower salt effect on yield and yield components than susceptible ones. Filled grain weight and total dry matter weight contributed the most variation to grain yield under salinity stress and these traits were selected for tagging the salinity tolerance genes. The results of our investigation are also in line with the findings of Singh *et al.* (2000); Moud and Maghsoudi (2008) who also found varied sensitivity of wheat genotypes on the basis of dry weight of seedling.

#### **4.4.17.2 Effect of salinity level**

Different salinity levels exerted significant variation on total dry weight hill<sup>-1</sup> (Table 4.4.20). The maximum total dry weight hill<sup>-1</sup> (266.60 g) was produced by S<sub>1</sub> treatment and the minimum total dry weight hill<sup>-1</sup> (98.15 g) was produced by S<sub>3</sub> treatment. Dry weight is the consequence of plant physiological and biological activity. The decreasing trend of dry matter production under salinity stress might be due to inadequate uptake of nutrients present in the growth medium and the decreased water entry rate of the plants and the decreased in photosynthetic output with a suppressed supply of CO<sub>2</sub> (Rahman *et al.*, 2016). Lawlor and Cornic (2002) reported that salinity disturbs the normal electron flow for carbon reduction in the Calvin cycle by impairing water uptake, which acts as an electron donor. Again abscisic acid (ABA) mediated stomatal closure limits CO<sub>2</sub> fixation, resulting in decreasing carbon reduction by Calvin cycle that leads to low photosynthesis. As it is proved that dry matter production is associated with photosynthesis, low photosynthesis rate causes low dry matter production. Meiri and Poljakoff-Mayber (1970); Long and Baker (1986) and Seeman and Sharkey (1986) also reported that under salinity stress condition photosynthetic rate is reduced markedly, spent huge energy in salt removal mechanism, reduced transportation of compatible nutrient, arrested cell division and enlargement, decreased root and shoot length, leaf number and ultimately reduction of plant growth and consequently accumulation of dry matter is occurred. Cherian and Reddy (2000) found that salt level 7.50 dSm<sup>-1</sup> was quite detrimental for saline sensitive plant, which results about 60% reduction of dry weight in *Suaeda nudiflora* whereas Zeng and Shannon (2003) showed that salinity (3.6 to 8.3 dSm<sup>-1</sup>) does not affect the dry matter weight of rice before heading stage. Corroborate findings was

also reported by Senanayake *et al.* (2017); Baque *et al.* (2018); Polash *et al.* (2018); Malumpong *et al.* (2019) who reported that salt stress enhanced the stunting of plant growth consequently a measurable decrease in dry weights of plant occurs.

#### 4.4.17.3 Interaction effect of species and salinity level

Different varieties and salinity levels exerted significant variation on total dry weight hill<sup>-1</sup> (Table 4.4.21). The maximum total dry weight hill<sup>-1</sup> (359.40 g) was produced by V<sub>4</sub>S<sub>1</sub> which was statistically similar with V<sub>8</sub>S<sub>1</sub>, V<sub>8</sub>S<sub>2</sub>, V<sub>4</sub>S<sub>2</sub> and V<sub>6</sub>S<sub>1</sub> and the minimum total dry weight hill<sup>-1</sup> (0.00 g) was produced by treatment combinations V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub>.

At 50 mM NaCl the maximum decrease of total dry weight hill<sup>-1</sup>(39.34%) attained by wild rice genotype *O. rufipogon* (V<sub>1</sub>) and minimum decrease of total dry weight hill<sup>-1</sup>(1.98%) attained by wild rice genotype *O. punctata* (V<sub>9</sub>)while at 100 mM NaCl the maximum decrease of total dry weight hill<sup>-1</sup>(68.88%) attained by wild rice genotype *O. punctata* (V<sub>9</sub>)and minimum decrease of total dry weight hill<sup>-1</sup>(7.18%) attained by wild rice genotype *O. latifolia* (V<sub>4</sub>) (Table 4.4.25).

**Table 4.4.25 Total dry weight hill<sup>-1</sup> of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 355.10    | 215.40     | 39.34                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 119.20    | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 277.40    | 180.20     | 35.04                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 359.40    | 349.40     | 2.78                      | 333.60      | 7.18                      |
| V <sub>5</sub>  | 82.42     | 77.22      | 6.31                      | 74.92       | 9.10                      |
| V <sub>6</sub>  | 345.60    | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 342.10    | 212.50     | 37.88                     | 110.70      | 67.64                     |
| V <sub>8</sub>  | 358.90    | 348.30     | 2.95                      | 195.00      | 45.67                     |
| V <sub>9</sub>  | 303.60    | 297.60     | 1.98                      | 94.49       | 68.88                     |
| V <sub>10</sub> | 302.10    | 284.60     | 5.79                      | 267.30      | 11.52                     |
| V <sub>11</sub> | 103.90    | 96.93      | 6.71                      | 0.00        | 100.00                    |
| V <sub>12</sub> | 250.10    | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### **4.4.18 Chlorophyll a content on leaf**

##### **4.4.18.1 Effect of species**

Different varieties of wild rice exerted significant variation on chlorophyll a (Chlorophyll a) content on leaf are presented in Table 4.4.26. Data revealed that the maximum chlorophyll a content on leaf ( $21.40 \text{ mg g}^{-1} \text{ FW}$ ) was recorded from *O. latifolia* ( $V_4$ ) which was statistically similar with  $V_5$  and the minimum chlorophyll a content on leaf ( $6.83 \text{ mg g}^{-1} \text{ FW}$ ) was recorded from BRRI Dhan 29 ( $V_{12}$ ) (Check variety as salt sensitive) which was statistically similar with  $V_2$ . Under salt stress the ability to sustain chlorophyll a on leaf is depends on genetic potentiality of a genotype. Several researchers have stated that pigment stabilization in salt-tolerant rice varieties, HJ salt tolerant (Cha-um *et al.*, 2007), FL478 (Demiral and Türkan, 2006) and Pokkali (Walia *et al.*, 2005), is more reliable than in salt-sensitive varieties, IR29 and IR28. Saeedipour (2014) reported that the degradation of chlorophyll a in salt-stressed IR29 was 19.43 %, while that in FL485 was 14.66 %. Considering that chlorophyll *a* is the main photosynthetic pigment (Daiz *et al.*, 2002; Santo, 2004), this reduction in ratio could probably be one of the main reasons for reduced photosynthesis under salt stress as reported in rice before (Moradi and Ismail, 2007). The ability of the tolerant genotype to maintain higher concentration of chlorophyll 'a' is probably one of the important mechanisms contributing to salinity tolerance in this genotype, which could consequently result in higher photosynthetic capacity. The results of our investigation corroborates with results of Datta *et al.* (2009); Chutipaijit (2011); Saeedipour (2014) who explained that with increasing the salt concentration the chlorophyll a content on leaf is decreased.

##### **4.4.18.2 Effect of salinity level**

Different salinity levels exerted significant variations on chlorophyll a content on leaf are presented in Table 4.4.26. Data revealed that the maximum chlorophyll a content on leaf ( $20.91 \text{ mg g}^{-1} \text{ FW}$ ) was recorded from  $S_1$  and the minimum chlorophyll a content on leaf ( $6.94 \text{ mg g}^{-1} \text{ FW}$ ) was recorded from  $S_3$ . Leaf photosynthetic pigments are key variables in characterizing photosynthetic response and gross primary production in the biosphere (Huang *et al.*, 2015; Cannella *et al.*, 2016) with the pigments playing a central role in light harvesting, photosystem protection, and other



growth functions (Abramavicius and Valkunas, 2016 and Batjuka *et al.*, 2016). Chlorophylls control the photosynthetic potential of plants by capturing light energy from the sun (Kocks *et al.*, 1995) and represent one of the most important photosynthetic pigments. The leaf chlorophyll content provides a key indicator of the photosynthetic capacity (Houborg *et al.*, 2015; Cannella *et al.*, 2016). Akcin and Yalcin (2016) reported that in their investigation that chlorophyll a, content decreased with increasing the salinity level. Reduction in chlorophyll a content under salt stress could be attributed to the destruction of chlorophyll a pigments (Levitt, 1980). Beinsan *et al.* (2009) reported that the decrease in chlorophyll a content was due to the increase in the activity of chlorophylls enzyme and instability of protein complexity of pigments. Hussain *et al.* (2017) also reported that rice plants under salt stress have decreased photosynthetic efficiency by the complex of photosystem II (PSII). Moreover, chlorophyll contents in rice leaves are damaged by the addition of Na<sup>+</sup> and Cl<sup>-</sup>, which might hinder the major electron transport in PSII (Sudhir and Murthy, 2004; Munns *et al.*, 2006). Molazem *et al.* (2010) and Kanawapee *et al.* (2012) reported that chlorophyll content of leaves decreased under salt stress and salt-sensitive cultivar had often-lower chlorophyll content than salt resistant ones. Essential pathways that lead to synthesis of osmotically active metabolites (such as proline, glycinebetaine, sugars, etc.) and certain free radical scavenging enzymes help control ion and water flux and support scavenging of oxygen radicals (Sanchez *et al.*, 2008). Salt-sensitive cultivars had more reduction in chlorophyll content than salt-tolerant ones. Salt induced deteriorative processes leading to leaf senescence including chlorophyll and protein degradation and decrease in membrane stability and lipid peroxidation occurred earlier and more severely affected salt-sensitive rice (Lutts *et al.*, 1996; Misra *et al.*, 1997). Accordingly, higher chlorophyll accumulation is considered to be a potential indicator of salinity tolerance (Akram and Ashraf, 2011; Khan *et al.*, 2011). The results obtained in this study are in agreement with those studies of Shah *et al.* (2017); Datir *et al.* (2018) in rice; Aghaleh *et al.* (2009) in *S. persica* and *S. europaea* L. who also reported significant reduction in chlorophyll contents at increasing levels of salinity.

**Table 4.4.26 Effect of species and salinity level on the physiological characteristics of wild species of rice**

| Treatments                      | Chlorophyll a<br>content on leaf<br>(mg g <sup>-1</sup> FW) | Chlorophyll b<br>content on leaf<br>(mg g <sup>-1</sup> FW) | Carotenoid<br>content<br>(mg g <sup>-1</sup> FW) | Proline content<br>on leaf<br>(μmol g <sup>-1</sup> FW) |
|---------------------------------|-------------------------------------------------------------|-------------------------------------------------------------|--------------------------------------------------|---------------------------------------------------------|
| <b>Effect of species</b>        |                                                             |                                                             |                                                  |                                                         |
| V <sub>1</sub>                  | 9.91 f                                                      | 7.66 f                                                      | 2.49 f                                           | 0.24 f                                                  |
| V <sub>2</sub>                  | 6.98 g                                                      | 6.18 g                                                      | 1.63 gh                                          | 0.14 gh                                                 |
| V <sub>3</sub>                  | 10.68 e                                                     | 7.99 f                                                      | 3.02 e                                           | 0.24 f                                                  |
| V <sub>4</sub>                  | 21.40 a                                                     | 15.91 a                                                     | 5.74 a                                           | 0.40 b                                                  |
| V <sub>5</sub>                  | 20.93 ab                                                    | 15.76 a                                                     | 5.24 b                                           | 0.42 a                                                  |
| V <sub>6</sub>                  | 5.57 h                                                      | 4.15 h                                                      | 1.86 g                                           | 0.13 h                                                  |
| V <sub>7</sub>                  | 11.87 d                                                     | 9.27 e                                                      | 2.90 e                                           | 0.29 e                                                  |
| V <sub>8</sub>                  | 15.85 c                                                     | 12.28 c                                                     | 4.39 d                                           | 0.40 b                                                  |
| V <sub>9</sub>                  | 15.17 c                                                     | 11.15 d                                                     | 4.44 d                                           | 0.35 c                                                  |
| V <sub>10</sub>                 | 20.50 b                                                     | 14.98 b                                                     | 4.85 c                                           | 0.42 a                                                  |
| V <sub>11</sub>                 | 11.45 d                                                     | 7.53 f                                                      | 2.88 e                                           | 0.32 d                                                  |
| V <sub>12</sub>                 | 6.83 g                                                      | 5.76 g                                                      | 1.53 h                                           | 0.15 g                                                  |
| <b>LSD<sub>(0.05)</sub></b>     | <b>0.73</b>                                                 | <b>0.70</b>                                                 | <b>0.25</b>                                      | <b>0.01</b>                                             |
| <b>CV (%)</b>                   | <b>5.97</b>                                                 | <b>7.57</b>                                                 | <b>7.94</b>                                      | <b>6.81</b>                                             |
| <b>Effect of salinity level</b> |                                                             |                                                             |                                                  |                                                         |
| S <sub>1</sub>                  | 20.91 a                                                     | 15.57 a                                                     | 5.46 a                                           | 0.399 a                                                 |
| S <sub>2</sub>                  | 11.43 b                                                     | 8.77 b                                                      | 3.05 b                                           | 0.288 b                                                 |
| S <sub>3</sub>                  | 6.94 c                                                      | 5.32 c                                                      | 1.73 c                                           | 0.189 c                                                 |
| <b>LSD<sub>(0.05)</sub></b>     | <b>0.37</b>                                                 | <b>0.35</b>                                                 | <b>0.13</b>                                      | <b>0.001</b>                                            |
| <b>CV (%)</b>                   | <b>5.97</b>                                                 | <b>7.57</b>                                                 | <b>7.94</b>                                      | <b>6.81</b>                                             |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant)and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive); S<sub>1</sub>= 0 mM NaCl (Control), S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl

#### 4.4.18.3 Interaction effect of species and salinity level

Different wild rice genotypes and salinity levels exerted significant variations on ‘Chlorophyll a’ content on leaf are presented in Table 4.4.27. Data revealed that the maximum ‘Chlorophyll a’ content on leaf (23.25 mg g<sup>-1</sup> FW) was recorded from V<sub>4</sub>S<sub>1</sub> which was statistically similar with V<sub>5</sub>S<sub>1</sub> and V<sub>11</sub>S<sub>1</sub> and minimum value (0.00 mg g<sup>-1</sup> FW) for ‘Chlorophyll a’ content on leaf similar trend was followed.

**Table 4.4.27 Interaction effect of species and salinity level on the physiological characteristics of wild species of rice**

| Treatments                     | Chlorophyll a<br>content on leaf<br>(mg g <sup>-1</sup> FW) | Chlorophyll b<br>content on leaf<br>(mg g <sup>-1</sup> FW) | Carotenoid<br>content<br>(mg g <sup>-1</sup> FW) | Proline content<br>on leaf<br>(μmol g <sup>-1</sup> FW) |
|--------------------------------|-------------------------------------------------------------|-------------------------------------------------------------|--------------------------------------------------|---------------------------------------------------------|
| V <sub>1</sub> S <sub>1</sub>  | 19.47 hi                                                    | 14.23 hi                                                    | 4.99 f-i                                         | 0.41 de                                                 |
| V <sub>1</sub> S <sub>2</sub>  | 10.25 lm                                                    | 8.74 kl                                                     | 2.48 lm                                          | 0.32 l                                                  |
| V <sub>1</sub> S <sub>3</sub>  | 0.00 o                                                      | 0.00 n                                                      | 0.00 o                                           | 0.00 o                                                  |
| V <sub>2</sub> S <sub>1</sub>  | 20.95 c-f                                                   | 18.55 a                                                     | 4.89 g-j                                         | 0.42 d                                                  |
| V <sub>2</sub> S <sub>2</sub>  | 0.00 o                                                      | 0.00 n                                                      | 0.00 o                                           | 0.00 o                                                  |
| V <sub>2</sub> S <sub>3</sub>  | 0.00 o                                                      | 0.00 n                                                      | 0.00 o                                           | 0.00 o                                                  |
| V <sub>3</sub> S <sub>1</sub>  | 20.75 d-g                                                   | 14.86 e-h                                                   | 5.68 b-d                                         | 0.39 fg                                                 |
| V <sub>3</sub> S <sub>2</sub>  | 11.30 kl                                                    | 9.110 k                                                     | 3.39 k                                           | 0.32 l                                                  |
| V <sub>3</sub> S <sub>3</sub>  | 0.00 o                                                      | 0.00 n                                                      | 0.00 o                                           | 0.00 o                                                  |
| V <sub>4</sub> S <sub>1</sub>  | 23.25 a                                                     | 16.99 bc                                                    | 6.29 a                                           | 0.36 ij                                                 |
| V <sub>4</sub> S <sub>2</sub>  | 21.40 b-e                                                   | 16.06 c-e                                                   | 5.70 bc                                          | 0.40 ef                                                 |
| V <sub>4</sub> S <sub>3</sub>  | 19.56 g-i                                                   | 14.68 gh                                                    | 5.24 d-g                                         | 0.44 c                                                  |
| V <sub>5</sub> S <sub>1</sub>  | 22.50 ab                                                    | 16.67 b-d                                                   | 5.98 ab                                          | 0.38 gh                                                 |
| V <sub>5</sub> S <sub>2</sub>  | 20.85 d-f                                                   | 15.81 c-g                                                   | 5.10 e-h                                         | 0.42 d                                                  |
| V <sub>5</sub> S <sub>3</sub>  | 19.45 hi                                                    | 14.81 f-h                                                   | 4.62 ij                                          | 0.47 b                                                  |
| V <sub>6</sub> S <sub>1</sub>  | 16.70 j                                                     | 12.46 j                                                     | 5.57 b-d                                         | 0.40 ef                                                 |
| V <sub>6</sub> S <sub>2</sub>  | 0.00 o                                                      | 0.00 n                                                      | 0.00 o                                           | 0.00 o                                                  |
| V <sub>6</sub> S <sub>3</sub>  | 0.00 o                                                      | 0.00 n                                                      | 0.00 o                                           | 0.00 o                                                  |
| V <sub>7</sub> S <sub>1</sub>  | 19.27 hi                                                    | 14.80 f-h                                                   | 4.60 ij                                          | 0.39 efg                                                |
| V <sub>7</sub> S <sub>2</sub>  | 6.02 n                                                      | 4.75 m                                                      | 1.38 n                                           | 0.15 n                                                  |
| V <sub>7</sub> S <sub>3</sub>  | 10.31 lm                                                    | 8.26 kl                                                     | 2.71 l                                           | 0.34 k                                                  |
| V <sub>8</sub> S <sub>1</sub>  | 21.84 b-d                                                   | 15.94 c-f                                                   | 5.95 ab                                          | 0.39 fg                                                 |
| V <sub>8</sub> S <sub>2</sub>  | 16.11 j                                                     | 13.20 ij                                                    | 5.00 f-i                                         | 0.45 c                                                  |
| V <sub>8</sub> S <sub>3</sub>  | 9.59 m                                                      | 7.70 l                                                      | 2.21 m                                           | 0.35 jk                                                 |
| V <sub>9</sub> S <sub>1</sub>  | 21.61 b-e                                                   | 15.19 e-h                                                   | 6.32 a                                           | 0.41 de                                                 |
| V <sub>9</sub> S <sub>2</sub>  | 18.93 i                                                     | 14.28 hi                                                    | 5.46 c-e                                         | 0.47 b                                                  |
| V <sub>9</sub> S <sub>3</sub>  | 4.97 n                                                      | 3.97 m                                                      | 1.54 n                                           | 0.18 m                                                  |
| V <sub>10</sub> S <sub>1</sub> | 21.96 b-d                                                   | 15.66 d-g                                                   | 5.27 c-g                                         | 0.37 hi                                                 |
| V <sub>10</sub> S <sub>2</sub> | 20.11 f-i                                                   | 14.87 e-h                                                   | 4.80 h-j                                         | 0.42 d                                                  |
| V <sub>10</sub> S <sub>3</sub> | 19.42 hi                                                    | 14.40 hi                                                    | 4.47 j                                           | 0.48 b                                                  |
| V <sub>11</sub> S <sub>1</sub> | 22.18 a-c                                                   | 14.14 hi                                                    | 5.36 c-f                                         | 0.44 c                                                  |
| V <sub>11</sub> S <sub>2</sub> | 12.16 k                                                     | 8.44 kl                                                     | 3.29 k                                           | 0.51 a                                                  |
| V <sub>11</sub> S <sub>3</sub> | 0.00 o                                                      | 0.00 n                                                      | 0.00 o                                           | 0.00 o                                                  |
| V <sub>12</sub> S <sub>1</sub> | 20.49 e-h                                                   | 17.29 b                                                     | 4.60 ij                                          | 0.44 c                                                  |
| V <sub>12</sub> S <sub>2</sub> | 0.00 o                                                      | 0.00 n                                                      | 0.00 o                                           | 0.00 o                                                  |
| V <sub>12</sub> S <sub>3</sub> | 0.00 o                                                      | 0.00 n                                                      | 0.00 o                                           | 0.00 o                                                  |
| <b>LSD<sub>(0.05)</sub></b>    | <b>1.27</b>                                                 | <b>1.22</b>                                                 | <b>0.44</b>                                      | <b>0.02</b>                                             |
| <b>CV (%)</b>                  | <b>5.97</b>                                                 | <b>7.57</b>                                                 | <b>7.94</b>                                      | <b>6.81</b>                                             |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali

(Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive); S<sub>1</sub>= 0 mM NaCl (Control), S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl

At 50 mM NaCl concentration the maximum decrease of chlorophyll a content on leaf (47.35%) was found from wild rice genotype *O. rufipogon* (V<sub>1</sub>) and minimum decrease of Ch a content on leaf (7.33%) was found from wild rice genotype *Potericia coaractata* (V<sub>5</sub>) on the other hand at 100 mM NaCl concentration the maximum decrease of chlorophyll a content on leaf (77.00%) was found from wild rice genotype *O. punctata* (V<sub>9</sub>) and minimum decrease of Ch chlorophyll a content on leaf (11.57%) was found from wild rice genotype *O. alta* (V<sub>10</sub>) (Table 4.4.28).

**Table 4.4.28 Chlorophyll a content on leaf of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 19.47     | 10.25      | 47.35                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 20.95     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 20.75     | 11.30      | 45.54                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 23.25     | 21.40      | 7.96                      | 19.56       | 15.87                     |
| V <sub>5</sub>  | 22.50     | 20.85      | 7.33                      | 19.45       | 13.56                     |
| V <sub>6</sub>  | 16.70     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 19.27     | 10.31      | 46.50                     | 6.02        | 68.76                     |
| V <sub>8</sub>  | 21.84     | 16.11      | 26.24                     | 9.59        | 56.09                     |
| V <sub>9</sub>  | 21.61     | 18.93      | 12.40                     | 4.97        | 77.00                     |
| V <sub>10</sub> | 21.96     | 20.11      | 8.42                      | 19.42       | 11.57                     |
| V <sub>11</sub> | 22.18     | 12.16      | 45.18                     | 0.00        | 100.00                    |
| V <sub>12</sub> | 20.49     | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.19 Chlorophyll b content on leaf

##### 4.4.19.1 Effect of species

Chlorophyll b content on leaf significantly influenced by different rice varieties are presented in Table 4.4.26. The maximum chlorophyll b content on leaf (15.91 mg g<sup>-1</sup> FW) was obtained from *O. latifolia* (V<sub>4</sub>) which was closely related with V<sub>5</sub> (15.76 mg g<sup>-1</sup> FW) and the minimum chlorophyll b content on leaf (5.76 mg g<sup>-1</sup> FW) was obtained from BRRI Dhan 29 (V<sub>12</sub>) (Check variety as salt sensitive) which was statistically similar with V<sub>2</sub> treatment. Photosynthetic pigment degradation in salt stressed rice is one of the most effective parameters to be a criterion in screening for

salt tolerance rice genotypes (Wanichananan *et al.*, 2003). Our findings are close confirmation with the findings of Saeedipour (2014) who reported the both photosynthetic pigments, chlorophyll a and chlorophyll b contents in both salt-tolerant and salt-sensitive varieties decreased when exposed to salt stress. But the extent of the reduction of pigment is higher in salt-sensitive varieties compare to that of salt-tolerant ones.

#### **4.4.19.2 Effect of salinity level**

Chlorophyll b content on leaf significantly influenced by different salinity levels are presented in Table 4.4.26. The maximum chlorophyll b content on leaf ( $15.57 \text{ mg g}^{-1}$  FW) was obtained from  $S_1$  treatment and the minimum chlorophyll b content on leaf ( $5.32 \text{ mg g}^{-1}$  FW) was obtained from  $S_3$  treatment. Saeedipour (2014) reported that the chlorophyll b content showed a reduction in salt stress but with a greater magnitude than chlorophyll a content. Salt stress was found to be more deleterious to chlorophyll b indicating the susceptible nature of this compound towards the salt stress situation. The instability of chlorophyll b content for salt stress can be regarded as an index of tolerance, which might produce higher photosynthetic rate and eventually show higher yield. Our findings are consistent with those of Nunes *et al.* (2008); Akcin and Yalcin (2016); Bhusan *et al.* (2016) who concluded that salt stress caused a significant reduction in chlorophyll b and total chlorophyll contents of rice cultivars.

#### **4.4.19.3 Interaction effect of species and salinity level**

Chlorophyll b content on leaf significantly influenced by different rice varieties and salinity levels are presented in Table 4.4.27. The maximum chlorophyll b content on leaf ( $18.55 \text{ mg g}^{-1}$  FW) was obtained from  $V_2S_1$  treatment and no chlorophyll b content on leaf ( $0.00 \text{ mg g}^{-1}$  FW) was recorded for  $V_1S_3$ ,  $V_2S_2$ ,  $V_2S_3$ ,  $V_3S_3$ ,  $V_6S_2$ ,  $V_6S_3$ ,  $V_{11}S_3$ ,  $V_{12}S_2$  and  $V_{12}S_3$  treatment combinations.

At 50 mM NaCl concentration the maximum decrease of Ch 'b' content on leaf (44.19%) was found from wild rice genotype *O. longistaminata* ( $V_7$ ) and minimum decrease of Ch 'b' content on leaf (5.04%) was found from wild rice genotype *O. alta* ( $V_{10}$ ) while at 100 mM NaCl concentration the maximum decrease of Ch 'b' content on leaf (73.86%) was found from wild rice genotype *O. punctata* ( $V_9$ ) and minimum

decrease of Ch ‘b’ content on leaf (8.05%) was found from wild rice genotype *O. alta* (V<sub>10</sub>) (Table 4.4.29).

**Table 4.4.29 Chlorophyll b content on leaf of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease (%) | 100 mM NaCl | Decrease (%) |
|-----------------|-----------|------------|--------------|-------------|--------------|
| V <sub>1</sub>  | 14.23     | 8.74       | 38.58        | 0.00        | 100.00       |
| V <sub>2</sub>  | 18.55     | 0.00       | 100.00       | 0.00        | 100.00       |
| V <sub>3</sub>  | 14.86     | 9.11       | 38.69        | 0.00        | 100.00       |
| V <sub>4</sub>  | 16.99     | 16.06      | 5.47         | 14.68       | 13.60        |
| V <sub>5</sub>  | 16.67     | 15.81      | 5.16         | 14.81       | 11.16        |
| V <sub>6</sub>  | 12.46     | 0.00       | 100.00       | 0.00        | 100.00       |
| V <sub>7</sub>  | 14.80     | 8.26       | 44.19        | 4.75        | 67.91        |
| V <sub>8</sub>  | 15.94     | 13.20      | 17.19        | 7.70        | 51.69        |
| V <sub>9</sub>  | 15.19     | 14.28      | 5.99         | 3.97        | 73.86        |
| V <sub>10</sub> | 15.66     | 14.87      | 5.04         | 14.40       | 8.05         |
| V <sub>11</sub> | 14.14     | 8.44       | 40.31        | 0.00        | 100.00       |
| V <sub>12</sub> | 17.29     | 0.00       | 100.00       | 0.00        | 100.00       |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.20 Carotenoid content

##### 4.4.20.1 Effect of species

Carotenoid content significantly varied by different rice varieties are presented in Table 4.4.26. The maximum carotenoid content (5.74 mg g<sup>-1</sup> FW) was observed from *O. latifolia* (V<sub>4</sub>) followed by *P. coaractata* (V<sub>5</sub>) (15.24%) and the minimum carotenoid content (1.53 mg g<sup>-1</sup> FW) was observed from BRRI Dhan 29 (V<sub>12</sub>) (Check variety as salt sensitive) which was statistically similar with V<sub>2</sub> treatment.

##### 4.4.20.2 Effect of salinity level

Carotenoid content significantly varied by different salinity levels are presented in Table 4.4.26. The maximum carotenoid content (5.46 mg g<sup>-1</sup> FW) was observed from S<sub>1</sub> treatment and the minimum carotenoid content (1.73 mg g<sup>-1</sup> FW) was observed from S<sub>3</sub> treatment. Shah *et al.* (2017) revealed that carotenoids (Ct) are composed of carotenes and xanthophylls, and represent another key photosynthetic pigment group. Being essential structural components of the photosynthetic antenna, Ct participate in harvesting light energy for photosynthesis (Holt *et al.*, 2005; Zakar *et al.*, 2016). In

addition to the direct contribution in the photosynthetic process, Ct are also involved in the defense mechanism against oxidative stress (Bouvier *et al.*, 2005 and Campos *et al.*, 2016) and play an essential role in the dissipation of excess light energy and provide protection to reaction centers (Santabarbara *et al.*, 2013 and Nagy *et al.*, 2015). The response of Ct to stress is similar to the chlorophyll content in many plants (Marquardt, 1998; Nagy *et al.*, 2015). They are involved in the transcriptional modulation of a large set of genes responsive to reactive oxygen species (Shumbe *et al.*, 2014) and long-distance stress signaling in photosynthetic plants (García-Plazaola *et al.*, 2017). As a photo-protection mechanism, Ct is retained during the process of chlorophyll degeneration at leaf senescence (Biswal, 1995; Merzlyak *et al.*, 1999). Carotenoids also provide useful insights into the physiological state of plants under stress (Sarijeva *et al.*, 2007 and Yi *et al.*, 2014). In our investigation with increasing of salt concentration Ct was decreased. The results obtained in this study are in agreement with those studies of Akcin and Yalcin (2016) and Shah *et al.* (2017) who concluded that carotenoids remarkably decreased with the increasing of salinity stress.

#### **4.4.20.3 Interaction effect of species and salinity level**

Carotenoid content significantly varied by different rice genotypes and salinity levels are presented in Table 4.4.27. The maximum carotenoid content (6.32 mg g<sup>-1</sup> FW) was observed from V<sub>9</sub>S<sub>1</sub> treatment combination which was statistically similar with V<sub>4</sub>S<sub>1</sub>, V<sub>5</sub>S<sub>1</sub> and V<sub>8</sub>S<sub>1</sub> and the minimum carotenoid content (0.00 mg g<sup>-1</sup> FW) was observed from V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub> treatment combinations.

At 50 mM NaCl concentration the maximum decrease of carotenoid content on leaf (50.27%) was found from wild rice genotype *O. rufipogon* (V<sub>1</sub>) and minimum decrease of carotenoid content on leaf (8.97%) was found from wild rice genotype *O. alta* (V<sub>10</sub>) while at 100 mM NaCl concentration the maximum decrease of carotenoid content on leaf (75.63%) was found from wild rice genotype *O. punctata* (V<sub>9</sub>) and minimum decrease of carotenoid content on leaf (15.29%) was found from wild rice genotype *O. alta* (V<sub>10</sub>) (Table 4.4.30).

**Table 4.4.30 Carotenoid content on leaf of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 4.99      | 2.48       | 50.27                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 4.89      | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 5.68      | 3.39       | 40.29                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 6.29      | 5.70       | 9.38                      | 5.24        | 16.65                     |
| V <sub>5</sub>  | 5.98      | 5.10       | 14.76                     | 4.62        | 22.73                     |
| V <sub>6</sub>  | 5.57      | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 4.60      | 2.71       | 41.09                     | 1.38        | 70.00                     |
| V <sub>8</sub>  | 5.95      | 5.00       | 16.06                     | 2.21        | 62.88                     |
| V <sub>9</sub>  | 6.32      | 5.46       | 13.61                     | 1.54        | 75.63                     |
| V <sub>10</sub> | 5.27      | 4.80       | 8.97                      | 4.47        | 15.29                     |
| V <sub>11</sub> | 5.36      | 3.29       | 38.65                     | 0.00        | 100.00                    |
| V <sub>12</sub> | 4.60      | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potrericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.21 Proline content on leaf

##### 4.4.21.1 Effect of species

Statistically significant variation was found for proline content on leaf of wild rice due to different genotypes is presented in Table 4.4.26. The maximum proline content on leaf (0.42  $\mu\text{mol g}^{-1}$  FW) was attained by both *P. coaractata* (V<sub>5</sub>) and *O. alta* (V<sub>10</sub>) followed by *O. latifolia* (V<sub>4</sub>) (0.40  $\mu\text{mol g}^{-1}$  FW) and the minimum proline content on leaf (0.13  $\mu\text{mol g}^{-1}$  FW) was attained by *O. glaberrima* (V<sub>6</sub>) which was closely related with *O. barthii* (V<sub>2</sub>) (0.14  $\mu\text{mol g}^{-1}$  FW). The results might be due to the different genetic potentiality of different rice genotypes.

##### 4.4.21.2 Effect of salinity level

Statistically significant variation was found for proline content on leaf of wild rice due to different salinity levels are presented in Table 4.4.26. The maximum proline content on leaf (0.40  $\mu\text{mol g}^{-1}$  FW) was attained by S<sub>1</sub> and the minimum proline content on leaf (0.19  $\mu\text{mol g}^{-1}$  FW) was attained by S<sub>3</sub> treatment. According to Momayezi *et al.* (2009) the commonly characterized biochemical response of plant cells to osmotic stress is the synthesis of special organic solutes (osmolytes) which accumulate at high cytoplasm concentrations (Serrano and Gaxiola 1994); proline is



one of them. Several researchers reported that proline protects plants from stress through different processes, including osmoregulation (Delauney and Verma, 1993; Hien *et al.*, 2003), storage of carbon and nitrogen (Hare and Cress, 1997), reduction of NaCl-induced K<sup>+</sup> efflux from roots (Cuin and Shabala, 2005), salt-stress signaling (Khedr *et al.*, 2003; Szabados and Savoure, 2010), detoxification of ROS, protection of membrane integrity, and stabilization of enzymes and proteins, thus, it can be beneficial to plants in adapting to stress (Trovato, 2008). Plant cells accumulate proline as an osmo-protectant to conserve osmotic stability and to prevent damage. There is a general acceptance that under salt stress, many plants tend to accumulate proline as a defense mechanism against osmotic challenge by acting as a compatible solute (Liu and van Staden, 2000 and Ghoulam *et al.*, 2002). It is feasible that proline, with other free amino acids, is involved in ameliorating salt tolerance. High levels of proline may also display a salt defensive response mechanism in terms of pigment stabilization, protecting photosynthetic machinery of the plant organelles by stabilizing ultra structure of the chloroplast (Munns, 2006). Proline concentration has been shown to be generally higher in stress tolerant in rice plants (Ratnagiri-24 and Ratnagiri-711) than in stress-sensitive plants when under stress (Chutipaijit, 2011). Similar opinion also stated by Chunthaburee (2016) and Polash *et al.* (2018) who indicated that enhanced accumulation of proline in cytosol is positively correlated with higher tolerance to salt stress. But many researchers have also controversial opinion regarding proline synthesis under salt stress condition. Maggio *et al.* (2002); Datir *et al.* (2018) reported that although plant species can differ considerably in the amount of proline that accumulates upon salt stress, there is no clear relationship between the ability to accumulate proline on stress tolerance. Excessive levels of proline in salt sensitive cultivars may be a response of leaf damage or may be a symptom of stress is in agreement with the results presented by who demonstrated that over-accumulation of proline was related to a symptom of salt injury rather than an indicator of salt resistance. Increased proline accumulation did not contribute to improved salt tolerance in rice were consistent with (Demiral and Türkan, 2005) who reported that under salt stress the highly susceptible rice cultivars accumulated the highest level of proline than the tolerant cultivars. Proline might be most effective in alleviating degradation of photosynthetic pigments probably because the high ratio of osmolytes function in protecting macromolecules and stabilizing protein structures (Hayat, 2012). The amount of accumulated proline under long-term salt stress

correlated negatively with the level of salt tolerance and survival percentage and positively with  $\text{Na}^+/\text{K}^+$  ratio. Positive correlation between proline accumulation and  $\text{Na}^+/\text{K}^+$  ratios associated with increased salt sensitivity and growth reduction was also observed in a study using 30 wheat cultivars (Poustini *et al.*, 2007). These authors concluded that proline might not be involved in salt tolerance in wheat and played only a small role in osmotic adjustment. Kanawapee *et al.* (2012) reported that the hyper accumulation of endogenous proline in the salt-sensitive barley under salt stress did not appear to play a major role in salt tolerance but rather a symptom of salt susceptibility. Over accumulation of proline in salt-sensitive rice was suggested to be a symptom of salt stress (Lutts *et al.*, 1999), and reflected poor performance and greater damage in response to salt stress (Moradi and Ismail 2007). The relationship between high accumulation of proline and poor growth performance in salt-sensitive rice may be related to the fact that synthesis of compatible solutes including proline consumes high energy and nitrogen source (Chen *et al.*, 2007). This result corroborates with the findings of Theerakulpisut *et al.* (2005); Kanawapee *et al.* (2012) who found that salt-sensitive rice cultivars accumulated higher level of proline under salt stress than the salt-tolerant ones.

#### **4.4.21.3 Interaction effect of species and salinity level**

Statistically significant variation was found for proline content on leaf of wild rice due to interaction of different wild genotypes and salinity levels are presented in Table 4.4.27. The maximum proline content on leaf ( $0.51 \mu\text{mol g}^{-1} \text{FW}$ ) was attained by  $V_{11}S_2$  and the minimum proline content on leaf ( $0.00 \mu\text{mol g}^{-1} \text{FW}$ ) was attained by  $V_1S_3$ ,  $V_2S_2$ ,  $V_2S_3$ ,  $V_3S_3$ ,  $V_6S_2$ ,  $V_6S_3$ ,  $V_{11}S_3$ ,  $V_{12}S_2$  and  $V_{12}S_3$  treatment combinations.

At 50 mM NaCl concentration the maximum decrease of proline content on leaf (61.86%) was found from wild rice genotype *O. longistaminata* ( $V_7$ ) and increase of proline content on leaf (17.22%) was found from wild rice genotype *O. officinalis* ( $V_8$ ) while at 100 mM NaCl concentration the maximum decrease of proline content on leaf (55.74%) was found from wild rice genotype *O. punctata* ( $V_9$ ) and increase of proline content on leaf (29.73%) was found from wild rice genotype *O. alta* ( $V_{10}$ ) (Table 4.4.31).

**Table 4.4.31 Proline content of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 0.41      | 0.32       | 21.32                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 0.42      | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 0.39      | 0.32       | 17.25                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 0.36      | 0.40       | -10.19                    | 0.44        | -23.14                    |
| V <sub>5</sub>  | 0.38      | 0.42       | -9.66                     | 0.47        | -23.68                    |
| V <sub>6</sub>  | 0.40      | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 0.39      | 0.15       | 61.86                     | 0.34        | 13.55                     |
| V <sub>8</sub>  | 0.39      | 0.45       | -17.22                    | 0.35        | 9.49                      |
| V <sub>9</sub>  | 0.41      | 0.47       | -15.56                    | 0.18        | 55.74                     |
| V <sub>10</sub> | 0.37      | 0.42       | -12.62                    | 0.48        | -29.73                    |
| V <sub>11</sub> | 0.44      | 0.51       | -15.91                    | 0.00        | 100.00                    |
| V <sub>12</sub> | 0.44      | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.22 Relative water content

##### 4.4.22.1 Effect of species

The relative water content (RWC) was significantly influence by different genotypes (Table 4.4.32). Result showed that the maximum relative water content (93.72%) was scored by *O. latifolia* (V<sub>4</sub>) which was closely related with *P. coaractata* (V<sub>5</sub>) (93.42%) and *O. alta* (V<sub>10</sub>) (92.29%) and the minimum relative water content (28.92 %) was scored by *O. glaberrima* (V<sub>6</sub>) which was closely related with V<sub>2</sub> (29.42%) and V<sub>12</sub> (29.72%).

##### 4.4.22.2 Effect of salinity level

The relative water content (RWC) was significantly influence by different salt concentration (Table 4.4.32). The relative water content on leaf was inversely affected by salt concentration and with the increased of saline concentration the relative water content was decreased. Result showed that the maximum relative water content (91.12%) was scored by S<sub>1</sub> and the minimum relative water content (34.76 %) was scored by S<sub>3</sub> treatment. The RWC signifies the water content in plants. Salinity reduces the relative water content. When plants are subjected to salinity, firstly they face an osmotic shock due to lower water potential in the soil solution that reduces water uptake by roots (Greenway and Munns, 1980; Orcutt and Nilsen, 2000; Cha-um

*et al.*, 2007; Hasan *et al.*, 2019). Besides ABA mediated stomatal closure affects transpiration pull that lead low/no water uptake by roots, entail low relative water content in the cell (Blatt and Armstrong, 1993). But the salt tolerance species exerts a high capacity to resist salt stress through biosynthesis and accumulation of compatible solute. These solutes increase the overall osmotic pressure within the cell there by empowering plant cell to affirm both turgor and driving gradient for water absorption (Hasegawa *et al.*, 2000). According to Kumar *et al.* (2005) numerous plants have improved mechanism either to restrict salt uptake to their cell or to tolerate within the cell. Under salt stress condition tolerance plant can grow vigorously, minimize the salt uptake and maximize potential salt load per unit area by their compartmentalization technique and provide better water use efficiency thus plant growth not hampered (Flower *et al.*, 1998). Salt tolerance cultivar may be defined as the plant which has the capacity to grow under low water potential. In this point of view, high relative water content is one of tolerance technique to stress condition (Sinclair and Ludlow, 1985). Similar finding was reported by Hussain *et al.* (2017); Polash *et al.* (2018); Hasan *et al.* (2019) who reported that relative water content decreased with increasing salt concentration.

#### **4.4.22.3 Interaction effect of species and salinity level**

The relative water content was significantly influence by different genotypes and salinity levels (Table 4.4.33). Result showed that the maximum relative water content (95.21%) was scored by V<sub>4</sub>S<sub>1</sub> which was statistically similar with V<sub>5</sub>S<sub>1</sub>, V<sub>4</sub>S<sub>2</sub>, V<sub>5</sub>S<sub>2</sub>, V<sub>4</sub>S<sub>3</sub>, V<sub>7</sub>S<sub>1</sub>, V<sub>8</sub>S<sub>1</sub>, V<sub>10</sub>S<sub>1</sub>, V<sub>10</sub>S<sub>2</sub> and V<sub>11</sub>S<sub>1</sub>. On the other hand treatment combinations V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub> did not score relative water content.

At 50 mM NaCl concentration the maximum decrease of relative water content on leaf (39.99%) was found from rice genotype Pokkali (Check variety as salt tolerant) (V<sub>11</sub>) and minimum decrease of relative water content on leaf (1.54%) was found from wild rice genotype *Potericia coaractata* (V<sub>5</sub>) while at 100 mM NaCl concentration the maximum decrease of relative water content on leaf (69.87%) was found from wild rice genotype *O. punctata* (V<sub>9</sub>) and minimum decrease of relative water content on leaf (2.78%) was found from wild rice genotype *O. latifolia* (V<sub>4</sub>) (Table 4.4.34).

**Table 4.4.32 Effect of species and salinity level on the water relation behavior of wild species of rice**

| Treatments                      | Relative water content (%) | Water saturation deficit | Water retention capacity | Water uptake capacity |
|---------------------------------|----------------------------|--------------------------|--------------------------|-----------------------|
| <b>Effect of species</b>        |                            |                          |                          |                       |
| V <sub>1</sub>                  | 48.27 e                    | 18.39 d                  | 2.09 e                   | 0.192 d               |
| V <sub>2</sub>                  | 29.42 f                    | 3.91 g                   | 1.34 fg                  | 0.118 e               |
| V <sub>3</sub>                  | 48.49 e                    | 18.17 d                  | 2.06 e                   | 0.181 d               |
| V <sub>4</sub>                  | 93.72 a                    | 6.28 f                   | 7.10 a                   | 0.360 a               |
| V <sub>5</sub>                  | 93.42 a                    | 6.57 ef                  | 7.06 a                   | 0.367 a               |
| V <sub>6</sub>                  | 28.92 f                    | 4.42 g                   | 1.06 g                   | 0.098 e               |
| V <sub>7</sub>                  | 60.14 d                    | 39.86 a                  | 3.31 c                   | 0.241 c               |
| V <sub>8</sub>                  | 79.45 b                    | 20.55 c                  | 2.76 d                   | 0.173 d               |
| V <sub>9</sub>                  | 68.48 c                    | 31.52 b                  | 3.00 d                   | 0.241 c               |
| V <sub>10</sub>                 | 92.29 a                    | 7.71 e                   | 4.95 b                   | 0.280 b               |
| V <sub>11</sub>                 | 49.05 e                    | 17.61 d                  | 2.31 e                   | 0.169 d               |
| V <sub>12</sub>                 | 29.72 f                    | 3.61 g                   | 1.41 f                   | 0.113 e               |
| <b>LSD<sub>(0.05)</sub></b>     | <b>2.14</b>                | <b>1.14</b>              | <b>0.31</b>              | <b>0.03</b>           |
| <b>CV (%)</b>                   | <b>3.78</b>                | <b>8.15</b>              | <b>10.35</b>             | <b>11.57</b>          |
| <b>Effect of salinity level</b> |                            |                          |                          |                       |
| S <sub>1</sub>                  | 91.12 a                    | 8.88 c                   | 5.52 a                   | 0.349 a               |
| S <sub>2</sub>                  | 54.47 b                    | 20.53 a                  | 2.59 b                   | 0.179 b               |
| S <sub>3</sub>                  | 34.76 c                    | 15.24 b                  | 1.50 c                   | 0.105 c               |
| <b>LSD<sub>(0.05)</sub></b>     | <b>1.07</b>                | <b>0.57</b>              | <b>0.16</b>              | <b>0.01</b>           |
| <b>CV (%)</b>                   | <b>3.78</b>                | <b>8.15</b>              | <b>10.35</b>             | <b>11.57</b>          |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant)and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive); S<sub>1</sub>= 0 mM NaCl (Control), S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl

#### 4.4.23 Water saturation deficit

##### 4.4.23.1 Effect of species

Water saturation deficit was significantly affected by different rice genotypes (Table 4.4.32). The maximum water saturation deficit (39.86%) was recorded from *O. longistaminata* (V<sub>7</sub>) and the minimum water saturation deficit (3.61%) was recorded from BRRI Dhan 29 (V<sub>12</sub>) (Check variety as salt sensitive) which was statistically similar with V<sub>2</sub> and V<sub>6</sub> treatments.

**Table 4.4.33 Interaction effect of species and salinity level on the water relation behavior of wild species of rice**

| Treatments                     | Relative water content (%) | Water saturation deficit | Water retention capacity | Water uptake capacity |
|--------------------------------|----------------------------|--------------------------|--------------------------|-----------------------|
| V <sub>1</sub> S <sub>1</sub>  | 88.91 d-g                  | 11.09 f-h                | 4.22 g                   | 0.357 bc              |
| V <sub>1</sub> S <sub>2</sub>  | 55.91 h                    | 44.09 c                  | 2.04 k                   | 0.220 gh              |
| V <sub>1</sub> S <sub>3</sub>  | 0.00 j                     | 0.00 o                   | 0.00 n                   | 0.000 l               |
| V <sub>2</sub> S <sub>1</sub>  | 88.27 e-g                  | 11.73 e-g                | 4.02 g                   | 0.353 bc              |
| V <sub>2</sub> S <sub>2</sub>  | 0.00 j                     | 0.00 o                   | 0.00 n                   | 0.000 l               |
| V <sub>2</sub> S <sub>3</sub>  | 0.00 j                     | 0.00 o                   | 0.00 n                   | 0.000 l               |
| V <sub>3</sub> S <sub>1</sub>  | 88.91 d-g                  | 11.09 f-h                | 4.33 fg                  | 0.363 bc              |
| V <sub>3</sub> S <sub>2</sub>  | 56.57 h                    | 43.43 cd                 | 1.84 kl                  | 0.180 hi              |
| V <sub>3</sub> S <sub>3</sub>  | 0.00 j                     | 0.00 o                   | 0.00 n                   | 0.000 l               |
| V <sub>4</sub> S <sub>1</sub>  | 95.21 a                    | 4.79 n                   | 9.83 a                   | 0.427 a               |
| V <sub>4</sub> S <sub>2</sub>  | 93.39 a-c                  | 6.61 k-n                 | 6.40 c                   | 0.353 bc              |
| V <sub>4</sub> S <sub>3</sub>  | 92.56 a-d                  | 7.44 j-m                 | 5.06 e                   | 0.300 d-f             |
| V <sub>5</sub> S <sub>1</sub>  | 95.15 ab                   | 4.85 n                   | 9.35 a                   | 0.403 ab              |
| V <sub>5</sub> S <sub>2</sub>  | 93.68 a-c                  | 6.32 l-n                 | 7.01 b                   | 0.373 bc              |
| V <sub>5</sub> S <sub>3</sub>  | 91.45 b-e                  | 8.55 i-k                 | 4.82 ef                  | 0.323 c-e             |
| V <sub>6</sub> S <sub>1</sub>  | 86.75 g                    | 13.25 e                  | 3.19 hi                  | 0.293 ef              |
| V <sub>6</sub> S <sub>2</sub>  | 0.00 j                     | 0.00 o                   | 0.00 n                   | 0.000 l               |
| V <sub>6</sub> S <sub>3</sub>  | 0.00 j                     | 0.00 o                   | 0.00 n                   | 0.000 l               |
| V <sub>7</sub> S <sub>1</sub>  | 92.33 a-d                  | 7.67 j-m                 | 5.85 d                   | 0.373 bc              |
| V <sub>7</sub> S <sub>2</sub>  | 29.97 i                    | 70.03 b                  | 1.49 l                   | 0.120 jk              |
| V <sub>7</sub> S <sub>3</sub>  | 58.12 h                    | 41.88 d                  | 2.60 j                   | 0.230 gh              |
| V <sub>8</sub> S <sub>1</sub>  | 91.82 a-e                  | 8.18 j-l                 | 3.97 g                   | 0.240 g               |
| V <sub>8</sub> S <sub>2</sub>  | 89.58 d-g                  | 10.42 g-i                | 2.84 ij                  | 0.160 ij              |
| V <sub>8</sub> S <sub>3</sub>  | 56.95 h                    | 43.05 cd                 | 1.47 l                   | 0.120 jk              |
| V <sub>9</sub> S <sub>1</sub>  | 90.82 c-f                  | 9.18 h-j                 | 4.87 e                   | 0.350 cd              |
| V <sub>9</sub> S <sub>2</sub>  | 87.26 fg                   | 12.74 ef                 | 3.38 h                   | 0.300 d-f             |
| V <sub>9</sub> S <sub>3</sub>  | 27.36 i                    | 72.64 a                  | 0.73 m                   | 0.073 k               |
| V <sub>10</sub> S <sub>1</sub> | 94.12 a-c                  | 5.88 mn                  | 7.15 b                   | 0.360 bc              |
| V <sub>10</sub> S <sub>2</sub> | 92.13 a-d                  | 7.87 j-l                 | 4.33 fg                  | 0.263 fg              |
| V <sub>10</sub> S <sub>3</sub> | 90.63 c-f                  | 9.37 h-j                 | 3.36 hi                  | 0.217 gh              |
| V <sub>11</sub> S <sub>1</sub> | 91.97 a-e                  | 8.03 j-l                 | 5.19 e                   | 0.327 c-e             |
| V <sub>11</sub> S <sub>2</sub> | 55.19 h                    | 44.81 c                  | 1.75 kl                  | 0.180 hi              |
| V <sub>11</sub> S <sub>3</sub> | 0.00 j                     | 0.00 o                   | 0.00 n                   | 0.000 l               |
| V <sub>12</sub> S <sub>1</sub> | 89.16 d-g                  | 10.84 f-h                | 4.24 g                   | 0.340 c-e             |
| V <sub>12</sub> S <sub>2</sub> | 0.00 j                     | 0.00 o                   | 0.00 n                   | 0.000 l               |
| V <sub>12</sub> S <sub>3</sub> | 0.00 j                     | 0.00 o                   | 0.00 n                   | 0.000 l               |
| <b>LSD<sub>(0.05)</sub></b>    | <b>3.70</b>                | <b>1.98</b>              | <b>0.54</b>              | <b>0.05</b>           |
| <b>CV (%)</b>                  | <b>3.78</b>                | <b>8.15</b>              | <b>10.35</b>             | <b>11.57</b>          |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali

(Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive); S<sub>1</sub>= 0 mM NaCl (Control), S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl

**Table 4.4.34 Relative water content of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 88.91     | 55.91      | 37.12                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 88.27     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 88.91     | 56.57      | 36.37                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 95.21     | 93.39      | 1.91                      | 92.56       | 2.78                      |
| V <sub>5</sub>  | 95.15     | 93.68      | 1.54                      | 91.45       | 3.89                      |
| V <sub>6</sub>  | 86.75     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 92.33     | 58.12      | 37.05                     | 29.97       | 67.54                     |
| V <sub>8</sub>  | 91.82     | 89.58      | 2.44                      | 56.95       | 37.98                     |
| V <sub>9</sub>  | 90.82     | 87.26      | 3.92                      | 27.36       | 69.87                     |
| V <sub>10</sub> | 94.12     | 92.13      | 2.11                      | 90.63       | 3.71                      |
| V <sub>11</sub> | 91.97     | 55.19      | 39.99                     | 0.00        | 100.00                    |
| V <sub>12</sub> | 89.16     | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potrericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.23.2 Effect of salinity level

Water saturation deficit was significantly affected by different salinity levels (Table 4.4.32). The maximum water saturation deficit (20.53%) was recorded from S<sub>2</sub> treatment and the minimum water saturation deficit (8.88%) was recorded from S<sub>1</sub> treatment. The amount of water deficit in plants termed as WSD. Water saturation deficit is the opposite character of relative water content. So, presumably the water saturation deficit was higher for salinity sensitive genotype and vice versa. According to Aldesuquy *et al.* (2012); Rahman *et al.* (2016) decreased relative water content aggravates more water saturation deficit, therefore causing less leaf succulence and more sclerophylly. Due to lack of compartmentalization technique, the salinity sensitive cultivars fail to uptake enough water necessary for running the physiological process smoothly under salt stress condition, thus there will be a huge water deficit occur in sensitive cultivars than the tolerance cultivars. Similar result was reported by Baque *et al.* (2002) but tolerant cultivars might recover this physiological damage and minimize the water saturation deficit under moderate salinity stress. The results of our experiment also in line with the findings of Aldesuquy *et al.* (2012); Muhammad and Majid, (2013); Hasan *et al.* (2017); Hasan *et al.* (2019) who reported that there is a

positive relationship between salinity stress and water saturation deficit i.e. water saturation deficit increases with increasing the salt concentration.

#### 4.4.23.3 Interaction effect of species and salinity level

Water saturation deficit was significantly affected by different varieties and salinity levels (Table 4.4.33). The maximum water saturation deficit (72.64%) was recorded from V<sub>9</sub>S<sub>3</sub> followed by V<sub>7</sub>S<sub>2</sub> (70.03%) and no water saturation deficit value (0.00%) was scored by V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub>.

The water saturation deficit was increased with the increasing of salt concentration. At 50 mM NaCl concentration the maximum increase of water saturation deficit (457.82%) was observed from rice genotype Pokkali (Check variety as salt tolerant) (V<sub>11</sub>) and minimum increase of water saturation deficit (27.38%) was found from wild rice genotype *O. officinalis* (V<sub>8</sub>) while at 100 mM NaCl concentration the maximum increase of water saturation deficit (89.05%) was found from wild rice genotype *O. longistaminata* (V<sub>7</sub>) and minimum increase of water saturation deficit (35.62%) was found from wild rice genotype *O. latifolia* (V<sub>4</sub>) (Table 4.4.35).

**Table 4.4.35 Water saturation deficit of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Increase over control (%) | 100 mM NaCl | Increase over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 11.09     | 44.09      | 297.57                    | 0.00        | -100.00                   |
| V <sub>2</sub>  | 11.73     | 0.00       | -100.00                   | 0.00        | -100.00                   |
| V <sub>3</sub>  | 11.09     | 43.43      | 291.61                    | 0.00        | -100.00                   |
| V <sub>4</sub>  | 4.79      | 6.61       | 38.00                     | 7.44        | 35.62                     |
| V <sub>5</sub>  | 4.85      | 6.32       | 30.31                     | 8.55        | 43.27                     |
| V <sub>6</sub>  | 13.25     | 0.00       | -100.00                   | 0.00        | -100.00                   |
| V <sub>7</sub>  | 7.67      | 41.88      | 446.02                    | 70.03       | 89.05                     |
| V <sub>8</sub>  | 8.18      | 10.42      | 27.38                     | 43.05       | 81.00                     |
| V <sub>9</sub>  | 9.18      | 12.74      | 38.78                     | 72.64       | 87.36                     |
| V <sub>10</sub> | 5.88      | 7.87       | 33.78                     | 9.37        | 37.19                     |
| V <sub>11</sub> | 8.03      | 44.81      | 457.82                    | 0.00        | -100.00                   |
| V <sub>12</sub> | 10.84     | 0.00       | -100.00                   | 0.00        | -100.00                   |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)



#### **4.4.24 Water retention capacity**

##### **4.4.24.1 Effect of species**

Water retention capacity was significantly varied by different rice genotypes (Table 4.4.32). The highest water retention capacity (7.10) was obtained from *O. latifolia* (V<sub>4</sub>) which was closely related with *P. coaractata* (V<sub>5</sub>) (7.06) and the lowest water retention capacity (1.06) was obtained from *O. glaberrima* (V<sub>6</sub>) which was statistically similar with V<sub>2</sub>.

##### **4.4.24.2 Effect of salinity level**

Water retention capacity was significantly varied by different salinity levels (Table 4.4.32). The highest water retention capacity (5.52) was obtained from S<sub>1</sub> treatment and the lowest water retention capacity (1.50) was obtained from S<sub>3</sub>. The ratio of turgid weight to dry weight is termed as water retention capacity (WRC). The capacity of plant cell to retain water is greatly influenced by WRC at a particular stage. WRC is determined by the structure of the cell. Rahman *et al.* (2016) Water stress is one of the first and most obvious effects of salinity and thus the determination of water relations is crucial for understanding salinity tolerance mechanisms of a plant (Netondo *et al.*, 2004). Plant water status is important not only for its growth under favorable environmental conditions, but also for its ability to tolerate water deficit and high salt levels (Blumwald, 2000). Additionally, the importance of the internal water balance in plant water relations is generally accepted because of the close relationship between the balance and turgidity to the rates of physiological processes that control the quality and quantity of growth (Aldesuquy *et al.*, 2009). Under salinity stress condition sensitive cultivars losses their turgidity due to unable to uptake soil water and reduces the water retention capacity. But the tolerance cultivars have the capacity to uptake water under salt stress condition and gained the maximum turgid weight, in consequence they gained the maximum water retention capacity and perform better physiological and biochemical process. The higher reduction in WRC (% to the control) in mungbean than in black gram indicates a greater damage in cell structure due to salinity in mungbean (Islam, 2001; Kabir *et al.*, 2004). The result of our experiment also coincides with the result of Hasan *et al.* (2017); Baque *et al.* (2018); Hasan *et al.* (2019).

#### 4.4.24.3 Interaction effect of species and salinity level

Water retention capacity was significantly varied by different rice genotypes and salinity levels (Table 4.4.33). The highest water retention capacity (9.83) was obtained from V<sub>4</sub>S<sub>1</sub> treatment combination which was closely related with V<sub>5</sub>S<sub>1</sub> (9.35) and the lowest water retention capacity (0.00) was obtained from V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub>.

At 50 mM NaCl concentration the maximum decrease of water retention capacity (74.53%) was observed from wild rice genotype *O. longistaminata* (V<sub>7</sub>) and minimum decrease of water retention capacity (25.05%) was observed from wild rice genotype *Potericia coaractata* (V<sub>5</sub>) while at 100 mM NaCl concentration the maximum decrease of water retention capacity (85.02%) was observed from wild rice genotype *O. punctata* (V<sub>9</sub>) and minimum decrease of water retention capacity (48.50%) was observed from wild rice genotype *Potericia coaractata* (V<sub>5</sub>) (Table 4.4.36).

**Table 4.4.36 Water retention capacity of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 4.22      | 2.04       | 51.66                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 4.02      | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 4.33      | 1.84       | 57.48                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 9.83      | 6.40       | 34.86                     | 5.06        | 48.52                     |
| V <sub>5</sub>  | 9.35      | 7.01       | 25.05                     | 4.82        | 48.50                     |
| V <sub>6</sub>  | 3.19      | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 5.85      | 1.49       | 74.53                     | 2.60        | 55.56                     |
| V <sub>8</sub>  | 3.97      | 2.84       | 28.52                     | 1.47        | 63.00                     |
| V <sub>9</sub>  | 4.87      | 3.38       | 30.58                     | 0.73        | 85.02                     |
| V <sub>10</sub> | 7.15      | 4.33       | 39.44                     | 3.36        | 52.97                     |
| V <sub>11</sub> | 5.19      | 1.75       | 66.26                     | 0.00        | 100.00                    |
| V <sub>12</sub> | 4.24      | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### **4.4.25 Water uptake capacity**

##### **4.4.25.1 Effect of species**

Different rice genotypes exerted significant variation on water uptake capacity of wild rice (Table 4.4.32). *P. coaractata* (V<sub>5</sub>) scored the maximum water uptake capacity (0.367) which was closely connected with *O. latifolia* (V<sub>4</sub>) (0.360) and *O. glaberrima* (V<sub>6</sub>) scored the minimum water uptake capacity (0.098) which was closely connected with BRRI Dhan 29 (V<sub>12</sub>) (0.113).

##### **4.4.25.2 Effect of salinity level**

Different salinity levels exerted significant variation on water uptake capacity of wild rice (Table 4.4.32). S<sub>1</sub> scored the maximum water uptake capacity (0.349) and S<sub>3</sub> scored the minimum water uptake capacity (0.105). The results obtained in our study are in agreement with those studies Sangakkara *et al.* (1996); Kabir *et al.* (2004); Hasan *et al.* (2019) who reported that water uptake capacity (WUC) decreased with increasing salinity in all the treatments.

##### **4.4.25.3 Interaction effect of species and salinity level**

Interaction between wild rice varieties and salinity levels exerted significant difference on water uptake capacity of wild rice (Table 4.4.33). Treatment combination V<sub>4</sub>S<sub>1</sub> scored the maximum water uptake capacity (0.427) which was statistically at par with V<sub>5</sub>S<sub>1</sub> and treatment combinations V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub> scored the minimum water uptake capacity (0.00).

At 50 mM NaCl concentration the maximum decrease of water uptake capacity (67.85%) was observed from wild rice genotype *O. longistaminata* (V<sub>7</sub>) and minimum decrease of water uptake capacity (7.44%) was found from wild rice genotype *Potericia coaractata* (V<sub>5</sub>) while at 100 mM NaCl concentration the maximum decrease of water uptake capacity (79.05%) was found from wild rice genotype *O. punctata* (V<sub>9</sub>) and minimum decrease of water uptake capacity (19.84%) was found from wild rice genotype *Potericia coaractata* (V<sub>5</sub>) (Table 4.4.37).

**Table 4.4.37 Water uptake capacity of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 0.36      | 0.22       | 38.32                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 0.35      | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 0.36      | 0.18       | 50.45                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 0.43      | 0.35       | 17.20                     | 0.30        | 29.69                     |
| V <sub>5</sub>  | 0.40      | 0.37       | 7.44                      | 0.32        | 19.84                     |
| V <sub>6</sub>  | 0.29      | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 0.37      | 0.12       | 67.85                     | 0.23        | 38.39                     |
| V <sub>8</sub>  | 0.24      | 0.16       | 33.33                     | 0.12        | 50.00                     |
| V <sub>9</sub>  | 0.35      | 0.30       | 14.29                     | 0.07        | 79.05                     |
| V <sub>10</sub> | 0.36      | 0.26       | 26.86                     | 0.22        | 39.81                     |
| V <sub>11</sub> | 0.33      | 0.18       | 44.90                     | 0.00        | 100.00                    |
| V <sub>12</sub> | 0.34      | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.26 Plant survival rate

The plant survival rate was investigated under different salt stress condition and wild rice genotypes affected at different extent by salinity stress for plant survival rate (Table 4.4.38). The result revealed that, at 50 mM NaCl concentration the maximum plant survival rate was recorded from *P. coaractata* (V<sub>5</sub>) (99.08%) followed by *O. alta* (V<sub>10</sub>) (84.53%) and *O. latifolia* (V<sub>4</sub>) (81.62%) while *O. barthii* (V<sub>2</sub>), *O. glaberrima* (V<sub>6</sub>) and BRRI Dhan 29 (V<sub>12</sub>) rice genotypes did not survived. At 100 mM NaCl concentration the maximum plant survival rate was recorded from *P. coaractata* (V<sub>5</sub>) (98.55%) followed by *O. alta* (V<sub>10</sub>) (80.67%) and *O. latifolia* (V<sub>4</sub>) (79.75%) whereas *O. rufipogon* (V<sub>1</sub>), *O. barthii* (V<sub>2</sub>), *O. nivara* (V<sub>3</sub>), *O. glaberrima* (V<sub>6</sub>), Pokkali (V<sub>11</sub>) and BRRI Dhan 29 (V<sub>12</sub>) genotypes did not survived.

#### 4.4.27 Phenotypic acceptability (PAcp)

For phenotypic acceptability (PAcp) the lowest mean value is desirable. With the advancement of growth duration and salinity stress the phenotypic acceptability was decreased (Table 4.4.39). At 7 DAT *O. latifolia* (V<sub>4</sub>), *P. coaractata* (V<sub>5</sub>), *O. alta* (V<sub>10</sub>), *O. rufipogon* (V<sub>1</sub>), *O. officinalis* (V<sub>8</sub>) and Pokkali (V<sub>11</sub>) were Excellent; *O. nivara* (V<sub>3</sub>), *O. longistaminata* (V<sub>7</sub>) and *O. punctata* (V<sub>9</sub>) were good and *O. glaberrima* (V<sub>6</sub>), *O. barthii* (V<sub>2</sub>) and BRRI Dhan 29 (V<sub>12</sub>) were fair at 50 mM NaCl

according to Modified Standard Evaluation System. But with the advancement of growth duration the phenotypic acceptability decreased. At 21 DAT *P. coaractata* (V<sub>5</sub>), *O. alta* (V<sub>10</sub>), *O. officinalis* (V<sub>8</sub>), Pokkali (V<sub>11</sub>) and *O. latifolia* (V<sub>4</sub>) were excellent and *O. barthii* (V<sub>2</sub>), *O. glaberrima* (V<sub>6</sub>) and BRRI Dhan 29 (V<sub>12</sub>) were unacceptable at 50 mM NaCl. Similar trend was observed for 100 mM NaCl concentration. Under 100 mM NaCl concentration wild rice genotypes *O. latifolia* (V<sub>4</sub>), *P. coaractata* (V<sub>5</sub>) and *O. alta* (V<sub>10</sub>) consistently performed excellent and *O. rufipogon* (V<sub>1</sub>), *O. nivara* (V<sub>3</sub>), *O. glaberrima* (V<sub>6</sub>), BRRI Dhan 29 (V<sub>12</sub>) and Pokkali (V<sub>11</sub>) were unacceptable according to Modified Standard Evaluation System at 21 DAT.

**Table 4.4.38 Plant survival rate under salinity stress condition**

| Treatments      | Survival rate at 50 mM NaCl (%) | Survival rate at 100 mM NaCl (%) |
|-----------------|---------------------------------|----------------------------------|
| V <sub>1</sub>  | 20.34                           | 0.00                             |
| V <sub>2</sub>  | 0.00                            | 0.00                             |
| V <sub>3</sub>  | 17.41                           | 0.00                             |
| V <sub>4</sub>  | 81.62                           | 79.75                            |
| V <sub>5</sub>  | 99.08                           | 98.55                            |
| V <sub>6</sub>  | 0.00                            | 0.00                             |
| V <sub>7</sub>  | 9.09                            | 13.89                            |
| V <sub>8</sub>  | 29.93                           | 13.31                            |
| V <sub>9</sub>  | 30.45                           | 8.33                             |
| V <sub>10</sub> | 84.53                           | 80.67                            |
| V <sub>11</sub> | 55.60                           | 0.00                             |
| V <sub>12</sub> | 0.00                            | 0.00                             |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potercia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

**Table 4.4.39 Phenotypic acceptability (PAcp) of studied wild rice species of rice with two check varieties at 50 and 100 mM NaCl concentration**

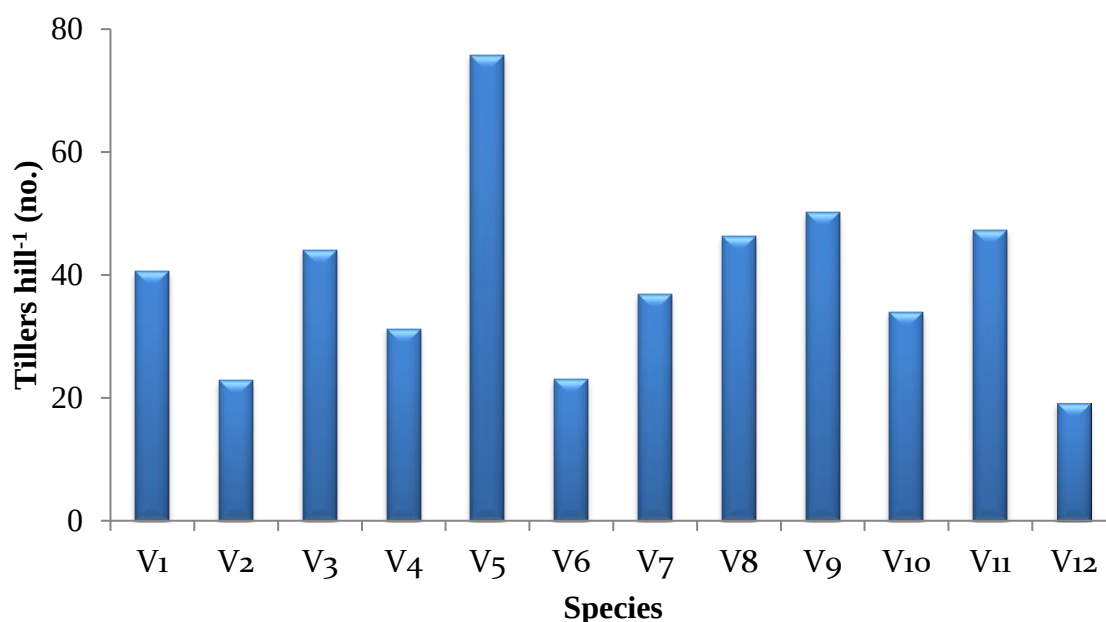
| Treatment       | 50 mM NaCl |        |        | 100 mM NaCl |        |        |
|-----------------|------------|--------|--------|-------------|--------|--------|
|                 | 7 DAT      | 14 DAT | 21 DAT | 7 DAT       | 14 DAT | 21 DAT |
| V <sub>1</sub>  | 1.67       | 5.67   | 5.00   | 5.00        | 9.00   | 9.00   |
| V <sub>2</sub>  | 5.00       | 7.67   | 9.00   | 5.67        | 8.33   | 9.00   |
| V <sub>3</sub>  | 3.00       | 6.33   | 5.67   | 6.33        | 9.00   | 9.00   |
| V <sub>4</sub>  | 1.00       | 2.33   | 2.33   | 2.33        | 1.67   | 2.33   |
| V <sub>5</sub>  | 1.00       | 1.00   | 1.00   | 1.00        | 1.00   | 1.00   |
| V <sub>6</sub>  | 6.33       | 8.33   | 9.00   | 7.00        | 9.00   | 9.00   |
| V <sub>7</sub>  | 4.33       | 8.33   | 7.67   | 4.33        | 6.33   | 7.00   |
| V <sub>8</sub>  | 1.67       | 3.67   | 1.67   | 3.67        | 5.00   | 5.00   |
| V <sub>9</sub>  | 4.33       | 5.67   | 5.00   | 4.33        | 7.67   | 7.67   |
| V <sub>10</sub> | 1.00       | 2.33   | 1.00   | 3.00        | 3.67   | 1.67   |
| V <sub>11</sub> | 1.67       | 3.00   | 2.33   | 5.67        | 7.67   | 9.00   |
| V <sub>12</sub> | 5.67       | 7.67   | 9.00   | 7.00        | 9.00   | 9.00   |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.28 Tillers hill<sup>-1</sup>

##### 4.4.28.1 Effect of species

Tillers hill<sup>-1</sup> for wild rice genotypes are depicted in figure 4.4.1 has shown significant difference among all the wild rice genotypes. The highest tillers hill<sup>-1</sup> (75.78) was obtained from *P. coaractata* (V<sub>5</sub>) and the minimum one (19.11) was obtained from BRRI Dhan 29 (V<sub>12</sub>) (Check variety as salt sensitive). Channa *et al.* (2019) observed better performance in genotypes DR-92, Shua-92 and NIA-19A at moderately salinity (EC <8.00 dS m<sup>-1</sup>) in respect of number of tillers hill<sup>-1</sup> but at higher salinity level (EC 12.8 dS m<sup>-1</sup>) had severe impact on tiller production of rice plant. The findings of our investigation are close confirmation with the findings of Dawit (2010); Hakim *et al.* (2014); Channa *et al.* (2019).

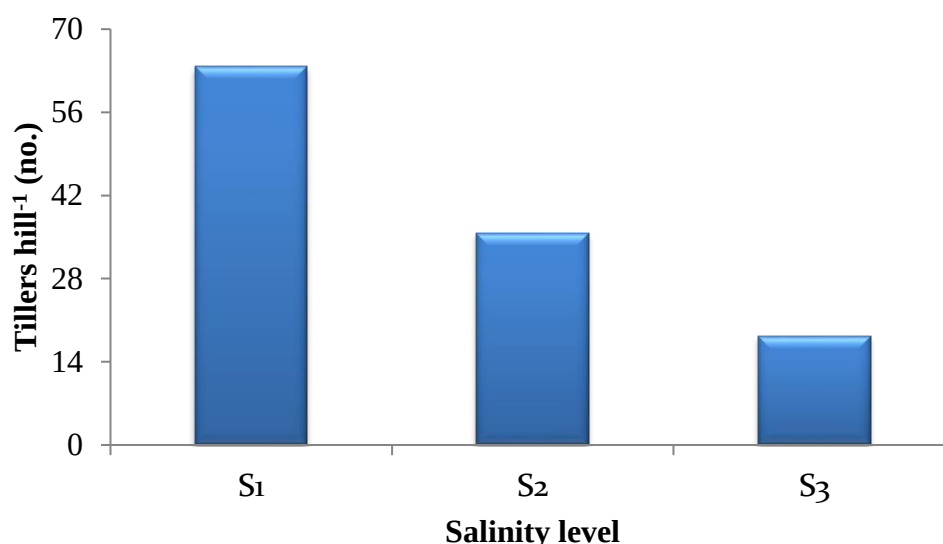


V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

**Figure 4.4.1 Tillers hill<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=3.09)**

#### 4.4.28.2 Effect of salinity level

Tillers hill<sup>-1</sup> for wild rice genotypes are depicted in figure 4.4.2 has shown significant difference among the salinity levels. The highest tillers hill<sup>-1</sup> (63.75) was obtained from S<sub>1</sub> treatment and the lowest one (18.33) was obtained from S<sub>3</sub> treatment. Tillering in plant reveals a valuable evidence of stress on plants in response to detrimental abiotic conditions (Nobuhiro *et al.*, 2005). Zeng *et al.* (2003b); Khanam *et al.* (2018) reported that salinity decreases number of tillers while imposing before panicle emergence. Nicolas *et al.* (1994) found that salt stress during tiller emergence can inhibit their formation and can cause their abortion at later stages consequently reduced the number of tiller hill<sup>-1</sup>. Our findings are close confirmation with the findings of Khanam *et al.* (2018); Channa *et al.* (2019); Malumpong *et al.* (2019) who concluded that the number of tillers hill<sup>-1</sup> decreased with increasing salinity levels.



S<sub>1</sub>= 0 mM NaCl (Control), S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl

**Figure 4.4.2 Effect of salinity level on the tillers hill<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=1.54)**

#### 4.4.28.3 Interaction effect of species and salinity level

Tillers hill<sup>-1</sup> for wild rice genotypes are presented in Table 4.4.40 has shown significant difference among the wild rice varieties and salinity levels. The highest tillers hill<sup>-1</sup> (89.00) was obtained from V<sub>3</sub>S<sub>1</sub> treatment combination and the minimum one (0.00) was obtained from treatment combinations V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub>.

At 50 mM NaCl the maximum decrease of tillers hill<sup>-1</sup> (51.31%) attained by wild rice genotype *O. nivara* (V<sub>3</sub>) and minimum decrease of tillers hill<sup>-1</sup> (2.56%) attained by wild rice genotype *Potericia coaractata* (V<sub>5</sub>) while at 100 mM NaCl the maximum decrease of tillers hill<sup>-1</sup> (73.33%) attained by wild rice genotype *O. punctata* (V<sub>9</sub>) and minimum decrease of tillers hill<sup>-1</sup> (5.99%) attained by wild rice genotype *Potericia coaractata* (V<sub>5</sub>) (Table 4.4.41).



**Table 4.4.40 Interaction effect of species and salinity level on the morphological characteristics of wild rice**

| Treatments                     | Tillers hill <sup>-1</sup><br>(no.) | Effective tillers<br>hill <sup>-1</sup> (no.) | Non-effective tillers<br>hill <sup>-1</sup> (no.) | Panicle length<br>(cm) |
|--------------------------------|-------------------------------------|-----------------------------------------------|---------------------------------------------------|------------------------|
| V <sub>1</sub> S <sub>1</sub>  | 76.00 b                             | 52.00 c                                       | 24.00 bc                                          | 22.20 l                |
| V <sub>1</sub> S <sub>2</sub>  | 45.67 gh                            | 28.33 g                                       | 17.33 g                                           | 10.30 p                |
| V <sub>1</sub> S <sub>3</sub>  | 0.00 l                              | 0.00 l                                        | 0.00 p                                            | 0.00 r                 |
| V <sub>2</sub> S <sub>1</sub>  | 68.33 c                             | 53.33 c                                       | 15.00 h                                           | 28.63 f-h              |
| V <sub>2</sub> S <sub>2</sub>  | 0.00 l                              | 0.00 l                                        | 0.00 p                                            | 0.00 r                 |
| V <sub>2</sub> S <sub>3</sub>  | 0.00 l                              | 0.00 l                                        | 0.00 p                                            | 0.00 r                 |
| V <sub>3</sub> S <sub>1</sub>  | 89.00 a                             | 67.33 a                                       | 21.67 de                                          | 23.50 kl               |
| V <sub>3</sub> S <sub>2</sub>  | 43.33 h                             | 32.00 fg                                      | 11.33 kl                                          | 14.17 o                |
| V <sub>3</sub> S <sub>3</sub>  | 0.00 l                              | 0.00 l                                        | 0.00 p                                            | 0.00 r                 |
| V <sub>4</sub> S <sub>1</sub>  | 34.00 ij                            | 18.67 hi                                      | 15.33 h                                           | 49.37 a                |
| V <sub>4</sub> S <sub>2</sub>  | 30.67 j                             | 17.00 i                                       | 13.00 i-k                                         | 47.03 b                |
| V <sub>4</sub> S <sub>3</sub>  | 29.00 j                             | 16.00 ij                                      | 13.00 i-k                                         | 43.13 c                |
| V <sub>5</sub> S <sub>1</sub>  | 78.00 b                             | 52.33 c                                       | 25.67 b                                           | 17.47 m                |
| V <sub>5</sub> S <sub>2</sub>  | 76.00 b                             | 51.33 c                                       | 24.67 bc                                          | 16.27 mn               |
| V <sub>5</sub> S <sub>3</sub>  | 73.33 bc                            | 50.00 c                                       | 23.33 cd                                          | 14.80 no               |
| V <sub>6</sub> S <sub>1</sub>  | 69.33 c                             | 59.00 b                                       | 15.33 h                                           | 23.60 kl               |
| V <sub>6</sub> S <sub>2</sub>  | 0.00 l                              | 0.00 l                                        | 0.00 p                                            | 0.00 r                 |
| V <sub>6</sub> S <sub>3</sub>  | 0.00 l                              | 0.00 l                                        | 0.00 p                                            | 0.00 r                 |
| V <sub>7</sub> S <sub>1</sub>  | 58.00 de                            | 33.33 f                                       | 24.67 bc                                          | 26.47 ij               |
| V <sub>7</sub> S <sub>2</sub>  | 18.00 k                             | 10.00 k                                       | 7.67 no                                           | 8.07 q                 |
| V <sub>7</sub> S <sub>3</sub>  | 34.33 ij                            | 19.67 hi                                      | 14.67 hi                                          | 15.13 no               |
| V <sub>8</sub> S <sub>1</sub>  | 54.67 ef                            | 33.67 f                                       | 21.00 ef                                          | 29.98 ef               |
| V <sub>8</sub> S <sub>2</sub>  | 51.00 fg                            | 31.67 fg                                      | 19.33 f                                           | 27.27 g-i              |
| V <sub>8</sub> S <sub>3</sub>  | 33.33 ij                            | 18.67 hi                                      | 12.00 k                                           | 17.30 m                |
| V <sub>9</sub> S <sub>1</sub>  | 70.00 c                             | 42.33 de                                      | 27.67 a                                           | 29.07 e-g              |
| V <sub>9</sub> S <sub>2</sub>  | 61.67 d                             | 40.67 e                                       | 21.33 e                                           | 26.27 ij               |
| V <sub>9</sub> S <sub>3</sub>  | 18.67 k                             | 12.00 jk                                      | 6.67 o                                            | 8.07 q                 |
| V <sub>10</sub> S <sub>1</sub> | 37.00 i                             | 21.67 h                                       | 15.33 h                                           | 32.50 d                |
| V <sub>10</sub> S <sub>2</sub> | 33.67 ij                            | 19.67 hi                                      | 14.00 h-j                                         | 29.67 ef               |
| V <sub>10</sub> S <sub>3</sub> | 31.33 j                             | 19.00 hi                                      | 12.33 jk                                          | 26.93 h-j              |
| V <sub>11</sub> S <sub>1</sub> | 73.33 bc                            | 63.33 ab                                      | 10.00 lm                                          | 26.47 ij               |
| V <sub>11</sub> S <sub>2</sub> | 68.67 c                             | 59.33 b                                       | 9.33 mn                                           | 25.13 jk               |
| V <sub>11</sub> S <sub>3</sub> | 0.00 l                              | 0.00 l                                        | 0.00 p                                            | 0.00 r                 |
| V <sub>12</sub> S <sub>1</sub> | 57.33 de                            | 45.33 d                                       | 12.00 k                                           | 30.60 e                |
| V <sub>12</sub> S <sub>2</sub> | 0.00 l                              | 0.00 l                                        | 0.00 p                                            | 0.00 r                 |
| V <sub>12</sub> S <sub>3</sub> | 0.00 l                              | 0.00 l                                        | 0.00 p                                            | 0.00 r                 |
| <b>LSD (0.05)</b>              | <b>5.35</b>                         | <b>4.55</b>                                   | <b>1.70</b>                                       | <b>1.83</b>            |
| <b>CV (%)</b>                  | <b>8.37</b>                         | <b>10.39</b>                                  | <b>8.38</b>                                       | <b>6.06</b>            |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive); S<sub>1</sub>= 0 mM NaCl (Control), S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl

**Table 4.4.41 Tillers hill<sup>-1</sup> of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 76.00     | 45.67      | 39.91                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 68.33     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 89.00     | 43.33      | 51.31                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 34.00     | 30.67      | 9.79                      | 29.00       | 14.71                     |
| V <sub>5</sub>  | 78.00     | 76.00      | 2.56                      | 73.33       | 5.99                      |
| V <sub>6</sub>  | 69.33     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 58.00     | 34.33      | 40.81                     | 18.00       | 68.97                     |
| V <sub>8</sub>  | 54.67     | 51.00      | 6.71                      | 33.33       | 39.03                     |
| V <sub>9</sub>  | 70.00     | 61.67      | 11.90                     | 18.67       | 73.33                     |
| V <sub>10</sub> | 37.00     | 33.67      | 9.00                      | 31.33       | 15.32                     |
| V <sub>11</sub> | 73.33     | 68.67      | 6.35                      | 0.00        | 100.00                    |
| V <sub>12</sub> | 57.33     | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.29 Effective tillers hill<sup>-1</sup>

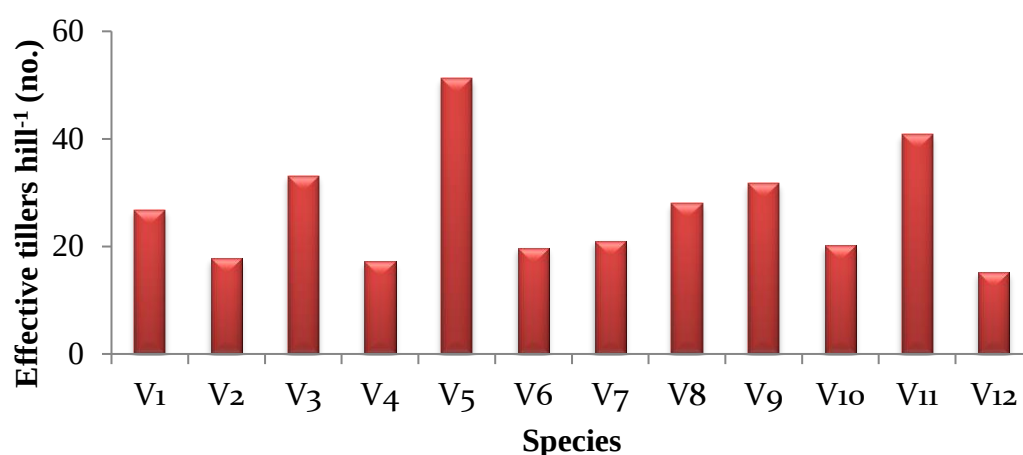
##### 4.4.29.1 Effect of species

Data on effective tillers hill<sup>-1</sup> for wild rice genotypes are depicted in figure 4.4.3. A significant variation was observed in effective tillers hill<sup>-1</sup> among the wild rice genotypes. The maximum effective tillers hill<sup>-1</sup> (51.22) was produced by *P. coaractata* (V<sub>5</sub>) and the minimum effective tillers hill<sup>-1</sup> (15.11) was produced by BRRI Dhan 29 (V<sub>12</sub>) (Check variety as salt sensitive) followed by *O. latifolia* (V<sub>4</sub>) (17.22). *P. coaractata* produced 238.98% more effective tillers hill<sup>-1</sup> than check variety BRRI Dhan 29. Similar findings were also reported by Dawit (2010); Hakim *et al.* (2014); Channa *et al.* (2019) who reported that the number of effective tillers hill<sup>-1</sup> varied with the variation of rice genotypes.

##### 4.4.29.2 Effect of salinity level

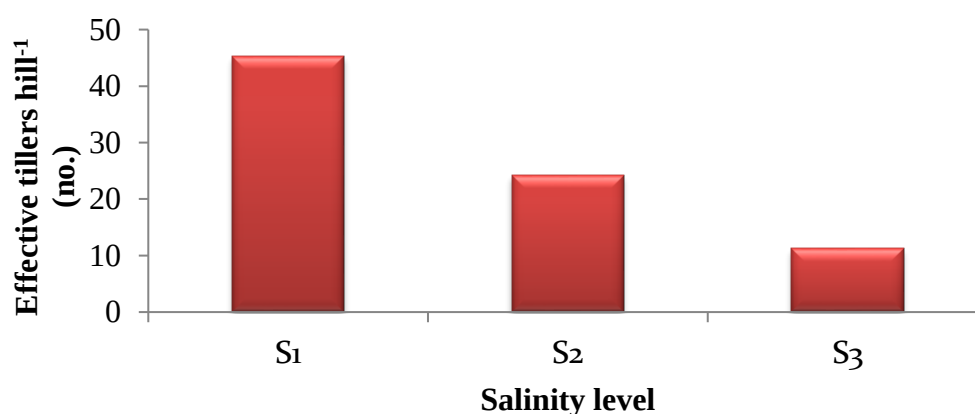
Data on effective tillers hill<sup>-1</sup> for salinity level are depicted in figure 4.4.4. A significant variation was observed in effective tillers hill<sup>-1</sup> among the salinity levels. There was a stiff reduction of effective tillers hill<sup>-1</sup> was observed with the increasing of salt concentration. The maximum effective tillers hill<sup>-1</sup> (45.19) was produced by S<sub>1</sub> treatment and the minimum effective tillers hill<sup>-1</sup> (11.28) was produced by S<sub>3</sub>

treatment. Control treatment ( $S_1$ ) produced 300.62% more effective tillers hill<sup>-1</sup> than 100 mM NaCl ( $S_3$ ). Results obtained from the study of Kamal *et al.* (2015); Khanam *et al.* (2018) showed that salinity-induced reduction in the panicle number per plant was mainly attributed to that in the effective tillers hill<sup>-1</sup>. This results of our study also supported by Hasamuzzaman *et al.* (2009); Farshid and Hassan (2012); Hussain *et al.* (2017) who revealed that the effective tillers hill<sup>-1</sup> reduced with the increase of salinity level.



V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant)and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

**Figure 4.4.3 Effective tillers hill<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=2.63)**



S<sub>1</sub>= 0 mM NaCl (Control), S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl

**Figure 4.4.4 Effect of salinity level on the effective tillers hill<sup>-1</sup> of wild species rice (LSD<sub>0.05</sub>=1.31)**

#### 4.4.29.3 Interaction effect of species and salinity level

Data on effective tillers hill<sup>-1</sup> for the interaction of wild rice varieties and salinity level are presented in Table 4.4.40. A significant variation was observed in effective tillers hill<sup>-1</sup> among the wild rice varieties and salinity levels. The maximum effective tillers hill<sup>-1</sup> (67.33) was produced by the interaction of V<sub>3</sub>S<sub>1</sub> which was statistically at par with V<sub>11</sub>S<sub>1</sub>. On the other hand effective tillers hill<sup>-1</sup> values (0.00) was found for V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub> interactions.

At 50 mM NaCl the maximum decrease of effective tillers hill<sup>-1</sup> (52.47%) attained by wild rice genotype *O. nivara* (V<sub>3</sub>) and minimum decrease of effective tillers hill<sup>-1</sup> (1.91%) attained by wild rice genotype *Potericia coaractata* (V<sub>5</sub>) whereas at 100 mM NaCl the maximum decrease of effective tillers hill<sup>-1</sup> (71.65%) attained by wild rice genotype *O. punctata* (V<sub>9</sub>) and minimum decrease of effective tillers hill<sup>-1</sup> (4.45%) attained by wild rice genotype *Potericia coaractata* (V<sub>5</sub>) (Table 4.4.42).

**Table 4.4.42 Effective tillers hill<sup>-1</sup> of wild species of rice as influenced by salinity stress**

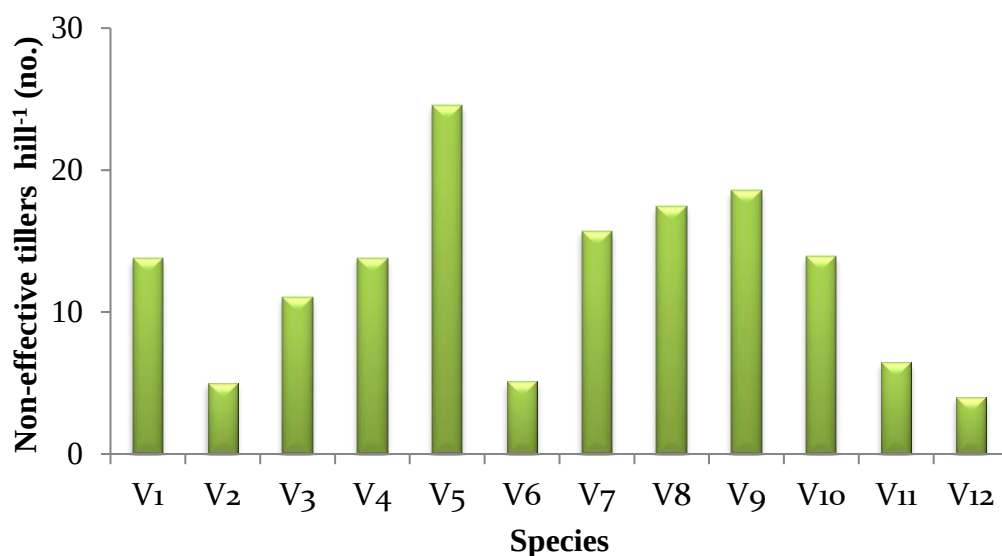
| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 52.00     | 28.33      | 45.52                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 53.33     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 67.33     | 32.00      | 52.47                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 18.67     | 17.00      | 8.94                      | 16.00       | 14.30                     |
| V <sub>5</sub>  | 52.33     | 51.33      | 1.91                      | 50.00       | 4.45                      |
| V <sub>6</sub>  | 59.00     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 33.33     | 19.67      | 40.98                     | 10.00       | 70.00                     |
| V <sub>8</sub>  | 33.67     | 31.67      | 5.94                      | 18.67       | 44.55                     |
| V <sub>9</sub>  | 42.33     | 40.67      | 3.92                      | 12.00       | 71.65                     |
| V <sub>10</sub> | 21.67     | 19.67      | 9.23                      | 19.00       | 12.32                     |
| V <sub>11</sub> | 63.33     | 59.33      | 6.32                      | 0.00        | 100.00                    |
| V <sub>12</sub> | 45.33     | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.30 Non-effective tillers hill<sup>-1</sup>

##### 4.4.30.1 Effect of species

Significant difference among the genotypes was found for non-effective tillers hill<sup>-1</sup> (Figure 4.4.5). Result showed that the maximum non-effective tillers hill<sup>-1</sup> (24.56) was found from *P. coaractata* (V<sub>5</sub>) and the minimum non-effective tillers hill<sup>-1</sup> (4.00) was found from BRRI Dhan 29 (V<sub>12</sub>) (Check variety as salt sensitive).

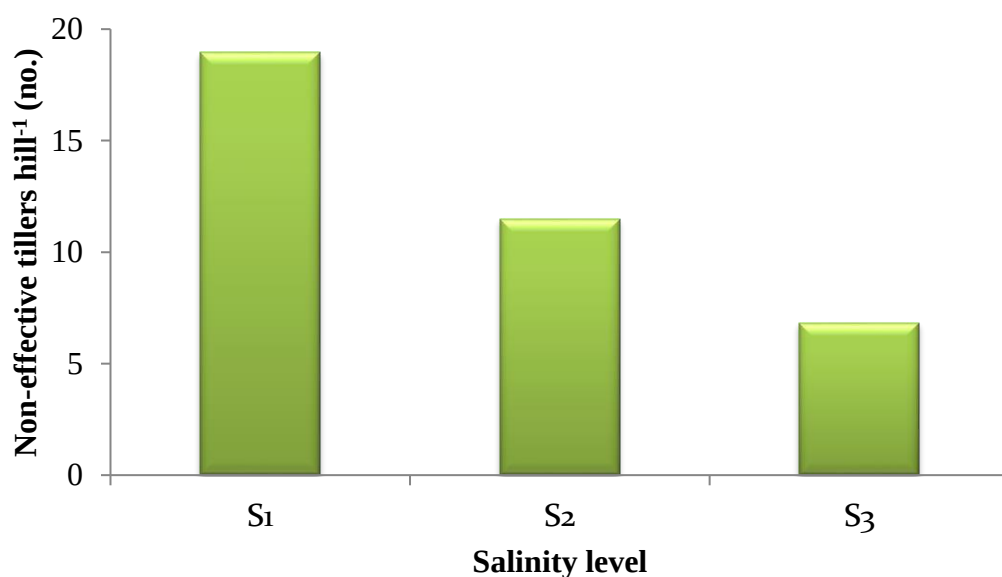


V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

**Figure 4.4.5 Non-effective tillers hill<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=0.98)**

##### 4.4.30.2 Effect of salinity level

Significant difference among the salinity levels was found for non-effective tillers hill<sup>-1</sup> (Figure 4.4.6). Result showed that the maximum non-effective tillers hill<sup>-1</sup> (18.97) was found from S<sub>1</sub> treatment and the minimum non-effective tillers hill<sup>-1</sup> (6.83) was found from S<sub>3</sub> treatment. In some rice cultivars, salt stress caused panicle sterility (non-effective tiller), especially at pollination and fertilization stages due to some genetic mechanisms resulting from salinity effect (Khatun and Flowers, 1995; Hasamuzzaman *et al.* 2009). The results of our experiment are supported by Flowers and Yeo (1981); Hussain *et al.* (2017) who reported that the non-effective tillers hill<sup>-1</sup> were increased with the increasing the salinity levels.



S<sub>1</sub>= 0 mM NaCl (Control), S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl

**Figure 4.4.6 Effect of salinity level on the non-effective tillers hill<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=0.49)**

#### 4.4.30.3 Interaction effect of species and salinity level

Significant difference among the varieties and salinity levels was found for non-effective tillers hill<sup>-1</sup> (Table 4.4.40). Result showed that the maximum non-effective tillers hill<sup>-1</sup> (27.67) was found from V<sub>9</sub>S<sub>1</sub> and the minimum non-effective tillers hill<sup>-1</sup> (0.00) was found from V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub> interactions.

At 50 mM NaCl the maximum decrease of non-effective tillers hill<sup>-1</sup>(47.72%) attained by wild rice genotype *O. nivara* (V<sub>3</sub>) and minimum decrease of non-effective tillers hill<sup>-1</sup>(3.90%) attained by wild rice genotype *Potericia coaractata* (V<sub>5</sub>) whereas at 100 mM NaCl the maximum decrease of non-effective tillers hill<sup>-1</sup>(75.89%) attained by wild rice genotype *O. punctata* (V<sub>9</sub>)and minimum decrease of non-effective tillers hill<sup>-1</sup>(9.12%) attained by wild rice genotype *Potericia coaractata* (V<sub>5</sub>) (Table 4.4.43).

#### 4.4.31 Panicle length

##### 4.4.31.1 Effect of species

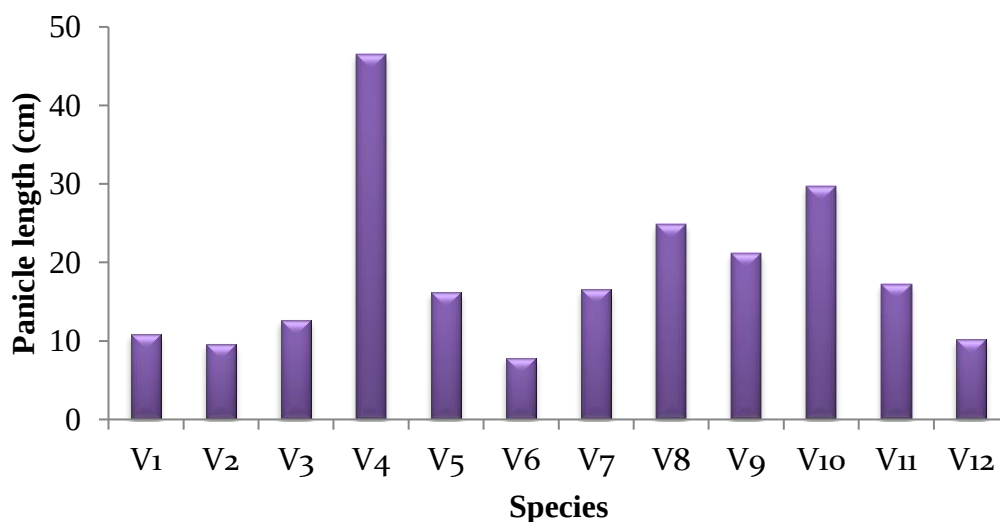
Data showed significant differences for panicle length among the wild rice genotypes (Figure 4.4.7). The results showed that the longest panicle (46.51 cm) was achieved

from *O. latifolia* (V<sub>4</sub>) and the shortest panicle (7.87 cm) was achieved from *O. glaberrima* (V<sub>6</sub>).

**Table 4.4.43 Non-effective tillers hill<sup>-1</sup> of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 24.00     | 17.33      | 27.79                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 15.00     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 21.67     | 11.33      | 47.72                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 15.33     | 13.00      | 15.20                     | 13.00       | 15.20                     |
| V <sub>5</sub>  | 25.67     | 24.67      | 3.90                      | 23.33       | 9.12                      |
| V <sub>6</sub>  | 15.33     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 24.67     | 14.67      | 40.54                     | 7.67        | 68.91                     |
| V <sub>8</sub>  | 21.00     | 19.33      | 7.95                      | 12.00       | 42.86                     |
| V <sub>9</sub>  | 27.67     | 21.33      | 22.91                     | 6.67        | 75.89                     |
| V <sub>10</sub> | 15.33     | 14.00      | 8.68                      | 12.33       | 19.57                     |
| V <sub>11</sub> | 10.00     | 9.33       | 6.67                      | 0.00        | 100.00                    |
| V <sub>12</sub> | 12.00     | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

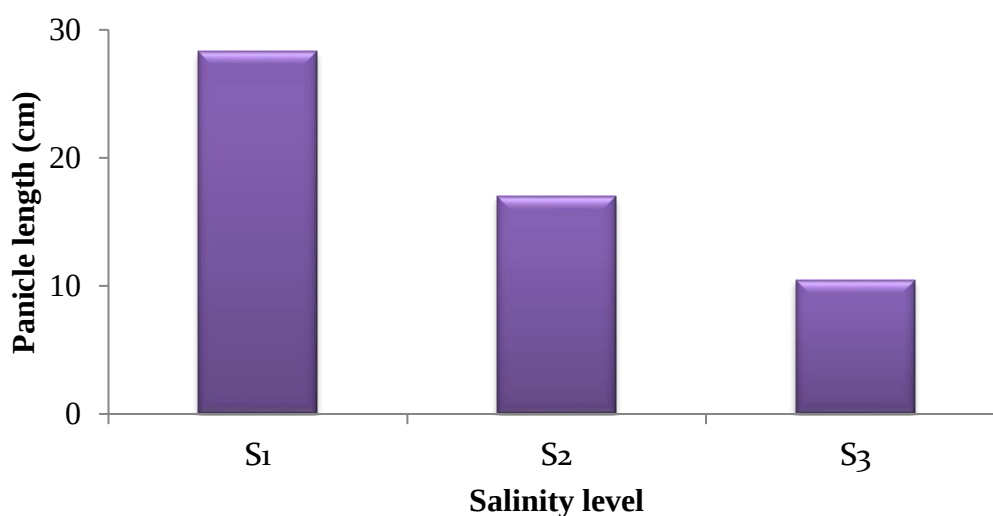


V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

**Figure 4.4.7 Panicle length of wild species of rice (LSD<sub>0.05</sub>=1.06)**

#### 4.4.31.2 Effect of salinity level

Data showed significant differences for panicle length among the salinity levels (Figure 4.4.8). The panicle length inversely related with salt concentration *ie* increasing the saline concentration decreasing the value of panicle length was observed. The results showed that the longest panicle (28.32 cm) was achieved from S<sub>1</sub> treatment and the shortest panicle (10.45 cm) was achieved from S<sub>3</sub> treatment. Salinity stress affected panicle development at panicle initiation (PI). Then salinity in these stages could be affected panicle development and finally caused to reduce the panicle length (Cheabu *et al.*, 2019). Hasamuzzaman *et al.* (2009) reported that the shorter panicle length in high salinity can be due to lower accumulation of photosynthates to the reproductive parts. When the plants are continuously exposed to saline media, salinity affects the panicle initiation. Similar results are earlier reported by Farshid and Hassan (2012); Hussain *et al.* (2017); Malumpong *et al.* (2019) who reported that panicle length is significantly reduced by salinity.



S<sub>1</sub>= 0 mM NaCl (Control), S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl

**Figure 4.4.8 Effect of salinity level on the panicle length of wild species of rice (LSD<sub>0.05</sub>=0.53)**

#### 4.4.31.3 Interaction effect of species and salinity level

Data showed significant differences for panicle length among the wild rice genotypes and salinity levels (Table 4.4.40). The results showed that the longest panicle (49.37 cm) was achieved from V<sub>4</sub>S<sub>1</sub> treatment combination and the shortest panicle (0.00 cm)



was achieved from V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub> interactions.

At 50 mM NaCl the maximum decrease of panicle length (53.60%) was observed from wild rice genotype *O. rufipogon* (V<sub>1</sub>) and minimum decrease of panicle length (4.74%) was observed from wild rice genotype *O. latifolia* (V<sub>4</sub>) whereas at 100 mM NaCl the maximum decrease of panicle length (72.24%) was observed from wild rice genotype *O. punctata* (V<sub>9</sub>) and minimum decrease of panicle length (12.64%) was observed from wild rice genotype *O. latifolia* (V<sub>4</sub>) (Table 4.4.44).

**Table 4.4.44 Panicle length of wild species of rice as influenced by salinity stress**

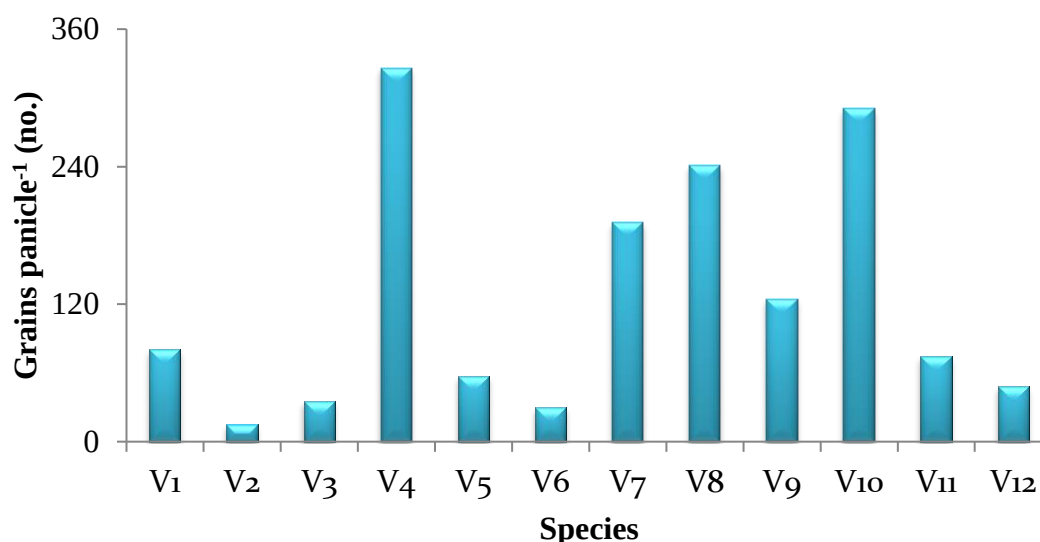
| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 22.20     | 10.30      | 53.60                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 28.63     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 23.50     | 14.17      | 39.70                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 49.37     | 47.03      | 4.74                      | 43.13       | 12.64                     |
| V <sub>5</sub>  | 17.47     | 16.27      | 6.87                      | 14.80       | 15.28                     |
| V <sub>6</sub>  | 23.60     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 26.47     | 15.13      | 42.84                     | 8.07        | 69.51                     |
| V <sub>8</sub>  | 29.98     | 27.27      | 9.04                      | 17.30       | 42.29                     |
| V <sub>9</sub>  | 29.07     | 26.27      | 9.63                      | 8.07        | 72.24                     |
| V <sub>10</sub> | 32.50     | 29.67      | 8.71                      | 26.93       | 17.14                     |
| V <sub>11</sub> | 26.47     | 25.13      | 5.06                      | 0.00        | 100.00                    |
| V <sub>12</sub> | 30.60     | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potrericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.32 Grains panicle<sup>-1</sup>

##### 4.4.32.1 Effect of species

Grains panicle<sup>-1</sup> varied significantly among the wild rice genotypes (Figure 4.4.9). The maximum grains panicle<sup>-1</sup> (326.20) was produced by *O. latifolia* (V<sub>4</sub>) and the minimum grains panicle<sup>-1</sup> (29.78) was produced by *O. glaberrima* (V<sub>6</sub>). The production of grains is depends on the genetic potentiality of a genotypes and it was varied with genotypic variation of wild rice.



V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

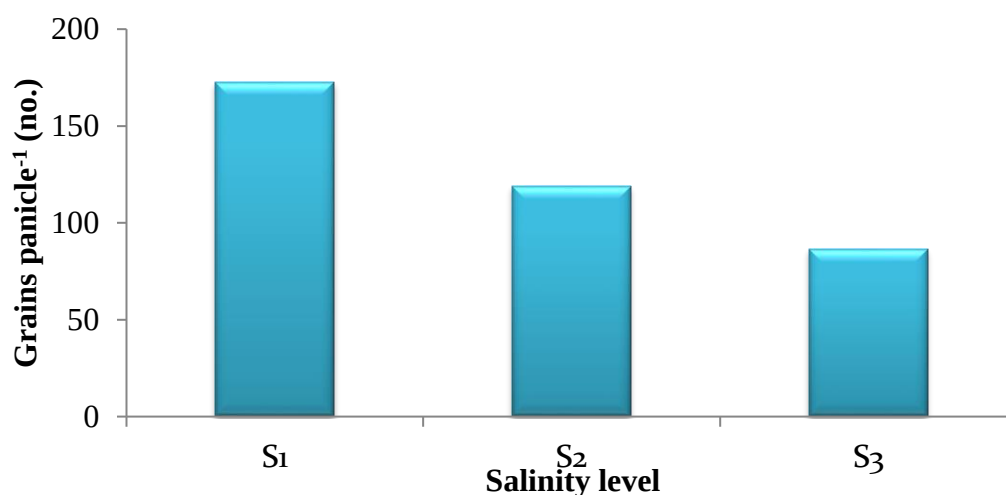
**Figure 4.4.9 Grains panicle<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=4.84)**

#### 4.4.32.2 Effect of salinity level

Grains panicle<sup>-1</sup> varied significantly among the salinity levels (Figure 4.4.10). The maximum grains panicle<sup>-1</sup> (172.70) was produced by S<sub>1</sub> and the minimum grains panicle<sup>-1</sup> (86.58) was produced by S<sub>3</sub>. When plant goes under salinity stress condition it retards the grain formation and development process and ultimately produce lower grains per panicle. Similar findings are also reported by Hussain *et al.* (2017); Khanam *et al.* (2018); Channa *et al.* (2019); Malumpong *et al.* (2019) who reported that salinity stress has detrimental effect on grain formation of rice and reduces the grains panicle<sup>-1</sup>.

#### 4.4.32.3 Interaction effect of species and salinity level

Grains panicle<sup>-1</sup> varied significantly among the rice genotypes and salinity levels (Table 4.4.45). The maximum grains panicle<sup>-1</sup> (345.70) was produced by V<sub>4</sub>S<sub>1</sub> followed by V<sub>4</sub>S<sub>2</sub> (322.30) and treatment combinations V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub> did not produce any grain.



S<sub>1</sub>= 0 mM NaCl (Control), S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl

**Figure 4.4.10 Effect of salinity level on the grains panicle<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=2.42)**

At 50 mM NaCl the maximum decrease of grains panicle<sup>-1</sup> (38.28%) was observed from wild rice genotype *O. longistaminata* (V<sub>7</sub>) and minimum decrease of grains panicle<sup>-1</sup> (3.77%) was observed from Pokkali (Check variety as salt tolerant) (V<sub>11</sub>) whereas at 100 mM NaCl the maximum decrease of grains panicle<sup>-1</sup> (68.83%) was observed from wild rice genotype *O. punctata* (V<sub>9</sub>) and minimum decrease of grains panicle<sup>-1</sup> (8.68%) was observed from wild rice genotype *O. alta* (V<sub>10</sub>) (Table 4.4.46).

#### 4.4.33 Filled grains panicle<sup>-1</sup>

##### 4.4.33.1 Effect of species

There was significant variation among the genotypes for the filled grains panicle<sup>-1</sup> (Figure 4.4.11). The maximum filled grains panicle<sup>-1</sup> (134.60) was recorded from *O. officinalis* (V<sub>8</sub>) and the minimum filled grains panicle<sup>-1</sup> (11.33) was recorded from *O. barthii* (V<sub>2</sub>). *O. officinalis* produced 1088.00% more filled grain than *O. barthii*. Our findings are close confirmation with the findings of Channa *et al.* (2019) who revealed that the genotypes Shua-92, DR-92 and DR-51 had better results with an average less than 15% reduction in number filled gains panicle<sup>-1</sup> in rice.

**Table 4.4.45 Interaction effect of species and salinity level on the yield contributing characteristics of wild rice**

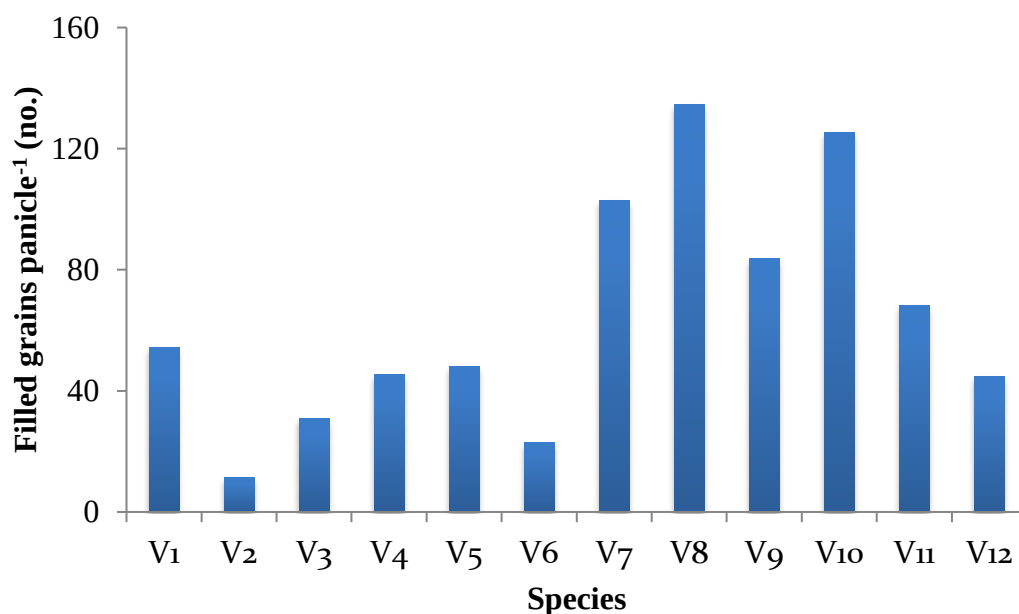
| Treatments                     | Grains<br>panicle <sup>-1</sup> (no.) | Filled grains<br>panicle <sup>-1</sup> (no.) | Unfilled grains<br>panicle <sup>-1</sup> (no.) | Thousand<br>grain weight (g) |
|--------------------------------|---------------------------------------|----------------------------------------------|------------------------------------------------|------------------------------|
| V <sub>1</sub> S <sub>1</sub>  | 148.30 i                              | 101.70 fg                                    | 46.67 l                                        | 24.22 d                      |
| V <sub>1</sub> S <sub>2</sub>  | 92.00 k                               | 61.00 j                                      | 26.63 m                                        | 16.08 f                      |
| V <sub>1</sub> S <sub>3</sub>  | 0.00 q                                | 0.00 r                                       | 0.00 q                                         | 0.00 l                       |
| V <sub>2</sub> S <sub>1</sub>  | 44.33 op                              | 34.00 q                                      | 10.33 o                                        | 33.35 a                      |
| V <sub>2</sub> S <sub>2</sub>  | 0.00 q                                | 0.00 r                                       | 0.00 q                                         | 0.00 l                       |
| V <sub>2</sub> S <sub>3</sub>  | 0.00 q                                | 0.00 r                                       | 0.00 q                                         | 0.00 l                       |
| V <sub>3</sub> S <sub>1</sub>  | 63.00 l                               | 54.67 k                                      | 8.33 op                                        | 28.98 b                      |
| V <sub>3</sub> S <sub>2</sub>  | 42.67 p                               | 38.33 pq                                     | 4.33 pq                                        | 17.49 f                      |
| V <sub>3</sub> S <sub>3</sub>  | 0.00 q                                | 0.00 r                                       | 0.00 q                                         | 0.00 l                       |
| V <sub>4</sub> S <sub>1</sub>  | 345.70 a                              | 53.33 k                                      | 292.30 a                                       | 11.26 h                      |
| V <sub>4</sub> S <sub>2</sub>  | 322.30 b                              | 42.33 n-p                                    | 280.00 b                                       | 11.26 h                      |
| V <sub>4</sub> S <sub>3</sub>  | 310.70 c                              | 40.67 op                                     | 270.00 c                                       | 11.20 h                      |
| V <sub>5</sub> S <sub>1</sub>  | 61.00 lm                              | 51.67 kl                                     | 9.33 o                                         | 13.29 g                      |
| V <sub>5</sub> S <sub>2</sub>  | 55.67 l-n                             | 46.67 l-n                                    | 9.00 op                                        | 13.22 g                      |
| V <sub>5</sub> S <sub>3</sub>  | 54.33 mn                              | 45.67 m-o                                    | 8.67 op                                        | 13.12 g                      |
| V <sub>6</sub> S <sub>1</sub>  | 89.33 k                               | 69.00 i                                      | 20.33 n                                        | 20.17 e                      |
| V <sub>6</sub> S <sub>2</sub>  | 0.00 q                                | 0.00 r                                       | 0.00 q                                         | 0.00 l                       |
| V <sub>6</sub> S <sub>3</sub>  | 0.00 q                                | 0.00 r                                       | 0.00 q                                         | 0.00 l                       |
| V <sub>7</sub> S <sub>1</sub>  | 297.00 d                              | 158.30 ab                                    | 138.70 f                                       | 8.90 i                       |
| V <sub>7</sub> S <sub>2</sub>  | 94.33 k                               | 50.67 k-m                                    | 43.67 l                                        | 2.94 k                       |
| V <sub>7</sub> S <sub>3</sub>  | 183.30 g                              | 99.67 g                                      | 84.17 i                                        | 5.71 j                       |
| V <sub>8</sub> S <sub>1</sub>  | 294.30 d                              | 163.00 a                                     | 131.30 g                                       | 8.15 i                       |
| V <sub>8</sub> S <sub>2</sub>  | 269.70 f                              | 153.70 b                                     | 116.00 h                                       | 8.13 i                       |
| V <sub>8</sub> S <sub>3</sub>  | 159.70 h                              | 87.00 h                                      | 72.67 j                                        | 5.42 j                       |
| V <sub>9</sub> S <sub>1</sub>  | 164.70 h                              | 110.30 e                                     | 54.33 k                                        | 8.47 i                       |
| V <sub>9</sub> S <sub>2</sub>  | 157.70 h                              | 105.70 ef                                    | 52.00 k                                        | 8.31 i                       |
| V <sub>9</sub> S <sub>3</sub>  | 51.33 no                              | 34.67 q                                      | 16.67 n                                        | 2.75 k                       |
| V <sub>10</sub> S <sub>1</sub> | 306.30 c                              | 131.30 c                                     | 175.00 d                                       | 8.12 i                       |
| V <sub>10</sub> S <sub>2</sub> | 285.70 e                              | 123.00 d                                     | 162.70 e                                       | 8.11 i                       |
| V <sub>10</sub> S <sub>3</sub> | 279.70 e                              | 121.30 d                                     | 158.30 e                                       | 8.10 i                       |
| V <sub>11</sub> S <sub>1</sub> | 114.00 j                              | 104.00 fg                                    | 10.00 o                                        | 27.08 c                      |
| V <sub>11</sub> S <sub>2</sub> | 109.70 j                              | 100.70 fg                                    | 9.00 op                                        | 27.09 c                      |
| V <sub>11</sub> S <sub>3</sub> | 0.00 q                                | 0.00 r                                       | 0.00 q                                         | 0.00 l                       |
| V <sub>12</sub> S <sub>1</sub> | 144.70 i                              | 134.70 c                                     | 10.00 o                                        | 22.50 d                      |
| V <sub>12</sub> S <sub>2</sub> | 0.00 q                                | 0.00 r                                       | 0.00 q                                         | 0.00 l                       |
| V <sub>12</sub> S <sub>3</sub> | 0.00 q                                | 0.00 r                                       | 0.00 q                                         | 0.00 l                       |
| <b>LSD<sub>(0.05)</sub></b>    | <b>8.38</b>                           | <b>5.86</b>                                  | <b>4.84</b>                                    | <b>1.76</b>                  |
| <b>CV (%)</b>                  | <b>4.08</b>                           | <b>5.59</b>                                  | <b>4.82</b>                                    | <b>10.39</b>                 |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive); S<sub>1</sub>= 0 mM NaCl (Control), S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl

**Table 4.4.46 Grains panicle<sup>-1</sup> of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 148.30    | 92.00      | 37.96                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 44.33     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 63.00     | 42.67      | 32.27                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 345.70    | 322.30     | 6.77                      | 310.70      | 10.12                     |
| V <sub>5</sub>  | 61.00     | 55.67      | 8.74                      | 54.33       | 10.93                     |
| V <sub>6</sub>  | 89.33     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 297.00    | 183.30     | 38.28                     | 94.33       | 68.24                     |
| V <sub>8</sub>  | 294.30    | 269.70     | 8.36                      | 159.70      | 45.74                     |
| V <sub>9</sub>  | 164.70    | 157.70     | 4.25                      | 51.33       | 68.83                     |
| V <sub>10</sub> | 306.30    | 285.70     | 6.73                      | 279.70      | 8.68                      |
| V <sub>11</sub> | 114.00    | 109.70     | 3.77                      | 0.00        | 100.00                    |
| V <sub>12</sub> | 144.70    | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)



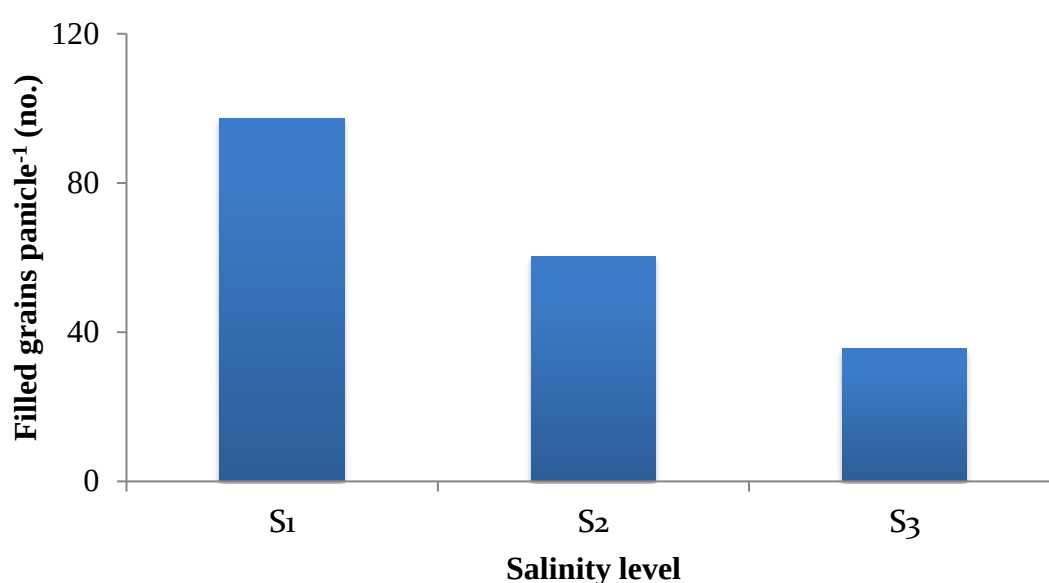
V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

**Figure 4.4.11 Filled grains panicle<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=3.39)**

#### 4.4.33.2 Effect of salinity level

There was significant variation among the salinity levels for the filled grains panicle<sup>-1</sup> (Figure 4.4.12). The maximum filled grains panicle<sup>-1</sup> (97.17) was recorded from S<sub>1</sub>

and the minimum filled grains panicle<sup>-1</sup> (35.75) was recorded from S<sub>3</sub>. Treatment S<sub>1</sub> produced 171.80% more filled grains panicle<sup>-1</sup> than treatment S<sub>3</sub>. The reduction of filled grains might be due to failure of grain formation in rice grain which could be caused by lack of pollen viability. Khatun and Flowers (1995) earlier also reported that salinity stress reduces pollen viability and seed set. Reduction in filled grains panicle<sup>-1</sup> also could be due to salinity-induced disturbance of source sink relationship of crop plants (Greenway and Munns, 1980; Blum, 1988). Reduction in filled grains panicle<sup>-1</sup> in rice have also been reported by Senanayake *et al.* (2017); Khanam *et al.* (2018); Channa *et al.* (2019).



S<sub>1</sub>= 0 mM NaCl (Control), S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl

**Figure 4.4.12 Effect of salinity level on the filled grains panicle<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=1.69)**

#### 4.4.33.3 Interaction effect of species and salinity level

There was significant variation among the genotypes and salinity levels for the filled grains panicle<sup>-1</sup> (Table 4.4.45). The maximum filled grains panicle<sup>-1</sup> (163.00) was recorded from V<sub>8</sub>S<sub>1</sub> which was statistically similar with V<sub>7</sub>S<sub>1</sub>. As the tested samples were not survived under V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub> treatment combinations so, there was no filled grains panicle<sup>-1</sup> for these treatment combinations.

At 50 mM NaCl the maximum decrease of filled grains panicle<sup>-1</sup> (40.02%) attained by wild rice genotype *O. rufipogon* (V<sub>1</sub>) and minimum decrease of filled grains panicle<sup>-1</sup> (3.17%) attained by Pokkali (Check variety as salt tolerant) (V<sub>11</sub>) whereas at 100 mM NaCl the maximum decrease of filled grains panicle<sup>-1</sup> (68.57%) attained by wild rice genotype *O. punctata* (V<sub>9</sub>) and minimum decrease of filled grains panicle<sup>-1</sup> (7.62%) attained by wild rice genotype *O. alta* (V<sub>10</sub>) (Table 4.4.47).

**Table 4.4.47 Filled grains panicle<sup>-1</sup> of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 101.70    | 61.00      | 40.02                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 34.00     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 54.67     | 38.33      | 29.89                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 53.33     | 42.33      | 20.63                     | 40.67       | 23.74                     |
| V <sub>5</sub>  | 51.67     | 46.67      | 9.68                      | 45.67       | 11.61                     |
| V <sub>6</sub>  | 69.00     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 158.30    | 99.67      | 37.04                     | 50.67       | 67.99                     |
| V <sub>8</sub>  | 163.00    | 153.70     | 5.71                      | 87.00       | 46.63                     |
| V <sub>9</sub>  | 110.30    | 105.70     | 4.17                      | 34.67       | 68.57                     |
| V <sub>10</sub> | 131.30    | 123.00     | 6.32                      | 121.30      | 7.62                      |
| V <sub>11</sub> | 104.00    | 100.70     | 3.17                      | 0.00        | 100.00                    |
| V <sub>12</sub> | 134.70    | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potrericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.34 Unfilled grains panicle<sup>-1</sup>

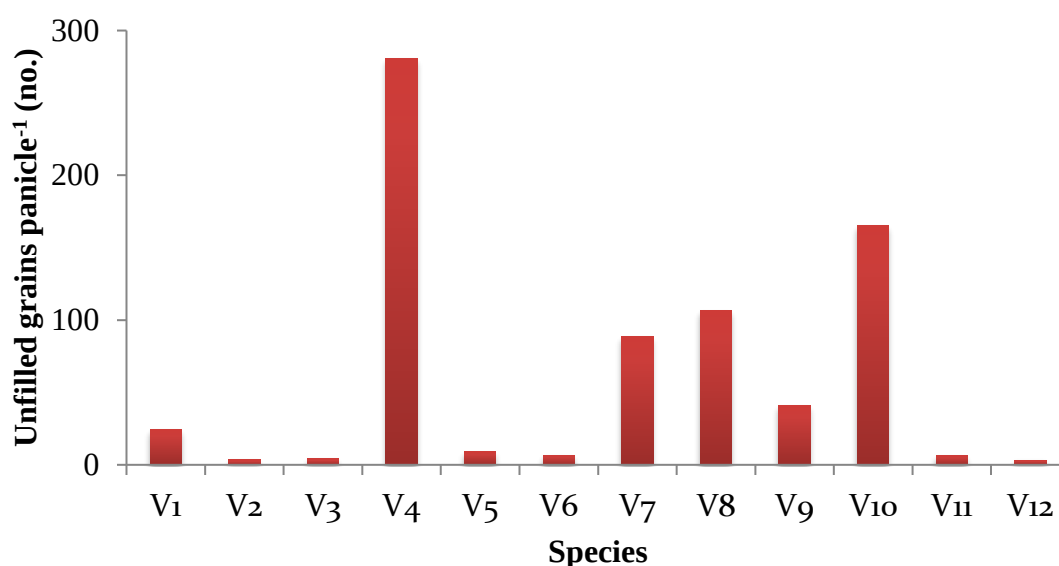
##### 4.4.34.1 Effect of species

Unfilled grains panicle<sup>-1</sup> was significantly varied for the genotypic variation of wild rice (Figure 4.4.13). The maximum unfilled grains panicle<sup>-1</sup> (280.80) was found from *O. latifolia* (V<sub>4</sub>) followed by *O. alta* (V<sub>10</sub>) (165.30) and the minimum unfilled grains panicle<sup>-1</sup> (3.33) was found from BRRI Dhan 29 (V<sub>12</sub>) which was statistically similar with V<sub>2</sub> and V<sub>3</sub> treatment.

##### 4.4.34.2 Effect of salinity level

Unfilled grains panicle<sup>-1</sup> was significantly varied for the variation of salt concentration (Figure 4.4.14). The maximum unfilled grains panicle<sup>-1</sup> (75.56) was

found from S<sub>1</sub> and the minimum unfilled grains panicle<sup>-1</sup> (50.88) was found from S<sub>3</sub> treatment. Khan *et al.* (1997); Hasamuzzaman *et al.* (2009); Malumpong *et al.* (2019) reported that the final yield of grain is dependent on spikelet fertility and is severely affected by salinity, thus, seed setting decreased in the panicle due to salinity stress. The seed setting decreased drastically due to pollen viability, ultimately the unfilled grains panicle<sup>-1</sup> increased. The findings of our experiment also were supported by Heenan and Lewin (1988); Khatun and Rizzo (1995); Hasamuzzaman *et al.* (2009) who reported that salinity stress drastically increased the unfilled grains panicle<sup>-1</sup>.



V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

**Figure 4.4.13 Unfilled grains panicle<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=2.80)**

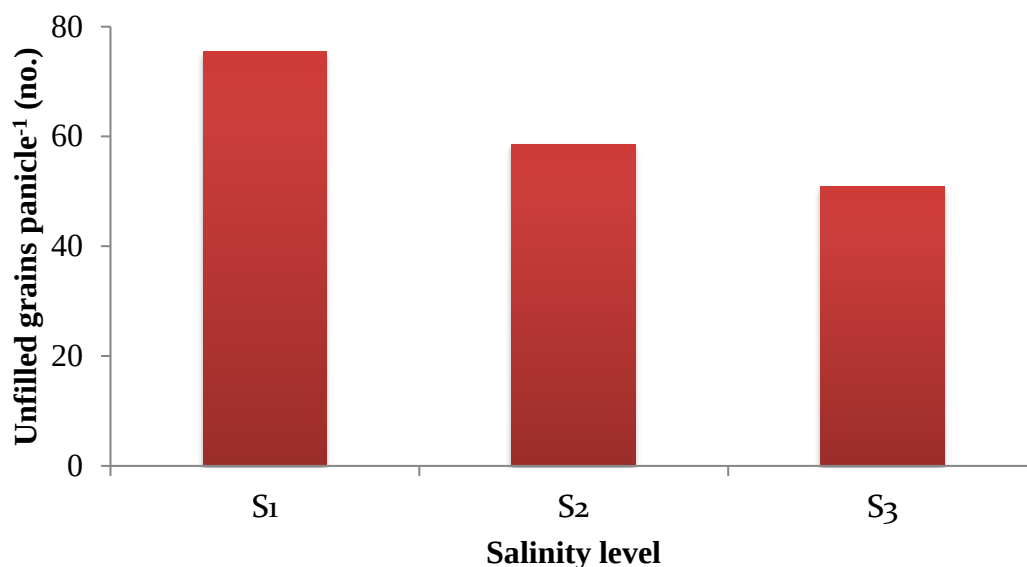
#### 4.4.34.3 Interaction effect of species and salinity level

Unfilled grains panicle<sup>-1</sup> was significantly varied for the variation of rice genotypes and salt concentration (Table 4.4.45). The maximum unfilled grains panicle<sup>-1</sup> (292.30) was found from V<sub>4</sub>S<sub>1</sub> treatment combination followed by V<sub>4</sub>S<sub>2</sub> (280.00) and no unfilled grains panicle<sup>-1</sup> (0.00) was found from V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub>.

At 50 mM NaCl the maximum decrease of unfilled grains panicle<sup>-1</sup> (48.04%) was observed from wild rice genotype *O. nivara* (V<sub>3</sub>) and minimum decrease of unfilled grains panicle<sup>-1</sup> (3.57%) was observed from wild rice genotype *Potericia coaractata*



(V<sub>5</sub>) whereas at 100 mM NaCl the maximum decrease of unfilled grains panicle<sup>-1</sup> (69.32%) was observed from wild rice genotype *O. punctata* (V<sub>9</sub>) and minimum decrease of unfilled grains panicle<sup>-1</sup> (7.14%) was observed from wild rice genotype *Potericia coaractata* (V<sub>5</sub>) (Table 4.4.48).



S<sub>1</sub>= 0 mM NaCl (Control), S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl

**Figure 4.4.14 Effect of salinity level on the unfilled grains panicle<sup>-1</sup> of wild species rice (LSD<sub>0.05</sub>=1.40)**

**Table 4.4.48 Unfilled grains panicle<sup>-1</sup> of wild species of rice as influenced by salinity stress**

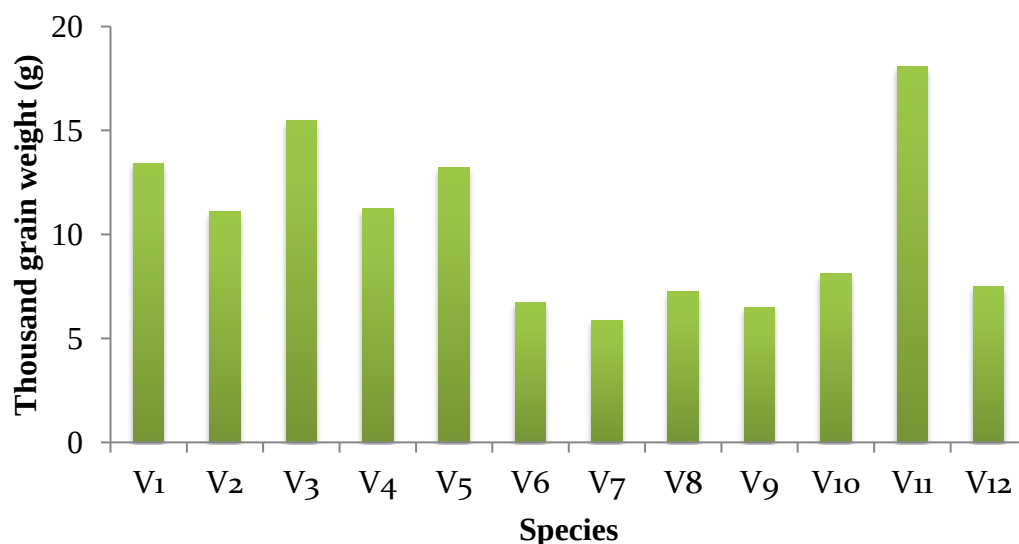
| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 46.67     | 26.63      | 42.94                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 10.33     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 8.33      | 4.33       | 48.04                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 292.30    | 280.00     | 4.21                      | 270.00      | 7.63                      |
| V <sub>5</sub>  | 9.33      | 9.00       | 3.57                      | 8.67        | 7.14                      |
| V <sub>6</sub>  | 20.33     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 138.70    | 84.17      | 39.32                     | 43.67       | 68.51                     |
| V <sub>8</sub>  | 131.30    | 116.00     | 11.65                     | 72.67       | 44.65                     |
| V <sub>9</sub>  | 54.33     | 52.00      | 4.29                      | 16.67       | 69.32                     |
| V <sub>10</sub> | 175.00    | 162.70     | 7.03                      | 158.30      | 9.54                      |
| V <sub>11</sub> | 10.00     | 9.00       | 10.00                     | 0.00        | 100.00                    |
| V <sub>12</sub> | 10.00     | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.35 Thousand grain weight

##### 4.4.35.1 Effect of species

Statistically significant variation was found for thousand grain weight of rice due to different rice genotypes (Figure 4.4.15). Result revealed that the highest thousand grain weight (18.06 g) was attained by Pokkali (V<sub>11</sub>) (Check variety as salt tolerant) followed by *O. nivara* (V<sub>3</sub>) (15.49 g) while the lowest thousand grain weight (5.85 g) was attained by *O. longistaminata* (V<sub>7</sub>) which was statistically similar with V<sub>9</sub> and V<sub>6</sub> treatments. Rice variety Pokkali produced 208.72% more thousand grain weight than *O. longistaminata*. This result supported by Asch *et al.* (1999) who worked with 8 rice cultivars and found that cultivars differed in their salt uptake and tolerant cultivars had lower salt effect on yield and yield components (thousand grain weight) than susceptible. This trait was selected for tagging the salinity tolerance genes. Saeedipour (2014) revealed that the salinity reduced the thousand-grain weight by 11.19%. The thousand-grain weight of IR485 (22.13 g) was more than IR29 (17.71 g) Genotypes Super Basmati, DR-66 and Shahkar were more affected even at lower salinity treatment (EC 6.0 dS m<sup>-1</sup>). Similar results also reported by Rubel *et al.* (2014); Channa *et al.* (2019).

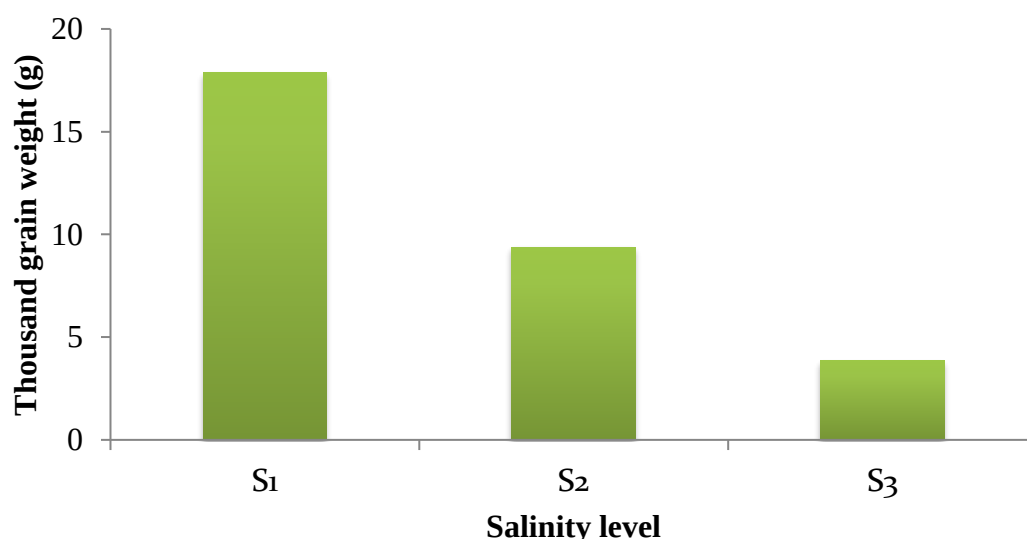


V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

**Figure 4.4.15 Thousand grain weight of wild species of rice (LSD<sub>0.05</sub>=1.01)**

#### 4.4.35.2 Effect of salinity level

Statistically significant variation was found for thousand grain weight of rice due to different salinity level (Figure 4.4.16). Salt concentration negatively affected thousand grain weight of rice; with the increasing of salt concentration the thousand grain weight of rice was decreased. Result revealed that the highest thousand grain weight (17.87 g) was attained by  $S_1$  while the lowest thousand grain weight (3.86 g) was attained by  $S_3$ . Control treatment  $S_1$  produced 362.95 more thousand grain weight than  $S_3$ . The reduction of thousand grain weight might be due to lower accumulation of photosynthates and other food materials from source (leaf) to sink (grain). Because under salinity stresses condition the photosynthesis process is hampered and retards the partitioning process towards sink. Fabre *et al.* (2005) reported that salinity stress decreases yield through decreasing thousand grain weight actually brought about by reduced hull size, as evidenced by its dimensions, and therefore took place already before flowering. Similar results were reported by Aref (2013); Hakim *et al.* (2014); Saeedipour (2014); Hussain *et al.* (2017); Channa *et al.* (2019) who reported that thousand grain weight decreased progressively with increase in salinity levels. But Mahmood *et al.* (2009) studied the effect of salinity on rice and has a little bit controversial opinion. They reported that thousand grain weight of rice was least affected by salinity.



$S_1$ = 0 mM NaCl (Control),  $S_2$ =50 mM NaCl and  $S_3$ =100 mM NaCl

**Figure 4.4.16 Effect of salinity level on the thousand grain weight of wild species of rice ( $LSD_{0.05}=0.51$ )**

#### 4.4.35.3 Interaction effect of species and salinity level

Statistically significant variation was found for thousand grain weight of rice due to different rice genotypes and salinity levels (Table 4.4.45). Result revealed that the highest thousand grain weight (33.35 g) was attained by V<sub>2</sub>S<sub>1</sub> treatment combination followed by V<sub>3</sub>S<sub>1</sub> (28.98) while the lowest thousand grain weight (0.00 g) was attained by V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub> treatment combinations.

At 50 mM NaCl the maximum decrease of thousand grain weight(39.65%) was observed from wild rice genotype *O. nivara* (V<sub>3</sub>) and increase of thousand grain weight(0.04%) was observed from rice genotype Pokkali (Check variety as salt tolerant) (V<sub>11</sub>) whereas at 100 mM NaCl the maximum decrease of thousand grain weight(67.52%) was observed from wild rice genotype *O. punctata* (V<sub>9</sub>)and minimum decrease of thousand grain weight(0.53%) was observed from wild rice genotype *O. latifolia* (V<sub>4</sub>) (Table 4.4.49).

**Table 4.4.49 Thousand grain weight of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 24.22     | 16.08      | 33.61                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 33.35     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 28.98     | 17.49      | 39.65                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 11.26     | 11.26      | 0.00                      | 11.20       | 0.53                      |
| V <sub>5</sub>  | 13.29     | 13.22      | 0.53                      | 13.12       | 1.28                      |
| V <sub>6</sub>  | 20.17     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 8.90      | 5.71       | 35.82                     | 2.94        | 66.96                     |
| V <sub>8</sub>  | 8.15      | 8.13       | 0.25                      | 5.42        | 33.50                     |
| V <sub>9</sub>  | 8.47      | 8.31       | 1.82                      | 2.75        | 67.52                     |
| V <sub>10</sub> | 8.12      | 8.11       | 0.12                      | 8.10        | 0.25                      |
| V <sub>11</sub> | 27.08     | 27.09      | -0.04                     | 0.00        | 100.00                    |
| V <sub>12</sub> | 22.50     | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.4.36 Grain yield hill<sup>-1</sup>

##### 4.4.36.1 Effect of species

Grain yield hill<sup>-1</sup> was significantly influenced by different wild rice genotypes (Figure 4.4.17). The maximum grain yield hill<sup>-1</sup> (77.98 g) was produced by Pokkali (V<sub>11</sub>) (Check variety as salt tolerant) followed by *O. nivara* (V<sub>3</sub>) (45.36 g) whereas the minimum grain yield hill<sup>-1</sup> (12.07 g) was produced by *O. barthii* (V<sub>2</sub>) which showed similarity with V<sub>6</sub>, V<sub>7</sub>, V<sub>8</sub> and V<sub>10</sub> treatments. Check variety Pokkali and *O. nivara* produced (546.06% and 275.81%, respectively) more grain than *O. barthii*. The result might be due to genetic variation of wild rice genotypes. Similar result also reported by Bhusan *et al.* (2016) who reported that salt stress (25 mM NaCl) decreased grain yield by 2-fold and 1.5 fold of salt-sensitive and salt-tolerant rice, respectively. Drastic reduction of growth was observed when plants of both cultivars were exposed to 50 and 100 mM NaCl, and finally both cultivars failed to produce grains. Moreover Zeng and Shannon (2000) and Moradi and Ismail (2007) concluded that certain rice varieties have been reported as being salt sensitive in their seedling and reproductive stages leading to a reduction in crop productivity of more than 50% when exposed to 6.65 dS m<sup>-1</sup> electrical conductivity (EC) and soil salinity. Mondal *et al.* (2013); Malumpong *et al.* (2019) reported that Na<sup>+</sup> accumulation was comparatively less in saline-tolerant genotypes like Pokkali. Malumpong *et al.* (2019) also concluded that the top three leaves are mainly associated with contributions to grain yield. This means that the flag leaf is the closest source of panicles that significantly reduces the translocation of soluble sugars to spikelets and inhibits starch synthetase activity during grain development, which are the main reasons behind lower rice grain yield under salt stress (Abdullah *et al.*, 2018). This suggests that the tolerant cultivars have an osmotic mechanism to prevent NaCl transportation up to the panicle.

##### 4.4.36.2 Effect of salinity level

Grain yield hill<sup>-1</sup> was significantly influenced by different salinity levels (Figure 4.4.18). It was observed that the magnitude of the reduction of grain yield hill<sup>-1</sup> was increased with the increasing of salinity level. The data of our investigation revealed that the maximum grain yield hill<sup>-1</sup> (47.71 g) was produced by S<sub>1</sub> treatment followed

by S<sub>2</sub> (25.59 g) whereas the minimum grain yield hill<sup>-1</sup> (5.83 g) was produced by S<sub>3</sub> treatment. S<sub>1</sub> and S<sub>2</sub> produced 718.35% and 338.94%, respectively more grain than S<sub>3</sub> treatment. Salt stress has a major impact on plant growth and development. The major inhibitory effect of salinity on plant growth and development has been attributed to osmotic inhibition of water availability as well as the toxic effect of salt ions responsible for salinization (Verma and Mishra, 2005 and Duan *et al.*, 2008).

The osmotic stress is caused due to abscisic acid (ABA) mediated root signal that limits the availability of water to plant cell, which leads to reduce relative water content, slower plant growth and finally reduces dry matter accumulation (Zhang *et al.*, 2006). Ndayiragije and Lutts (2006) and Aref (2013) reported that salt stress results from a number of detrimental processes including a toxic action of Na<sup>+</sup>, the impairment of K<sup>+</sup> nutrition, a modification in the plant water status. The water deficit always has a negative effect, but many crop plants are primarily sensitive to Na<sup>+</sup> excess due to its adverse effects on cytosolic enzyme activities, photosynthesis and metabolism (Quintero *et al.*, 2008). Salt stress disturbs cytoplasmic K<sup>+</sup>/Na<sup>+</sup> homeostasis, causing an increase in Na<sup>+</sup>/K<sup>+</sup> ratio in the cytosol (Zhu, 2003). Accumulation of excess Na<sup>+</sup> and Cl<sup>-</sup> causes ionic imbalances that may impair the selectivity of root membranes and enhanced K<sup>+</sup> leakage from the cell (Shabala, 2000; Shabala, 2003), induce K<sup>+</sup> deficiency (Gadallah, 1999). Saeedipour (2014) also reported that salinity affected plants may suffer from metabolic toxicity, nutrient deficiencies and imbalances, membrane dysfunction, and antioxidative stress, which damage tissue and induce early senescence.

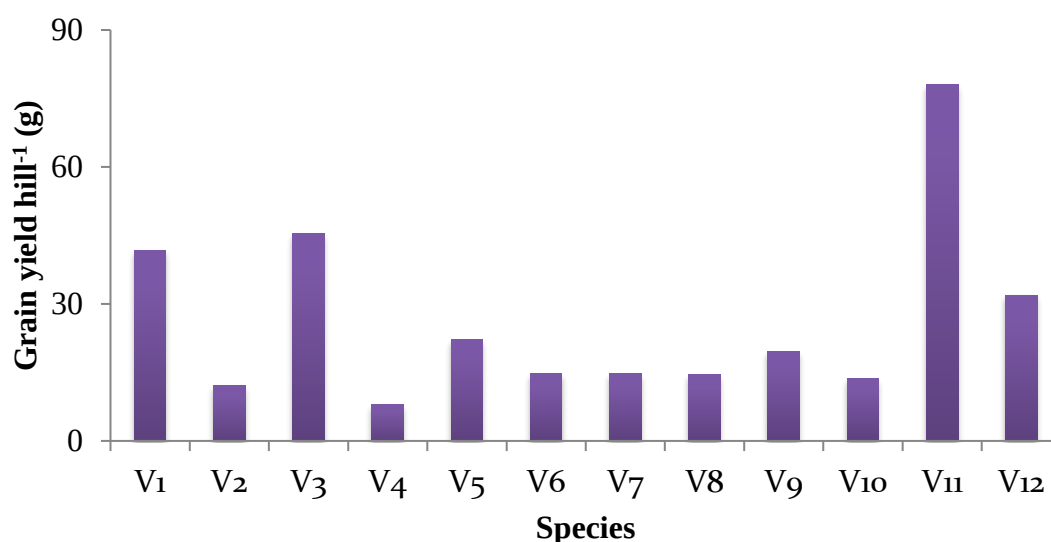
In rice, there evolve several mechanisms for salinity tolerance including ion homeostasis, particularly low Na<sup>+</sup>/K<sup>+</sup> ratio, through exclusion partitioning of Na<sup>+</sup>, the modification of membrane, translocation and compartmentalization (Li *et al.*, 2008 and Kanawapee *et al.*, 2012). Reducing the entry of salt into the plant and reducing the concentration of salt in the cytoplasm are the two main mechanisms for salt tolerance in plant. Moreover, salt tolerant plants have lower rate of Na<sup>+</sup> and Cl<sup>-</sup> transport to leaves and higher ability to prevent the build-up of ions in cytoplasm or cell wall. The compartmentalization of ions into vacuoles is also more efficient in salt-tolerant than salt-sensitive plants (Munns, 2002). Plant salt tolerance mechanisms also involve the protection of chloroplast functions. The ability of plants to reduce Na<sup>+</sup> uptake, exclude Na<sup>+</sup> and decrease NaCl induced K<sup>+</sup> efflux to maintain good Na<sup>+</sup>: K<sup>+</sup>

balance in the shoots has been accepted as the essential mechanisms of salinity tolerance (Tester and Davenport 2003; Shabala and Cuin, 2008).

Hichem *et al.* (2009); Xu *et al.* (2010) reported that the cell membrane, being at the interface between the cells and its surroundings, is the first organelle that is susceptible to salinity stress and the capacity of maintaining its integrity is an important process related to plant resistance against salt stress. Salt ion toxicity has numerous deleterious effects on plants such as denaturing cytosolic enzymes and facilitating the formation of reactive oxygen species (ROS) (Banu *et al.*, 2010). The excess production of ROS is toxic to plants and causes oxidative damage to cellular constituents, leading to cell death (Hossain *et al.*, 2014b). Plants develop a variety of adaptive mechanisms in response to salt stress. Accumulation of compatible solutes in plants is one of the main adaptive mechanisms to salt stress. Plants possess enzymatic and non-enzymatic antioxidant defense systems to protect cells against the damaging effects of ROS (Apel and Hirt, 2004). The major ROS-scavenging antioxidant enzymes are catalase (CAT), guaiacol peroxidase (POX) and ascorbate peroxidase (APX). Ascorbate directly scavenges ROS and functions as an electron donor to APX for scavenging H<sub>2</sub>O<sub>2</sub> (Noctor and Foyer, 1998).

Numerous authors have reported that salt stress differentially affects the components of antioxidant defense system in plants (Nounjan and Theerakulpisut, 2012 and Hasanuzzaman *et al.*, 2014). Yield components related to final grain yield are also severely affected by root-zone salinity. The strongest salinity effects on yield are observed around panicle initiation (PI). Under continuous salinity stress, the loss of grain yield results from a combination of reductions in plant stand, filled grains panicle<sup>-1</sup>, thousand grain weight and harvest index (Saqib *et al.*, 2012). Among all these contributing components studied the filled grains panicle<sup>-1</sup> is found most severely affected and thus causes significant reduction in total yield of grain. In addition to fertility, panicle length and effective tillers hill<sup>-1</sup> two important affected characters that contribute to grain yield. The magnitude of salt induced yield losses could not be attributed to a single factor. The important control mechanism (before flowering) of sodium uptake through root properties and its subsequent distribution in different vegetative and floral parts especially in leaves where it causes leaf mortality thereby reducing transportation of total assimilates to the growing region (Munns, 2002). Hussain *et al.* (2017) reported that the main cause of decreased grain yield

under salt stress is lack of transformation of carbohydrates to vegetative growth and spikelets development. Zeng and Shannon (2000) observed negative linear relationships in many yield components with increased salt stress such as tillers plant<sup>-1</sup>, grains panicle<sup>-1</sup> and percent of sterile florets. Moreover, significant reduction in translocation of soluble sugar contents to superior and inferior spikelets and inhibition of starch synthetase activity during grain development are the main reasons behind lower rice grain yield under salt stress (Abdullah *et al.* 2001). The results of our investigation are in harmony with those obtained by Datir *et al.* (2018), Khanam *et al.* (2018), Polash *et al.* (2018) in rice; Abeer *et al.* (2015) on tomato cultivars and Hassanein *et al.* (2012) on *Vicia faba* L. plants.



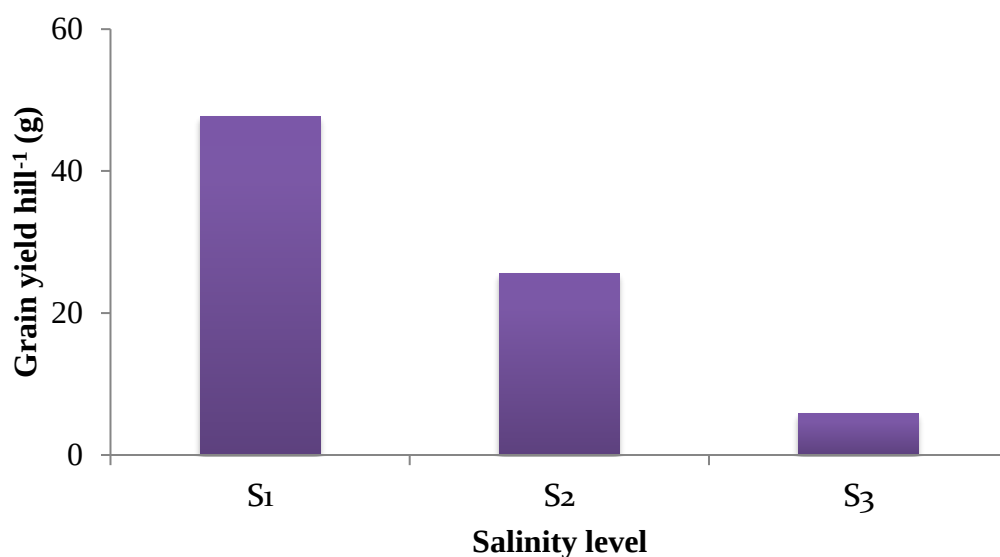
V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potricia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

**Figure 4.4.17 Grain yield hill<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=3.11)**

#### 4.4.36.3 Interaction effect of species and salinity level

Grain yield hill<sup>-1</sup> was significantly influence by the interaction of rice genotypes and salinity levels (Table 4.4.50). The data of our investigation revealed that the maximum grain yield hill<sup>-1</sup> (123.10 g) was produced by V<sub>11</sub>S<sub>1</sub> treatment followed by V<sub>11</sub>S<sub>2</sub> (110.80 g) whereas no grain yield hill<sup>-1</sup> (0.00 g) was attained by V<sub>1</sub>S<sub>3</sub>, V<sub>2</sub>S<sub>2</sub>, V<sub>2</sub>S<sub>3</sub>, V<sub>3</sub>S<sub>3</sub>, V<sub>6</sub>S<sub>2</sub>, V<sub>6</sub>S<sub>3</sub>, V<sub>11</sub>S<sub>3</sub>, V<sub>12</sub>S<sub>2</sub> and V<sub>12</sub>S<sub>3</sub> treatment combinations.





S<sub>1</sub>= 0 mM NaCl (Control), S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl

**Figure 4.4.18 Effect of salinity level on the grain yield hill<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=1.56)**

The magnitude of the reduction of grain yield hill<sup>-1</sup> was increased with the increasing of salt concentration. At 50 mM NaCl the maximum decrease of grain yield hill<sup>-1</sup> (38.80%) was recorded from wild rice genotype *O. rufipogon* (V<sub>1</sub>) and minimum decrease of grain yield hill<sup>-1</sup> (0.86%) was recorded from wild rice genotype *O. punctata* (V<sub>9</sub>). On the other hand, at 100 mM NaCl the maximum decrease of grain yield hill<sup>-1</sup> (67.73%) was recorded from wild rice genotype *O. longistaminata* (V<sub>7</sub>) and minimum decrease of grain yield hill<sup>-1</sup> (14.83%) was recorded from wild rice genotype *O. latifolia* (V<sub>4</sub>) (Table 4.4.51).

#### **4.4.37 Biological yield hill<sup>-1</sup>**

##### **4.4.37.1 Effect of species**

Biological yield hill<sup>-1</sup> significantly differed by rice genotypes (Figure 4.4.19). The maximum biological yield hill<sup>-1</sup> (189.30 g) was obtained from *O. latifolia* (V<sub>4</sub>) and the minimum biological yield hill<sup>-1</sup> (29.41 g) was obtained from *O. barthii* (V<sub>2</sub>).

**Table 4.4.50 Interaction effect of species and salinity level on the yield of wild species of rice**

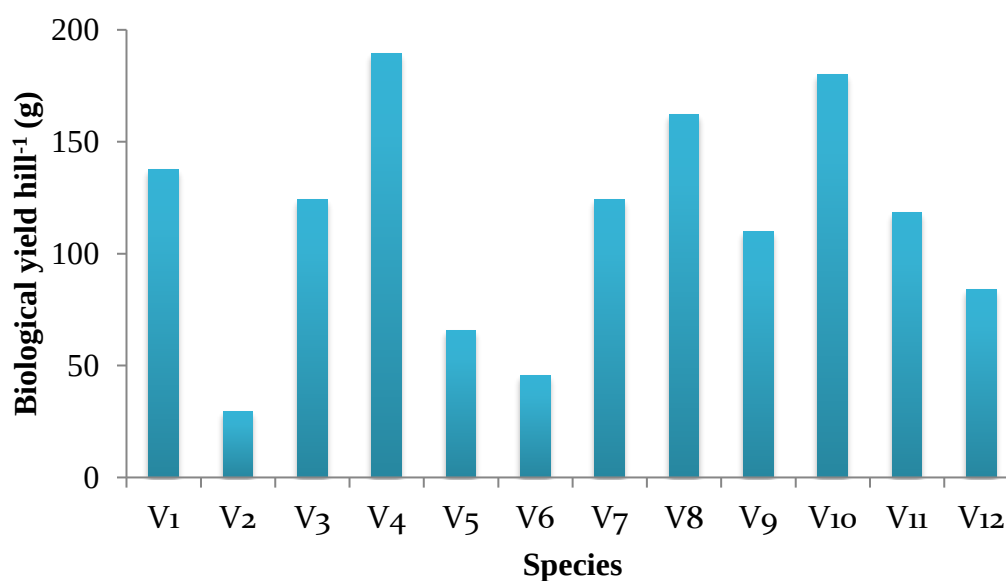
| Treatments                     | Grain yield hill <sup>-1</sup> (g) |     | Biological yield hill <sup>-1</sup> (g) |     | Harvest index (%) |
|--------------------------------|------------------------------------|-----|-----------------------------------------|-----|-------------------|
| V <sub>1</sub> S <sub>1</sub>  | 77.76                              | d   | 256.70                                  | a   | 30.29 f           |
| V <sub>1</sub> S <sub>2</sub>  | 47.59                              | f   | 156.40                                  | ij  | 20.25 h           |
| V <sub>1</sub> S <sub>3</sub>  | 0.00                               | q   | 0.00                                    | q   | 0.00 o            |
| V <sub>2</sub> S <sub>1</sub>  | 36.21                              | g   | 88.24                                   | m   | 40.93 c           |
| V <sub>2</sub> S <sub>2</sub>  | 0.00                               | q   | 0.00                                    | q   | 0.00 o            |
| V <sub>2</sub> S <sub>3</sub>  | 0.00                               | q   | 0.00                                    | q   | 0.00 o            |
| V <sub>3</sub> S <sub>1</sub>  | 81.18                              | d   | 221.90                                  | b   | 38.01 d           |
| V <sub>3</sub> S <sub>2</sub>  | 54.90                              | e   | 150.70                                  | j   | 24.29 g           |
| V <sub>3</sub> S <sub>3</sub>  | 0.00                               | q   | 0.00                                    | q   | 0.00 o            |
| V <sub>4</sub> S <sub>1</sub>  | 8.66                               | op  | 194.70                                  | cd  | 4.44 mn           |
| V <sub>4</sub> S <sub>2</sub>  | 7.84                               | p   | 189.80                                  | c-f | 4.13 mn           |
| V <sub>4</sub> S <sub>3</sub>  | 7.37                               | p   | 183.40                                  | d-f | 4.02 n            |
| V <sub>5</sub> S <sub>1</sub>  | 24.13                              | hi  | 70.81                                   | n   | 34.04 e           |
| V <sub>5</sub> S <sub>2</sub>  | 22.87                              | h-j | 68.31                                   | no  | 33.50 e           |
| V <sub>5</sub> S <sub>3</sub>  | 19.42                              | i-k | 58.29                                   | o   | 33.10 e           |
| V <sub>6</sub> S <sub>1</sub>  | 43.98                              | f   | 136.10                                  | k   | 32.28 ef          |
| V <sub>6</sub> S <sub>2</sub>  | 0.00                               | q   | 0.00                                    | q   | 0.00 o            |
| V <sub>6</sub> S <sub>3</sub>  | 0.00                               | q   | 0.00                                    | q   | 0.00 o            |
| V <sub>7</sub> S <sub>1</sub>  | 22.56                              | h-j | 197.00                                  | c   | 11.45 j           |
| V <sub>7</sub> S <sub>2</sub>  | 7.28                               | p   | 60.94                                   | no  | 3.98 n            |
| V <sub>7</sub> S <sub>3</sub>  | 14.27                              | k-n | 114.10                                  | l   | 8.34 kl           |
| V <sub>8</sub> S <sub>1</sub>  | 17.98                              | j-l | 200.70                                  | c   | 8.99 j-l          |
| V <sub>8</sub> S <sub>2</sub>  | 16.69                              | k-m | 181.10                                  | e-g | 9.23 jk           |
| V <sub>8</sub> S <sub>3</sub>  | 8.95                               | n-p | 104.30                                  | l   | 6.61 k-n          |
| V <sub>9</sub> S <sub>1</sub>  | 25.49                              | h   | 146.60                                  | jk  | 17.40 i           |
| V <sub>9</sub> S <sub>2</sub>  | 25.27                              | h   | 139.30                                  | k   | 18.14 hi          |
| V <sub>9</sub> S <sub>3</sub>  | 8.28                               | p   | 43.25                                   | p   | 6.38 l-n          |
| V <sub>10</sub> S <sub>1</sub> | 15.54                              | k-m | 190.70                                  | c-e | 8.14 kl           |
| V <sub>10</sub> S <sub>2</sub> | 13.77                              | l-o | 179.10                                  | fg  | 7.69 kl           |
| V <sub>10</sub> S <sub>3</sub> | 11.67                              | m-p | 170.30                                  | gh  | 6.85 k-m          |
| V <sub>11</sub> S <sub>1</sub> | 123.10                             | a   | 191.20                                  | c-e | 64.34 b           |
| V <sub>11</sub> S <sub>2</sub> | 110.80                             | b   | 163.60                                  | hi  | 67.76 a           |
| V <sub>11</sub> S <sub>3</sub> | 0.00                               | q   | 0.00                                    | q   | 0.00 o            |
| V <sub>12</sub> S <sub>1</sub> | 95.87                              | c   | 251.80                                  | a   | 38.03 d           |
| V <sub>12</sub> S <sub>2</sub> | 0.00                               | q   | 0.00                                    | q   | 0.00 o            |
| V <sub>12</sub> S <sub>3</sub> | 0.00                               | q   | 0.00                                    | q   | 0.00 o            |
| <b>LSD (0.05)</b>              | <b>5.39</b>                        |     | <b>11.41</b>                            |     | <b>2.74</b>       |
| <b>CV (%)</b>                  | <b>12.55</b>                       |     | <b>6.14</b>                             |     | <b>10.41</b>      |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive); S<sub>1</sub>= 0 mM NaCl (Control), S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl

**Table 4.4.51 Grain yield hill<sup>-1</sup> of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 77.76     | 47.59      | 38.80                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 36.21     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 81.18     | 54.90      | 32.37                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 8.66      | 7.84       | 9.47                      | 7.37        | 14.83                     |
| V <sub>5</sub>  | 24.13     | 22.87      | 5.22                      | 19.42       | 19.52                     |
| V <sub>6</sub>  | 43.98     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 22.56     | 14.27      | 36.75                     | 7.28        | 67.73                     |
| V <sub>8</sub>  | 17.98     | 16.69      | 7.17                      | 8.95        | 50.22                     |
| V <sub>9</sub>  | 25.49     | 25.27      | 0.86                      | 8.28        | 67.52                     |
| V <sub>10</sub> | 15.54     | 13.77      | 11.39                     | 11.67       | 24.90                     |
| V <sub>11</sub> | 123.10    | 110.80     | 9.99                      | 0.00        | 100.00                    |
| V <sub>12</sub> | 95.87     | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

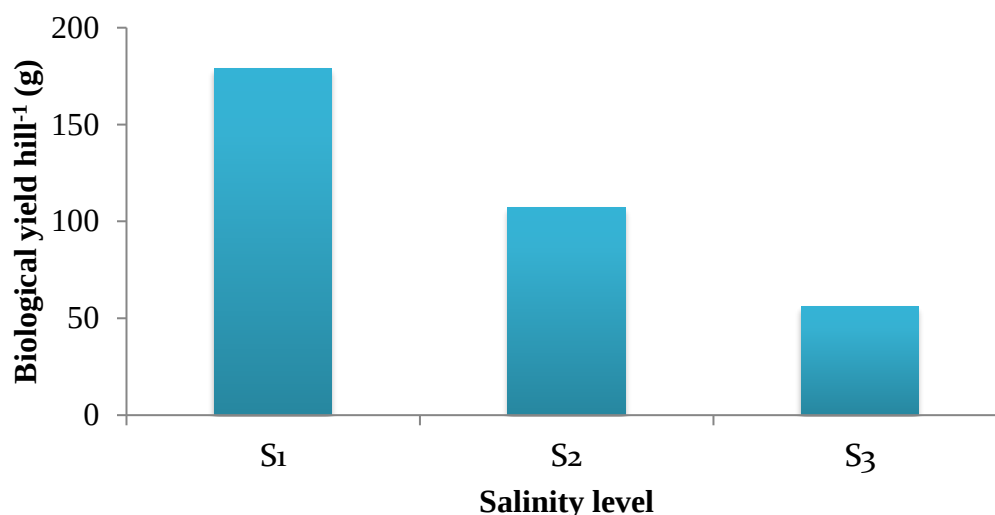


V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

**Figure 4.4.19 Biological yield hill<sup>-1</sup> of wild species of rice (LSD<sub>0.05</sub>=6.59)**

#### 4.4.37.2 Effect of salinity level

Biological yield  $\text{hill}^{-1}$  significantly differed by salinity level (Figure 4.4.20). The maximum biological yield  $\text{hill}^{-1}$  (178.90 g) was obtained from  $S_1$  treatment and the minimum biological yield  $\text{hill}^{-1}$  (56.13 g) was obtained from  $S_3$  treatment.



$S_1$ = 0 mM NaCl (Control),  $S_2$ =50 mM NaCl and  $S_3$ =100 mM NaCl

**Figure 4.4.20 Effect of salinity level on the biological yield  $\text{hill}^{-1}$  of wild species of rice ( $\text{LSD}_{0.05}=3.29$ )**

#### 4.4.37.3 Interaction effect of species and salinity level

Biological yield  $\text{hill}^{-1}$  significantly differed by rice genotypes and salinity level (Table 4.4.50). The maximum biological yield  $\text{hill}^{-1}$  (256.70 g) was obtained from  $V_1S_1$  treatment followed by  $V_{12}S_1$  (251.80 g) and incase of minimum value for biological yield  $\text{hill}^{-1}$  similar trend was observed.

The magnitude of the reduction of biological yield  $\text{hill}^{-1}$  was increased with the increasing of salt concentration. At 50 mM NaCl concentration the maximum decrease of biological yield  $\text{hill}^{-1}$ (42.08%) was recorded from wild rice genotype *O. longistaminata* ( $V_7$ )and minimum decrease ofbiological yield  $\text{hill}^{-1}$ (2.52%) was recorded from wild rice genotype *O. latifolia* ( $V_4$ ) on the other hand at 100 mM NaCl concentration the maximum decrease of biological yield  $\text{hill}^{-1}$ (70.50%) was recorded from wild rice genotype *O. punctata* ( $V_9$ )and minimum decrease of biological yield  $\text{hill}^{-1}$ (5.80%) was recorded from wild rice genotype *O. latifolia* ( $V_4$ ) (Table 4.4.52).

**Table 4.4.52 Biological yield  $\text{hill}^{-1}$  of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 256.70    | 156.40     | 39.07                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 88.24     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 221.90    | 150.70     | 32.09                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 194.70    | 189.80     | 2.52                      | 183.40      | 5.80                      |
| V <sub>5</sub>  | 70.81     | 68.31      | 3.53                      | 58.29       | 17.68                     |
| V <sub>6</sub>  | 136.10    | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 197.00    | 114.10     | 42.08                     | 60.94       | 69.07                     |
| V <sub>8</sub>  | 200.70    | 181.10     | 9.77                      | 104.30      | 48.03                     |
| V <sub>9</sub>  | 146.60    | 139.30     | 4.98                      | 43.25       | 70.50                     |
| V <sub>10</sub> | 190.70    | 179.10     | 6.08                      | 170.30      | 10.70                     |
| V <sub>11</sub> | 191.20    | 163.60     | 14.44                     | 0.00        | 100.00                    |
| V <sub>12</sub> | 251.80    | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

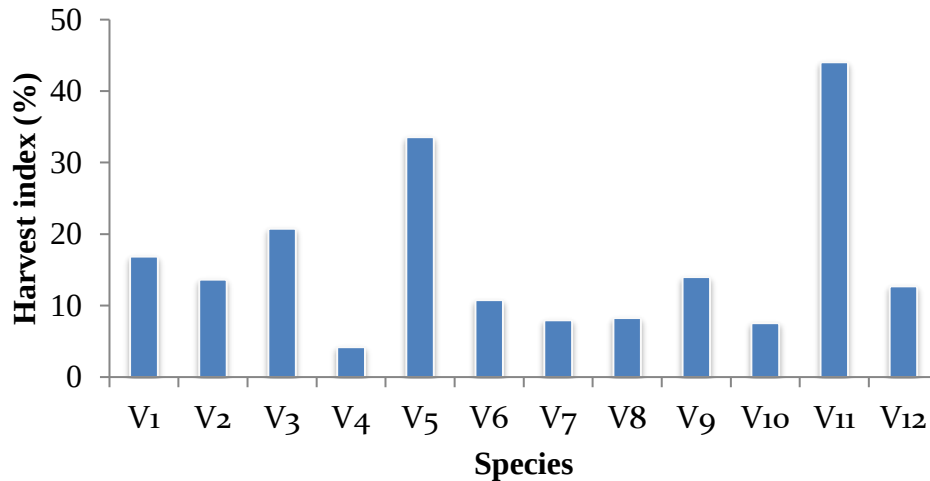
#### 4.4.38 Harvest index

##### 4.4.38.1 Effect of species

Data depicted in figure 4.4.21 revealed that there was a significant difference on harvest index due to genotypic variation. The maximum harvest index (44.03%) was scored by Pokkali (V<sub>11</sub>) (Check variety as salt tolerant) followed by *P. coaractata* (V<sub>5</sub>) (33.55%) and the minimum one (4.20%) was scored by *O. latifolia* (V<sub>4</sub>).

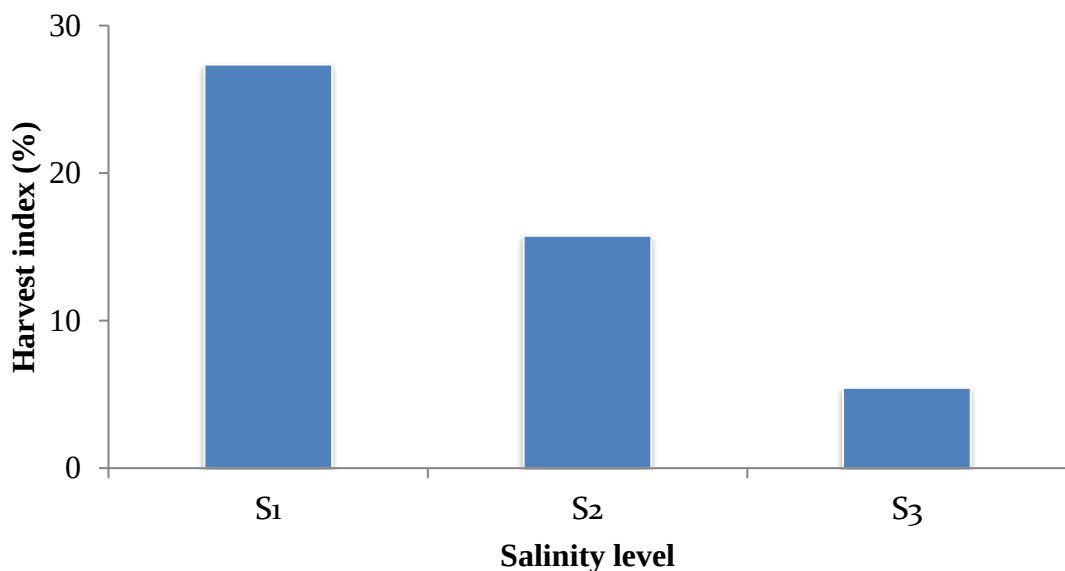
##### 4.4.38.2 Effect of salinity level

Data depicted in figure 4.4.22 revealed that there was a significant difference on harvest index due to the variation of salt concentration. With the increasing of salt concentration the harvest index was sharply decreased. The maximum harvest index (27.36%) was scored by S<sub>1</sub> followed by S<sub>2</sub> (15.75%) and the minimum one (5.44%) was scored by S<sub>3</sub> treatment. High influence of salinity on harvest index was reported by many researches. Zeng and Shannon (2000) stated that harvest index was significantly decreased when salinity was at 3.40 dS m<sup>-1</sup> and higher. The results of our experiment also similar with the findings of Zeng *et al.* (2003a); Cha-um *et al.* (2007); Aref (2013) who reported that the increasing level of salinity dramatically reduced the harvest index of rice.



V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

**Figure 4.4.21 Harvest index of wild species of rice (LSD<sub>0.05</sub>=1.58)**



S<sub>1</sub>= 0 mM NaCl (Control), S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl

**Figure 4.4.22 Effect of salinity level on the harvest index of wild species of rice (LSD<sub>0.05</sub>=0.79)**

#### 4.4.38.3 Interaction effect of species and salinity level

Data presented in Table 4.4.50 revealed that there was a significant variation on harvest index due to the variation of rice genotype and salt concentration. The maximum harvest index (67.76%) was scored by V<sub>11</sub>S<sub>2</sub> followed by V<sub>11</sub>S<sub>1</sub> (64.34%) and incase of minimum value for harvest index similar trend was observed.

At 50 mM NaCl concentration the maximum decrease of harvest index (36.10%) was recorded from wild rice genotype *O. nivara* (V<sub>3</sub>) and increase of harvest index (5.32%) was recorded from rice genotype Pokkali (Check variety as salt tolerant) (V<sub>11</sub>). On the other hand, at 100 mM NaCl concentration the maximum decrease of harvest index (65.24%) was recorded from wild rice genotype *O. longistaminata* (V<sub>7</sub>) and minimum decrease of harvest index (2.76%) was recorded from wild rice genotype *Potericia coaractata* (V<sub>5</sub>) (Table 4.4.53).

**Table 4.4.53 Harvest index of wild species of rice as influenced by salinity stress**

| Treatment       | 0 mM NaCl | 50 mM NaCl | Decrease over control (%) | 100 mM NaCl | Decrease over control (%) |
|-----------------|-----------|------------|---------------------------|-------------|---------------------------|
| V <sub>1</sub>  | 30.29     | 20.25      | 33.15                     | 0.00        | 100.00                    |
| V <sub>2</sub>  | 40.93     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>3</sub>  | 38.01     | 24.29      | 36.10                     | 0.00        | 100.00                    |
| V <sub>4</sub>  | 4.44      | 4.13       | 7.11                      | 4.02        | 9.45                      |
| V <sub>5</sub>  | 34.04     | 33.50      | 1.59                      | 33.10       | 2.76                      |
| V <sub>6</sub>  | 32.28     | 0.00       | 100.00                    | 0.00        | 100.00                    |
| V <sub>7</sub>  | 11.45     | 8.34       | 27.16                     | 3.98        | 65.24                     |
| V <sub>8</sub>  | 8.99      | 9.23       | -2.67                     | 6.61        | 26.45                     |
| V <sub>9</sub>  | 17.40     | 18.14      | -4.25                     | 6.38        | 63.33                     |
| V <sub>10</sub> | 8.14      | 7.69       | 5.60                      | 6.85        | 15.88                     |
| V <sub>11</sub> | 64.34     | 67.76      | -5.32                     | 0.00        | 100.00                    |
| V <sub>12</sub> | 38.03     | 0.00       | 100.00                    | 0.00        | 100.00                    |

V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety as salt tolerant) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive)

#### 4.5 Experiment 5: Allelic diversity of wild rice accession for salinity tolerance

The allelic diversity and relationship among 12 wild rice genotypes *ie.*, G<sub>1</sub>-*O. rufipogon*, G<sub>2</sub>- *O. alta*, G<sub>3</sub>- *O. longistiminata*, G<sub>4</sub>- *O. barthii*, G<sub>5</sub>- *O. latifolia*, G<sub>6</sub>- *O. officinalis*, G<sub>7</sub>- *O. nivara*, G<sub>8</sub>- *O. punctata*, G<sub>9</sub>- *O. glaberima*, G<sub>10</sub>-*Portericia coactata*, G<sub>11</sub>-Pokkali , G<sub>12</sub>-Nonabokra were determined through SSR markers. A total of 6 SSR markers were used to characterize all wild rice genotypes. All of them were polymorphic showing different salt tolerant markers. Genetic characterization of rice genotypes is an important step in any breeding program for selection of appropriate parental lines (Zhang *et al.*, 2009). Several DNA marker systems for germplasm genetic characterization are available but SSRs have been found most adequate in detecting relationships among populations as well as obtaining specific genetic fingerprints. One of the major objectives of the present study was to detect the genetic diversity of wild rice genotypes and to fulfill the objectives, PCR based microsatellite marker analysis was used in this study.

##### 4.5.1 Overall allelic diversity

Using 6 salt tolerant SSR markers, a total of 24 alleles were detected among 12 wild rice genotypes. The average number of allele per locus was 2.00 per primer pair. Each 24 amplified band was polymorphic. There was a relationship between the number of alleles detected at a locus and the types of simple repeats within the targeted microsatellite DNA.

Negawo *et al.* (2018) conducted an experiment with 171 genotypes and 20 microsatellite primer pairs they reported that the number of alleles for the EMBRAPA active gene bank collection, and the ILRI gene bank collection per marker ranged from 1 to 15 and 1 to 22 with averages of 4.65 and 7.0. Both collections (EMBRAPA and ILRI) were combined and noted that the number of alleles per marker ranged from 1 to 23 with an average of 7.45, which was higher than this present study. These differences might be due to different genotypes of wild rice, geographical environment, different microsatellite markers and different experimental set up.

The polymorphism information content (PIC) value provides an estimate of discriminating power of a marker based on the number of alleles at a locus and relative frequencies of these alleles. The SSR markers were highly informative and



polymorphic as evident from its polymorphic information content or PIC value. The PIC value of each primer pair ranged from 0.16 (*O. rufipogon*) to 0.37 (*O. alta*, *O. latifolia*, *O. officinalis*, *Portericia coactata* and *O. nivara*) with an average of 0.31 (Table 4.5.1). The level of polymorphism determined by the PIC value (mean= 0.48) was consistent with the reported PIC value in previous works (Wong *et al.*, 2009; Hossain *et al.*, 2012; Sajib *et al.*, 2012). This result revealed that *O. alta*, *O. latifolia*, *O. officinalis*, *Portericia coactata* and *O. nivara* would be the best salt tolerant wild rice genotypes among 12 wild rice genotypes. According to Nei *et al.* (1983) the highest level of genetic diversity (0.50) was observed in genotypes *O. alta*, *O. barthii*, *O. latifolia*, *O. officinalis* and *O. nivara* and the lowest level of genetic diversity (0.17) was observed in genotype *O. rufipogon* with a mean diversity of 0.43 (Table 4.5.3). Although allelic diversity and gene diversity index could be used as indicators of genetic variation, such estimates are relative and largely depend on the number of polymorphic loci and relatedness of genotypes included (Ren *et al.*, 2014). Despite salt tolerant wild rice genotypes found in different areas, rice genotypes from Bangladesh exhibited high levels of genetic diversity. The diverse nature of these landraces may be a reflection of the prevalent diverse agro-ecological features of the region. The allelic frequency of 6 primers and their variance with standard deviation are presented in (Table 4.5.1). The allelic frequency ranged from 0.50 to 0.90. The higher frequency showed in *O. rufipogon* counts highest and the lowest level of frequency was observed in genotypes *O. officinalis* and *Portericia coactata* with a mean frequency of 0.68. This study represent that there is a positive relation between allelic frequencies with the allele that counts and variance. The higher the variance the higher the frequency and the higher the allele count.

#### **4.5.2 UPGMA cluster of 12 wild rice genotypes based on SSR marker analysis**

Unweighted Pair Group Method of Arithmetic means (UPGMA) based dendrogram was constructed from the binary data obtained from the SSR marker based DNA profiles of the sample analyzed (Fig. 4.5.4). The genotypes that were genetically similar clustered together in the dendrogram. Using correlation coefficient (CP =0.00-0.73) were constructed the UPGMA dendrogram of the 12 wild rice genotypes.

**Table 4.5.1 Data of summary statistics of 12 wild rice genotypes for 6 microsatellites (SSR) markers**

| Genotypes       | Major Allele Frequency | Genotype no. | Sample Size | Allele no. | Availability | Gene Diversity | Heterozygosity | PIC         |
|-----------------|------------------------|--------------|-------------|------------|--------------|----------------|----------------|-------------|
| G <sub>1</sub>  | 0.90                   | 2.00         | 72.00       | 2.00       | 1.0000       | <b>0.17</b>    | 0.0000         | <b>0.16</b> |
| G <sub>2</sub>  | 0.56                   | 2.00         | 72.00       | 2.00       | 1.0000       | 0.50           | 0.0000         | 0.37        |
| G <sub>3</sub>  | 0.72                   | 2.00         | 72.00       | 2.00       | 1.0000       | 0.40           | 0.0000         | 0.32        |
| G <sub>4</sub>  | 0.83                   | 2.00         | 72.00       | 2.00       | 1.0000       | <b>0.50</b>    | 0.0000         | 0.25        |
| G <sub>5</sub>  | 0.53                   | 2.00         | 72.00       | 2.00       | 1.0000       | 0.50           | 0.0000         | 0.37        |
| G <sub>6</sub>  | 0.50                   | 2.00         | 72.00       | 2.00       | 1.0000       | <b>0.50</b>    | 0.0000         | 0.37        |
| G <sub>7</sub>  | 0.53                   | 2.00         | 72.00       | 2.00       | 1.0000       | 0.50           | 0.0000         | 0.37        |
| G <sub>8</sub>  | 0.72                   | 2.00         | 72.00       | 2.00       | 1.0000       | 0.40           | 0.0000         | 0.32        |
| G <sub>9</sub>  | 0.82                   | 2.00         | 72.00       | 2.00       | 1.0000       | 0.48           | 0.0000         | 0.26        |
| G <sub>10</sub> | 0.51                   | 2.00         | 72.00       | 2.00       | 1.0000       | 0.45           | 0.0000         | 0.37        |
| G <sub>11</sub> | 0.81                   | 2.00         | 72.00       | 2.00       | 1.0000       | 0.30           | 0.0000         | 0.26        |
| G <sub>12</sub> | 0.69                   | 2.00         | 72.00       | 2.00       | 1.0000       | 0.43           | 0.0000         | 0.34        |
| <b>Mean</b>     | 0.68                   | 2.00         | 72.00       | 2.00       | 1.0000       | 0.43           | 0.0000         | 0.31        |

Here, G<sub>1</sub>-*O. rufipogon*, G<sub>2</sub>- *O. alta*, G<sub>3</sub>- *O. longistiminata*, G<sub>4</sub>- *O. barthii*, G<sub>5</sub>- *O. latifolia*, G<sub>6</sub>- *O. officinalis*, G<sub>7</sub>- *O. nivara*, G<sub>8</sub>- *O. punctata*, G<sub>9</sub>- *O. glaberima*, G<sub>10</sub>-*Portericia coactata*, G<sub>11</sub>-Pokkali , G<sub>12</sub>-Nonabokra.

From an UPGMA cluster dendrogram observed four major clusters of 12 wild rice genotypes. Cluster I contained four genotypes which were *O. rufipogon*, *O. longistiminata*, *O. alta* and Pokkali. Cluster II contained two genotypes as *O. barthii*, and *O. latifolia*. Cluster III consisted of three genotypes namely *O. officinalis*, *O. punctata* and *O. nivara*,. Cluster IV consisted of three genotypes namely *O. glaberima*, *Portericia coactata*, and Nonabokra. This cluster tree analysis with the allelic diversity observed among 12 wild rice genotypes. So, SSR markers in this study presented adequate power of resolution to categorize between genotypes which could serve as a potential tool in the identification and characterization of wild rice genotypes from various sources. Genetically related genotypes were grouped into same cluster due to their similarity in genetic information and lower genetic distance. Higher genetic distance and lower genetic similarity were remained between one cluster to another. Similarly, Negawo *et al.* (2018) experiments showed that the hierarchical cluster analysis assembled the collections into 4 main clusters with further sub-clusters. Most of the EMBRAPA accessions were captured in Clusters II and IV, while the majority of the individuals in the other 2 clusters came from the ILRI gene bank collection.

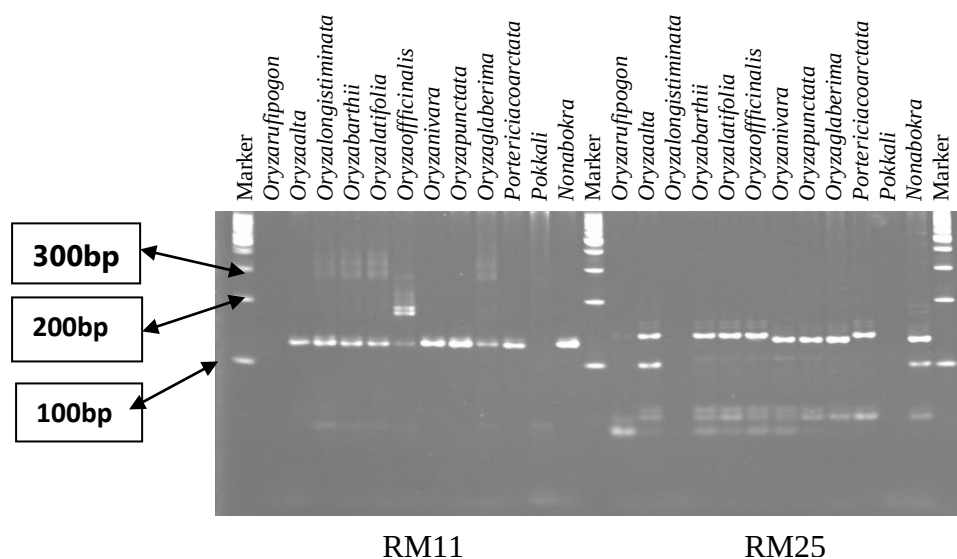


**Figure 4.5.1 Amplification profile of primer RM11 and RM25 for each 12 wild rice genotypes in 1.0% agarose gel stained with ethidium bromide. Three micro liter of PCR product was used in each sample**

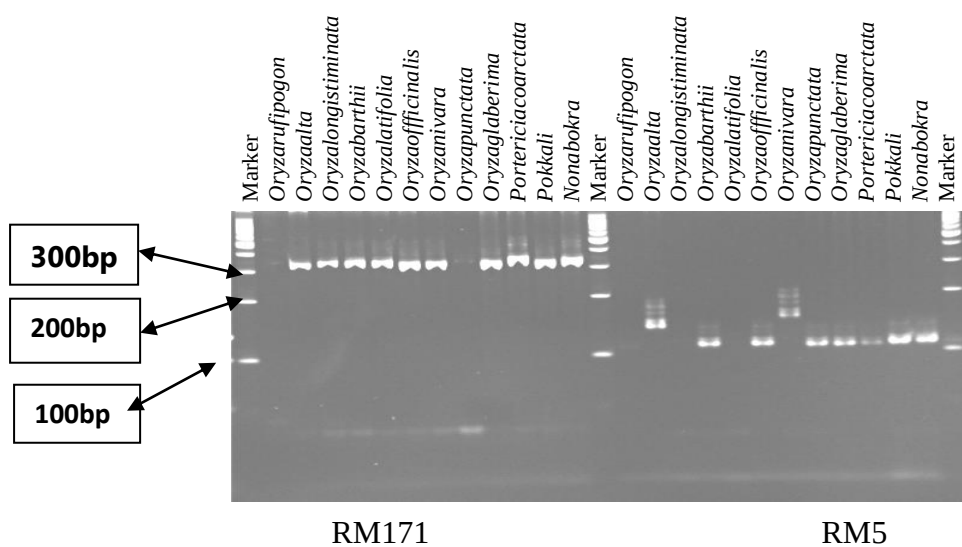


**Figure 4.5.2 Amplification profile of primer RM171 and RM5 for each 12 wild rice genotypes in 1.0% agarose gel stained with ethidium bromide. Three micro liter of PCR product was used in each sample**

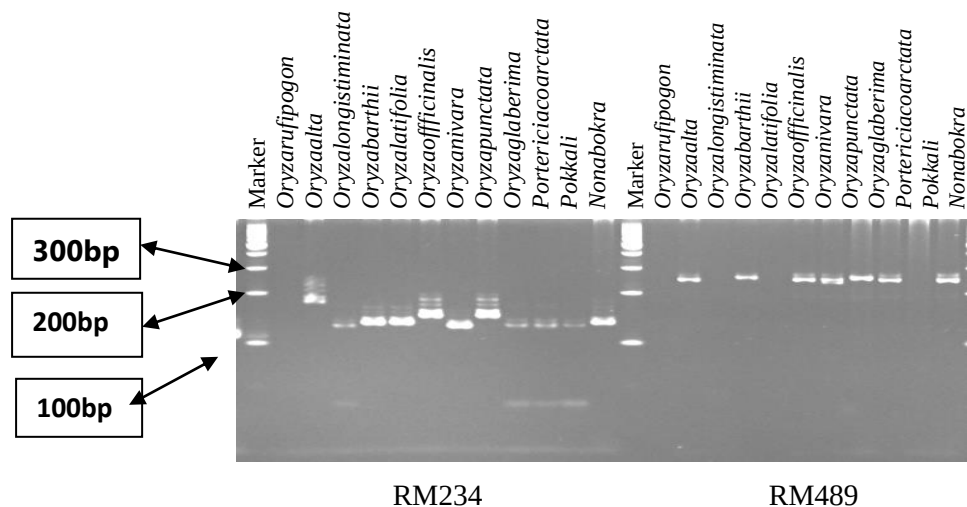


**Figure 4.5.3 Amplification profile of primer RM234 and RM489for each 12 wild rice genotypes in 1.0% agarose gel stained with ethidium bromide. Three micro liter of PCR product was used in each sample**

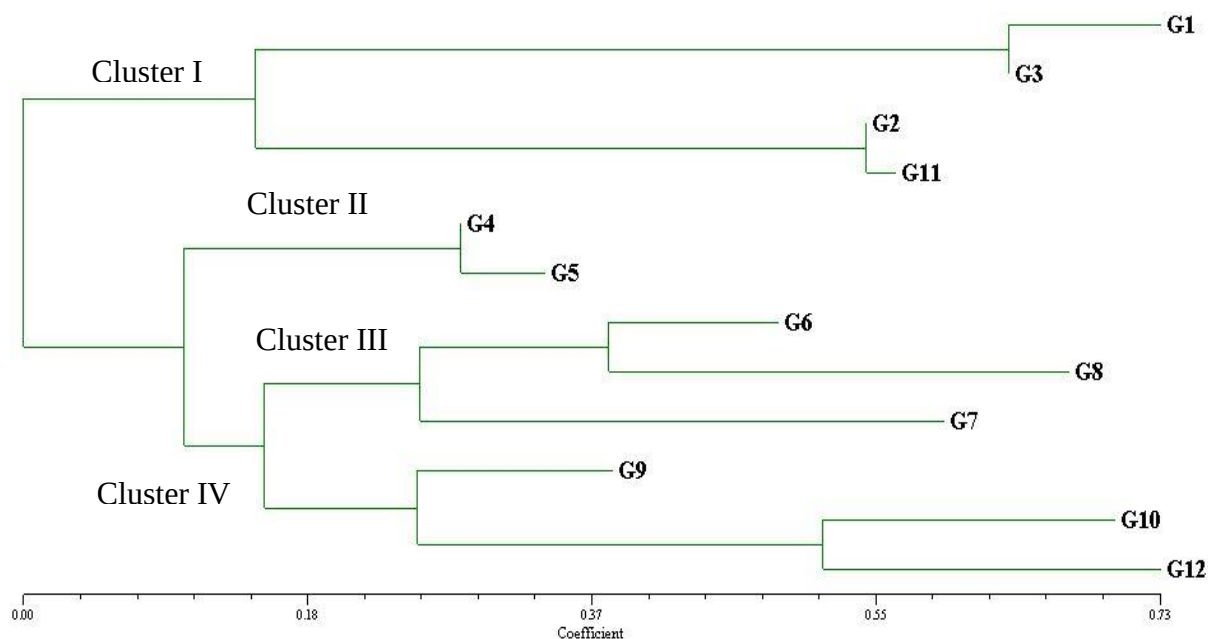


**Figure 4.5.4 An UPGMA cluster dendrogramin neighbor format showing genetic relationships among 12 wild rice genotypes based on 6 SSR markers. Here cophenetic correlation coefficient (CP) value is 0.00-0.73 and G<sub>1</sub>-*Oryza rufipogon*, G<sub>2</sub>- *Oryza alta*, G<sub>3</sub>- *Oryza longistiminata*, G<sub>4</sub>- *Oryza barhii*, G<sub>5</sub>- *Oryza latifolia*, G<sub>6</sub>- *Oryza officinalis*, G<sub>7</sub>- *Oryza nivara*, G<sub>8</sub>- *Oryza punctata*, G<sub>9</sub>- *Oryza glaberima*, G<sub>10</sub>-*Portericia coactata*, G<sub>11</sub>-*Pokkali* and G<sub>12</sub>-*Nonabokra***

#### 4.5.3 Genetic distance similarity based analysis

Nei genetic distance (1983) value and similarity matrix type 3 was computed by NTSYS-PC (version 2.10e) based on SM by Cols coefficient. The similarity matrix was used to determine the level of relatedness among the 12 wild rice genotypes. The values of pair-wise comparisons of genetic distance between 12 wild rice genotypes were computed from combined data sets for the 6 primers ranging from 0.6827 to 0.8654 (Table 4.5.2). Comparatively higher genetic distance (0.8654) was observed between Pokkali, Nonabokra vs *Portericia coarctata*. The lowest genetic distance (0.6827) was revealed between *O. officinalis* vs *O. nivara*. The smaller number of pair-wise differences (high genetic similarity value) among some wild rice genotypes were likely due to their genetically relatedness. On the other hand, large number of pair-wise differences (low genetic similarity value) was observed among those wild rice genotypes developed from genetically distant parental. According to the relationship of lower genetic distance among the genotypes all of them were tolerant. The rice population dynamics is some extent linked to human activities. In addition to the biological determinants, farmers' management practices and preferences greatly influence the distribution of genetic diversity and the levels of gene flow (Roy *et al.*, 2015). In conclusion, molecular characterization of salt tolerant wild rice landraces revealed that large variation exists among the genotypes. The genetic diversity preserved in the salt tolerant wild rice gene pool will facilitate proper maintenance, conservation and utilization of this valuable resource for further improvement in coastal area.

#### 4.5.4 Pair wise genetic dissimilarity

A dissimilarity matrix type 2 (Nei *et al.*, 1983) was constructed based on NEI72 by Cols coefficient. It was used to determine the level of genetic dissimilarity among the genotypes studied (Table 4.5.3). The pairwise genetic dissimilarity co-efficient indicated high genetic dissimilarity among most of the wild rice genotypes. The highest genetic dissimilarity was found 1.9945 between Pokkali and *Oryza punctata* of wild rice genotypes. Whereas, lowest genetic dissimilarity was found (0.0323) between the genotypes *Oryza latifolia* vs *Oryza barthii* among these tested genotypes. The pairwise genotypes having high genetic distance could be potential target for breeding program.

**Table 4.5.2 Genetic distance similarity among 12 wild rice genotypes obtained from microsatellite marker analysis**

| G <sub>1</sub>  | G <sub>2</sub> | G <sub>3</sub> | G <sub>4</sub> | G <sub>5</sub> | G <sub>6</sub> | G <sub>7</sub> | G <sub>8</sub> | G <sub>9</sub> | G <sub>10</sub> | G <sub>11</sub> | G <sub>12</sub> |   |
|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|-----------------|-----------------|-----------------|---|
| -----           |                |                |                |                |                |                |                |                |                 |                 |                 |   |
| G <sub>1</sub>  | 1.0000         |                |                |                |                |                |                |                |                 |                 |                 |   |
| G <sub>2</sub>  | 0.7981         | 1.0000         |                |                |                |                |                |                |                 |                 |                 |   |
| G <sub>3</sub>  | 0.7788         | 0.7500         | 1.0000         |                |                |                |                |                |                 |                 |                 |   |
| G <sub>4</sub>  | 0.7788         | 0.7885         | 0.8269         | 1.0000         |                |                |                |                |                 |                 |                 |   |
| G <sub>5</sub>  | 0.7404         | 0.7308         | 0.7692         | 0.7885         | 1.0000         |                |                |                |                 |                 |                 |   |
| G <sub>6</sub>  | 0.7788         | 0.7692         | 0.7692         | 0.8077         | 0.8654         | 1.0000         |                |                |                 |                 |                 |   |
| G <sub>7</sub>  | 0.7788         | 0.7692         | 0.7692         | 0.8077         | 0.7692         | 0.7692         | 1.0000         |                |                 |                 |                 |   |
| G <sub>8</sub>  | 0.7308         | 0.7212         | 0.7019         | 0.7596         | 0.7019         | 0.7212         | 0.8173         | 1.0000         |                 |                 |                 |   |
| G <sub>9</sub>  | 0.7115         | 0.7212         | 0.7212         | 0.7596         | 0.7212         | 0.7212         | 0.7596         | 0.6923         | 1.0000          |                 |                 |   |
| G <sub>10</sub> | 0.7500         | 0.7404         | 0.7596         | 0.7788         | 0.7596         | 0.7404         | 0.7788         | 0.7308         | 0.8077          | 1.0000          |                 |   |
| G <sub>11</sub> | 0.7596         | 0.7692         | 0.7692         | 0.7692         | 0.7308         | 0.7885         | 0.7500         | 0.6827         | 0.7019          | 0.7212          | 1.0000          |   |
| G <sub>12</sub> | 0.7596         | 0.7500         | 0.7500         | 0.7885         | 0.7692         | 0.8077         | 0.7500         | 0.6827         | 0.7212          | 0.7404          | 0.8269          | 1 |

Here, G<sub>1</sub>-*O. rufipogon*, G<sub>2</sub>- *O. alta*, G<sub>3</sub>- *O. longistiminata*, G<sub>4</sub>- *O. barthii*, G<sub>5</sub>- *O. latifolia*, G<sub>6</sub>- *O. officinalis*, G<sub>7</sub>- *O. nivara*, G<sub>8</sub>- *O. punctata*, G<sub>9</sub>- *O. glaberima*, G<sub>10</sub>-*Portericia coactata*, G<sub>11</sub>-Pokkali , G<sub>12</sub>-Nonabokra.

**Table 4.5.3 Genetic distance dissimilarity among 12 wild rice genotypes obtained from microsatellite marker analysis**

|                 | G <sub>1</sub> | G <sub>2</sub> | G <sub>3</sub> | G <sub>4</sub> | G <sub>5</sub> | G <sub>6</sub> | G <sub>7</sub> | G <sub>8</sub> | G <sub>9</sub> | G <sub>10</sub> | G <sub>11</sub> | G <sub>12</sub> |
|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|-----------------|-----------------|-----------------|
| G <sub>1</sub>  | 0.0000         |                |                |                |                |                |                |                |                |                 |                 |                 |
| G <sub>2</sub>  | 1.1757         | 0.0000         |                |                |                |                |                |                |                |                 |                 |                 |
| G <sub>3</sub>  | 0.0000         | 1.7250         | 0.0000         |                |                |                |                |                |                |                 |                 |                 |
| G <sub>4</sub>  | 1.2425         | 0.9141         | 0.4055         | 0.0000         |                |                |                |                |                |                 |                 |                 |
| G <sub>5</sub>  | 1.2102         | 0.8818         | 0.3732         | 0.0323         | 0.0000         |                |                |                |                |                 |                 |                 |
| G <sub>6</sub>  | 0.8370         | 0.7599         | 1.0986         | 0.3747         | 0.4377         | 0.0000         |                |                |                |                 |                 |                 |
| G <sub>7</sub>  | 0.8047         | 0.7276         | 1.3540         | 0.7944         | 0.7621         | 0.6609         | 0.0000         |                |                |                 |                 |                 |
| G <sub>8</sub>  | 1.6479         | 1.0318         | 1.5041         | 0.6931         | 0.8432         | 0.4055         | 0.6609         | 0.0000         |                |                 |                 |                 |
| G <sub>9</sub>  | 1.8318         | 1.2157         | 0.4352         | 0.3662         | 0.4393         | 0.7229         | 0.6906         | 0.5893         | 0.0000         |                 |                 |                 |
| G <sub>10</sub> | 1.7483         | 0.9090         | 1.1989         | 0.6393         | 0.7612         | 0.7935         | 1.1667         | 1.1989         | 0.6897         | 0.0000          |                 |                 |
| G <sub>11</sub> | 0.0000         | 0.0000         | 0.6082         | 0.8959         | 1.1513         | 0.8959         | 1.5568         | 1.9945         | 0.5689         | 0.9962          | 0.0000          |                 |
| G <sub>12</sub> | 1.7006         | 1.0845         | 1.5568         | 0.9281         | 1.1190         | 1.1513         | 0.7136         | 0.8636         | 0.4879         | 0.4043          | 0.9486          | 0.0000          |

Here, G<sub>1</sub>-*O. rufipogon*, G<sub>2</sub>- *O. alta*, G<sub>3</sub>- *O. longistiminata*, G<sub>4</sub>- *O. barthii*, G<sub>5</sub>- *O. latifolia*, G<sub>6</sub>- *O. officinalis*, G<sub>7</sub>- *O. nivara*, G<sub>8</sub>- *O. punctata*, G<sub>9</sub>- *O. glaberima*, G<sub>10</sub>-*Portericia coactata*, G<sub>11</sub>-Pokkali , G<sub>12</sub>-Nonabokr

## CHAPTER V

### SUMMARY AND CONCLUSION

The present piece of work was consisted of five experiments which were conducted during 2018 to 2020. The aim of the investigation was to screenout the desirable wild rice genotypes under stressed environmental condition (salinity and drought) through assessing their morpho-physiological, yield and yield determinant characters.

In the 1<sup>st</sup> experiment, 40 accessions under 10 wild species of rice were tested to assess their performance under normal environment. Some of the genotypes performed excellent and some performed poor, intermediated performance was also observed. The results of the 1<sup>st</sup> experiment revealed that, the longest plant (194.00 cm) was recorded from *O. latifolia* ACC. No.2 (V<sub>5</sub>) and the shortest plant (103.00 cm) was recorded from *P. coractata* ACC. No.3 (V<sub>33</sub>). The maximum leaves hill<sup>-1</sup> (10.07) was scored by *O. rufipogon* ACC. No.2 (V<sub>4</sub>) and the minimum leaves hill<sup>-1</sup> (5.53) was scored by *O. alta* ACC. No.3 (V<sub>38</sub>). The maximum nodes plant<sup>-1</sup> (10.00) was found from *O. rufipogon* ACC. No.2 (V<sub>4</sub>) where as the minimum nodes plant<sup>-1</sup> (3.47) was found from *O. alta* ACC. No.1 (V<sub>12</sub>), *O. alta* ACC. No.2 (V<sub>14</sub>) and *O. alta* ACC. No.3 (V<sub>38</sub>). The highest chlorophyll content on leaves (42.28%) was recorded from *O. latifolia* ACC. No.2 (V<sub>5</sub>) treatment on the other hand the lowest chlorophyll content on leaves (29.28%) was recorded from *O. nivara* ACC. No.2 (V<sub>6</sub>). The longest normal leaf (56.01 cm) was recorded from *O. latifolia* ACC. No.3 (V<sub>21</sub>) and the shortest normal leaf (11.93 cm) was recorded from *P. coractata* ACC. No.2 (V<sub>31</sub>). The widest normal leaf (3.00 cm) was observed from *O. latifolia* ACC. No.4 (V<sub>24</sub>) whereas the narrowest normal leaf (0.75 cm) was observed from both *P. coractata* ACC. No.2 (V<sub>31</sub>) and *P. coractata* ACC. No.3 (V<sub>33</sub>). The maximum length breadth ratio of normal leaf (27.90) was recorded from *O. rufipogon* ACC. No.5 (V<sub>26</sub>) and the minimum length breadth ratio of normal leaf (7.98) was recorded from *O. alta* ACC. No.1 (V<sub>12</sub>). The maximum normal leaf area (123.10 cm<sup>2</sup>) was distinctly recorded from *O. latifolia* ACC. No.2 (V<sub>5</sub>) and the minimum normal leaf area (7.44 cm<sup>2</sup>) was recorded from *P. coractata* ACC. No.3 (V<sub>33</sub>). The longest flag leaf (46.10 cm) was recorded from *O. latifolia* ACC. No.2 (V<sub>5</sub>) and the shortest flag leaf (8.43 cm) was recorded from *P. coaractata* ACC. No.1 (V<sub>9</sub>). The widest flag leaf (3.70 cm) was observed from *O. alta* ACC. No.3 (V<sub>38</sub>) whereas the narrowest flag leaf (0.69 cm) was

observed from both *P. coractata* ACC. No.2 (V<sub>31</sub>) and *P. coractata* ACC. No.3 (V<sub>33</sub>). The maximum length breadth ratio of flag leaf (14.49) was observed from *O. latifolia* ACC. No.2 (V<sub>5</sub>) and the minimum length breadth ratio of flag leaf (3.94) was observed from *O. alta* ACC. No.2 (V<sub>14</sub>). The maximum flag leaf area (98.90 cm<sup>2</sup>) was distinctly recorded from *O. latifolia* ACC. No.2 (V<sub>5</sub>) and the minimum flag leaf area (3.45 cm<sup>2</sup>) was recorded from *P. coaractata* ACC. No.1 (V<sub>9</sub>).

The longest root (45.00 cm) was recorded from *O. latifolia* ACC. No.2 (V<sub>5</sub>) and the shortest root (9.83 cm) was recorded from *O. glaberrima* ACC. No.1 (V<sub>29</sub>). The maximum root dry weight hill<sup>-1</sup> (190.90 g) was found from *O. glaberrima* ACC. No.3 (V<sub>37</sub>) rice genotype and the minimum root dry weight hill<sup>-1</sup> (24.92 g) was found from *P. coractata* ACC. No.2 (V<sub>31</sub>) rice genotype. The maximum shoot dry weight hill<sup>-1</sup> (211.70 g) was scored by *O. rufipogon* ACC. No.6 (V<sub>30</sub>) and the minimum shoot dry weight hill<sup>-1</sup> (39.92 g) was scored by *P. coractata* ACC. No.2 (V<sub>31</sub>). The maximum total dry weight hill<sup>-1</sup> (377.8 g) was scored by *O. latifolia* ACC. No.2 (V<sub>5</sub>) on the other hand the minimum total dry weight hill<sup>-1</sup> (58.53 g) was scored by *O. officinalis* ACC. No.1 (V<sub>7</sub>). The delayed 1<sup>st</sup> flowering (233.70 days) was observed from both *O. rufipogon* ACC. No.4 (V<sub>25</sub>) and *O. rufipogon* ACC. No.5 (V<sub>26</sub>) where as the earliest 1<sup>st</sup> flowering (106.30 days) was observed from *O. latifolia* ACC. No.3 (V<sub>21</sub>). The longest growth duration (270.00 days) was found in *O. rufipogon* ACC. No.2 (V<sub>4</sub>), *O. rufipogon* ACC. No.4 (V<sub>25</sub>), *O. rufipogon* ACC. No.6 (V<sub>30</sub>) and *O. rufipogon* ACC. No.7 (V<sub>34</sub>) and the shortest growth duration (145.00 days) was found in *O. latifolia* ACC. No.1 (V<sub>2</sub>), *O. latifolia* ACC. No.2 (V<sub>5</sub>), *O. alta* ACC. No.1 (V<sub>12</sub>), *O. alta* ACC. No.2 (V<sub>14</sub>), *O. latifolia* ACC. No.3 (V<sub>21</sub>), *O. latifolia* ACC. No.4 (V<sub>24</sub>) and *O. alta* ACC. No.3 (V<sub>38</sub>).

The maximum tillers hill<sup>-1</sup> (135.00) was achieved from *O. rufipogon* ACC. No.7 (V<sub>34</sub>) and the minimum tillers hill<sup>-1</sup> (24.00) was achieved from *O. latifolia* ACC. No.3 (V<sub>21</sub>). The highest effective tillers hill<sup>-1</sup> (81.33) was recorded from *O. rufipogon* ACC. No.7 (V<sub>34</sub>) and the lowest effective tillers hill<sup>-1</sup> (12.67) was recorded from both *O. latifolia* ACC. No.3 (V<sub>21</sub>) and *O. latifolia* ACC. No.4 (V<sub>24</sub>) wild rice varieties. The highest non-effective tillers hill<sup>-1</sup> (53.67) was recorded from *O. rufipogon* ACC. No.7 (V<sub>34</sub>) and the lowest non-effective tillers hill<sup>-1</sup> (10.33) was recorded from *O. barthii* ACC. No.6 (V<sub>18</sub>). The longest panicle (49.50 cm) was achieved from *O. latifolia* ACC. No.2



(V<sub>5</sub>) and the shortest panicle (14.87 cm) was achieved from *O. rufipogon* ACC. No.7 (V<sub>34</sub>). The maximum grains panicle<sup>-1</sup> (359.70) was observed from *O. latifolia* ACC. No.4 (V<sub>24</sub>) and the minimum grains panicle<sup>-1</sup> (35.00) was observed from *O. rufipogon* ACC. No.2 (V<sub>4</sub>). The maximum filled grains panicle<sup>-1</sup> (165.00) was observed from *O. longistaminata* ACC. No.3 (V<sub>20</sub>) and the minimum filled grains panicle<sup>-1</sup> (10.67) was observed from *O. latifolia* ACC. No.4 (V<sub>24</sub>). The maximum unfilled grains panicle<sup>-1</sup> (325.30) was observed from *O. latifolia* ACC. No.4 (V<sub>24</sub>) and the minimum unfilled grains panicle<sup>-1</sup> (5.00) was observed from *O. nivara* ACC. No.3 (V<sub>10</sub>). The highest thousand grain weight (33.61g) was recorded from *O. barthii* ACC. No.6 (V<sub>18</sub>) where as the lowest thousand grain weight (8.06 g) was recorded from *O. officinalis* ACC. No.1 (V<sub>7</sub>). The highest grain yield hill<sup>-1</sup> (101.60 g) was distinctly recorded from *O. nivara* ACC. No.6 (V<sub>28</sub>) and the lowest grain yield hill<sup>-1</sup> (3.52 g) was recorded from *O. latifolia* ACC. No.4 (V<sub>24</sub>). The maximum biological yield hill<sup>-1</sup> (288.00 g) was distinctly found from *O. nivara* ACC. No.6 (V<sub>28</sub>) and the minimum biological yield hill<sup>-1</sup> (63.20 g) was found from *P. coractata* ACC. No.2 (V<sub>31</sub>). The maximum harvest index (40.59 %) was distinctly recorded from *O. barthii* ACC. No.6 (V<sub>18</sub>) and the minimum harvest index (2.61 %) was recorded from *O. latifolia* ACC. No.3 (V<sub>21</sub>).

After cluster analysis the results revealed that the genotypes in cluster I showed the highest values of length breadth ratio (18.33), root dry weight (163.58 g), grain yield hill<sup>-1</sup> (61.85 g), biological yield (229.46 g) and growth duration (262.50 days). Cluster II had the maximum cluster mean values for the plant height (188.53 cm), leaf length (53.62) and leaf breadth (2.93), grain panicle<sup>-1</sup> (336.25) and minimum growth duration (145 d). Cluster III produced the highest cluster mean for the character of total tiller hill<sup>-1</sup> (99.07), effective tiller (61.53) and non-effective tiller (37.53), shoot dry weight (179.62 g), total dry weight (337.78 g) and maximum days to flowering (229.20). Cluster IV had showed the reasonable values highest filled grain panicle<sup>-1</sup> (119.88). Cluster V had the maximum mean values for the harvest index (36.78). The distribution of genotypes showed that clusters IV included the maximum number of accessions (17) followed by clusters III (11), cluster II (5), cluster V (4) and cluster I (3).

The principal component analysis (PCA) clearly and concisely explains the genetic diversity of wild rice genotypes. Out of sixteen principal components, three principal

components (PCs) depicted more than one Eigen value. The first three principal components PC1, PC2 and PC3 explained 44.57%, 16.34% and 11.85% of variation, respectively with 72.75% cumulative variance among all attributes. The results showed that the first two principal components accounted for 60.91% of the total variation among 16 component axes of the total genotypes, whereas the Eigen values were found as 82.03% in the first four component axes. The attributes of worthy importance in PC1 were total tiller hill<sup>-1</sup> (0.33), effective tiller (0.35), thousand-seed weight (0.25) and grain yield hill<sup>-1</sup> (0.25). The inter-cluster distances were larger than intra-cluster distances in all cases, suggesting wider genetic diversity among the genotypes of different groups. The maximum inter-cluster distance was observed between clusters II and V (602.11) followed by clusters I and II (588.51). The minimum inter-cluster distance was observed between clusters III and IV (311.90), indicating a close relation distance among the genotypes of those clusters. These results revealed that the genotypes in cluster III were distantly related. On the other hand, the genotypes in cluster IV were closely related. Ten genotypes were selected from these two clusters (III and IV) to use next trials for obtaining a wide spectrum of variation among the segregates.

In the 2<sup>nd</sup> experiment, 10 wild rice genotypes were evaluated through assessing their morpho-physiological, yield and yield contributing traits.

The results showed that, at harvest the tallest plant (198.50 cm), maximum leaf area hill<sup>-1</sup> (3797.00 cm<sup>2</sup>) and highest LAI (6.17) were recorded from *O. latifolia* (V<sub>4</sub>) and the shortest plant (106.3 cm), minimum leaf area hill<sup>-1</sup> (571.50 cm<sup>2</sup>) and minimum LAI (0.93) were recorded from *P. coactata* (V<sub>5</sub>). At harvest, the highest dry matter weight hill<sup>-1</sup> (390.60 g) was produced by *O. nivara* (V<sub>3</sub>) and the lowest dry matter weight hill<sup>-1</sup> (79.16 g) was produced by *P. coactata* (V<sub>5</sub>). Rice genotype *O. latifolia* (V<sub>4</sub>) produced the longest normal leaf (54.40 cm), widest normal leaf (2.93 cm), highest normal leaf area (123.10 cm<sup>2</sup>), longest flag leaf (46.10 cm) and highest flag leaf area (98.90 cm<sup>2</sup>) while *P. coactata* (V<sub>5</sub>) produced the shortest normal leaf (12.93 cm), narrowest normal leaf (0.76 cm), lowest normal leaf area (7.77 cm<sup>2</sup>), shortest flag leaf (8.43 cm) and lowest flag leaf area (3.45 cm<sup>2</sup>). The maximum normal leaf length breadth ratio (26.51) was scored by *O. rufipogon* (V<sub>1</sub>) and the minimum normal leaf length breadth ratio (11.76) was scored by *O. officinalis* (V<sub>8</sub>). *O. alta* (V<sub>2</sub>)

distinctly scored the widest flag leaf (3.70 cm) where as *P. coactata* (V<sub>5</sub>) distinctly scored the narrowest flag leaf (0.70 cm). The maximum flag leaf length breadth ratio (15.09) was produced by *O. latifolia* (V<sub>4</sub>) and the minimum flag leaf length breadth ratio (3.80) was distinctly produced by *O. alta* (V<sub>2</sub>). The maximum leaves hill<sup>-1</sup> (9.27) was obtained from *O. barthii* (V<sub>10</sub>) on the other hand the minimum leaves hill<sup>-1</sup> (5.53) was obtained from *O. alta* (V<sub>2</sub>). The maximum nodes plant<sup>-1</sup> (7.40) was obtained from both *O. rufipogon* (V<sub>1</sub>) and *O. barthii* (V<sub>10</sub>) and the minimum nodes plant<sup>-1</sup> (3.33) was obtained from *O. alta* (V<sub>2</sub>). The delayed 1<sup>st</sup> flowering (232.00 days) was observed in *O. rufipogon* (V<sub>1</sub>) and the earliest 1<sup>st</sup> flowering (107.00 days) was observed in both *O. latifolia* (V<sub>4</sub>) and *P. coactata* (V<sub>5</sub>). The longest growth duration (265.00 days) was observed in both *O. rufipogon* (V<sub>1</sub>) and *O. glaberrima* (V<sub>6</sub>) and the shortest growth duration (145.00 days) was observed in *O. alta* (V<sub>2</sub>).

The maximum chlorophyll content on leaf (35.07 % at harvest) was achieved from *O. latifolia* (V<sub>4</sub>) and the minimum chlorophyll content on leaf (29.30%) was achieved from *O. rufipogon* (V<sub>1</sub>). The maximum shoot dry weight hill<sup>-1</sup> (202.10 g), maximum root dry weight hill<sup>-1</sup> (188.10 g) and maximum total dry weight hill<sup>-1</sup> (390.50 g) were produced by *O. nivara* (V<sub>3</sub>) and the minimum shoot dry weight hill<sup>-1</sup> (39.79 g), minimum root dry weight hill<sup>-1</sup> (47.38 g) and minimum total dry weight hill<sup>-1</sup> (79.16 g) were produced by *P. coactata* (V<sub>5</sub>). At 100 DAT- harvest the maximum CGR (38.11 g m<sup>-2</sup>d<sup>-1</sup>) was observed from *O. nivara* (V<sub>3</sub>) and the minimum CGR (6.44 g m<sup>-2</sup>d<sup>-1</sup>) was observed from *P. coactata* (V<sub>5</sub>). At 100 DAT-harvest the maximum RGR (3.67 g g<sup>-1</sup> d<sup>-1</sup>) was scored by *O. barthii* (V<sub>10</sub>) and the minimum RGR (1.09 g g<sup>-1</sup> d<sup>-1</sup>) was scored by *O. glaberrima* (V<sub>6</sub>). At 100 DAT-harvest the maximum NAR (0.030 g cm<sup>-2</sup> d<sup>-1</sup>) was recorded from both *P. coactata* (V<sub>5</sub>) and *O. nivara* (V<sub>3</sub>) and the minimum NAR (0.010 g cm<sup>-2</sup> d<sup>-1</sup>) was recorded from *O. rufipogon* (V<sub>1</sub>), *O. alta* (V<sub>2</sub>) and *O. latifolia* (V<sub>4</sub>). The maximum LAD (1079.00 dm<sup>2</sup> at 100 DAT-harvest) was obtained from *O. latifolia* (V<sub>4</sub>) and the minimum LAD (146.60 dm<sup>2</sup> at 100 DAT-harvest) was obtained from *P. coactata* (V<sub>5</sub>). At harvest the maximum AGR (0.48 g day<sup>-1</sup> hill<sup>-1</sup>) was found from *O. latifolia* (V<sub>4</sub>) and the minimum AGR (0.16 g day<sup>-1</sup> hill<sup>-1</sup>) was found from *O. nivara* (V<sub>3</sub>), *O. glaberrima* (V<sub>6</sub>) and *O. longistaminata* (V<sub>7</sub>). *O. barthii* (V<sub>10</sub>) produced the maximum SLA (13.00 cm<sup>2</sup> g<sup>-1</sup> at 100 DAT-harvest) and *O. rufipogon* (V<sub>1</sub>) produced the minimum SLA (5.60 cm<sup>2</sup> g<sup>-1</sup> at 100 DAT-harvest).

The maximum tillers hill<sup>-1</sup> (93.00) and maximum effective tillers hill<sup>-1</sup> (72.00) were distinctly produced by *O. nivara* (V<sub>3</sub>) and the minimum tillers hill<sup>-1</sup> (29.67) and minimum effective tillers hill<sup>-1</sup> (19.33) were produced by *O. latifolia* (V<sub>4</sub>). The maximum non-effective tillers hill<sup>-1</sup> (44.00) was distinctly produced by *P. coactata* (V<sub>5</sub>) and the minimum non effective tillers hill<sup>-1</sup> (13.33) was produced by *O. glaberrima* (V<sub>6</sub>). The longest panicle (48.73 cm) was observed from *O. latifolia* (V<sub>4</sub>) and the shortest panicle (17.27 cm) was observed from *P. coactata* (V<sub>5</sub>). The maximum grains panicle<sup>-1</sup> (350.70) was distinctly observed from *O. latifolia* (V<sub>4</sub>) and the minimum grains panicle<sup>-1</sup> (42.00) was distinctly observed from *O. barthii* (V<sub>10</sub>). The maximum filled grains panicle<sup>-1</sup> (161.70) was distinctly produced by *O. longistaminata* (V<sub>7</sub>) and the minimum filled grains panicle<sup>-1</sup> (31.67) was distinctly produced by *O. barthii* (V<sub>10</sub>). The maximum unfilled grains panicle<sup>-1</sup> (295.00) was distinctly obtained from *O. latifolia* (V<sub>4</sub>) and the minimum unfilled grains panicle<sup>-1</sup> (6.33) was obtained from *O. nivara* (V<sub>3</sub>). The maximum thousand grain weight (26.66 g) was recorded from *O. nivara* (V<sub>3</sub>) and the minimum thousand grain weight (7.22 g) was recorded from *O. barthii* (V<sub>10</sub>). The maximum grain yield hill<sup>-1</sup> (101.90 g) was distinctly produced by *O. nivara* (V<sub>3</sub>) and the minimum grain yield hill<sup>-1</sup> (9.00 g) was produced by *O. latifolia* (V<sub>4</sub>). The maximum biological yield hill<sup>-1</sup> (303.90 g) was distinctly produced by *O. nivara* (V<sub>3</sub>) and the minimum biological yield hill<sup>-1</sup> (53.92 g) was distinctly produced by *P. coactata* (V<sub>5</sub>). The maximum harvest index (35.25 %) was recorded from *O. barthii* (V<sub>10</sub>) and the minimum harvest index (4.37 %) was distinctly recorded from *O. latifolia* (V<sub>4</sub>).

Form the above summarized data it may be concluded that, the wild rice genotypes exerted fluctuating result for different morpho-physiological traits. The maximum grain yield hill<sup>-1</sup> (101.90 g) was distinctly produced by wild rice genotype *O. nivara* (V<sub>3</sub>) and the minimum grain yield hill<sup>-1</sup> (9.00 g) was produced by wild rice genotype *O. latifolia* (V<sub>4</sub>).

The 3<sup>rd</sup> experiment was comprised of two factors; Factor A: 12 rice genotypes viz., V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. punctata*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. barthii*, V<sub>5</sub>= *O. longistaminata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= FR13A (Chec variety as drought tolerant), V<sub>8</sub>= BRRI Dhan29 (Check variety as drought sensitive), V<sub>9</sub>= *O. alta*, V<sub>10</sub>= *Potericia coaractata*, V<sub>11</sub>=*O. latifolia* and V<sub>12</sub>=*O. officinalis* and Factor B: 2 drought stress

levels viz., D<sub>1</sub>= No drought stress (Control) and D<sub>2</sub>= 40-45 % field capacity. Drought stress significantly affected the plant growth, yield, yield contributing traits and water relation behavior of wild rice. The results revealed that the maximum decrease of plant height (9.66%), root length (28.54%), panicle length (21.64%) and water uptake capacity (24.42%) was counted from FR13A (Check variety as drought tolerant) (V<sub>7</sub>) under drought stress condition. The maximum decrease of leaves plant<sup>-1</sup> (14.14%), normal leaf length (23.89%), normal leaf ratio (17.96%), normal leaf area (23.23%), grain fertility percentage (11.01%), thousand grain weight (4.13%), carotenoids content (29.18%) was recorded from wild rice genotype *O. punctata* (V<sub>2</sub>) under drought stress condition. But increase of unfilled grains panicle<sup>-1</sup> (20.45%), grain sterility percentage (25.37%) and increase of harvest index (10.77%), was observed from wild rice genotype *O. punctata* (V<sub>2</sub>) under drought stress condition. The maximum decrease of normal leaf breadth (17.50%), non-effective tillers hill<sup>-1</sup> (25.00%), harvest index (20.25%) and water retention capacity (38.33%) was counted from wild rice genotype *O. latifolia* (V<sub>11</sub>) under drought stress condition. The maximum decrease of nodes plant<sup>-1</sup> (23.18%), shoot dry weight hill<sup>-1</sup> (25.46%), total dry weight hill<sup>-1</sup> (18.29%), effective tillers hill<sup>-1</sup> (17.89%), grains panicle<sup>-1</sup> (14.61%), filled grains panicle<sup>-1</sup> (15.86%) and biological yield hill<sup>-1</sup> (22.84%) was counted from wild rice genotype *O. barthii* (V<sub>4</sub>) under drought stress condition. The maximum decrease of flag leaf length (19.03%), flag leaf ratio (16.24%), flag leaf area (14.71%) and tillers hill<sup>-1</sup> (18.68%) was recorded from wild rice genotype *O. rufipogon* (V<sub>1</sub>) under drought stress condition. The maximum decrease of flag leaf breadth (19.17%) was recorded from wild rice genotype *O. alta* (V<sub>9</sub>).

The maximum decrease of root dry weight hill<sup>-1</sup> (19.09%) was found from wild rice genotype *O. nivara* (V<sub>3</sub>) under 40-45% field capacity condition. The minimum decrease grain yield hill<sup>-1</sup> (6.20 %) was found from wild rice genotype *O. nivara* (V<sub>3</sub>). The increase of thousand grain weight (0.04%) and chlorophyll 'a' content on leaf (26.96%) was found from wild rice genotype *O. nivara* (V<sub>3</sub>) under drought stress condition. The maximum decrease of grain yield hill<sup>-1</sup> (22.78%) was obtained from wild rice genotype *O. latifolia* (V<sub>11</sub>). The maximum decrease of unfilled grains panicle<sup>-1</sup> (23.54%) was obtained from wild rice genotype *Potericia coaractata* (V<sub>10</sub>) under drought stress condition. The maximum decrease of relative water content (5.51%) was obtained from rice genotype BRRI Dhan29 (check variety as drought

sensitive) (V<sub>8</sub>) under drought stress condition. The maximum decrease of chlorophyll 'b' content on leaf (19.20%) was obtained from wild rice genotype *O. glaberrima* (V<sub>6</sub>) under drought stress condition. The minimum decrease of plant height (9.66%), shoot dry weight hill<sup>-1</sup> (2.22%), biological yield hill<sup>-1</sup> (3.02%), chlorophyll 'b' content on leaf (3.90%) was counted from wild rice genotype *O. latifolia* (V<sub>11</sub>) under drought stress condition. And the increase of normal leaf ratio (17.95%), minimum increase of proline content (11.11%) was counted from wild rice genotype *O. latifolia* (V<sub>11</sub>) under drought stress condition. The minimum decrease of leaves plant<sup>-1</sup> (1.46%), root length (1.85%), normal leaf area (1.31%), flag leaf area (1.26%), tillers hill<sup>-1</sup> (9.07%), effective tillers hill<sup>-1</sup> (7.71%), panicle length (3.40%), grain sterility percentage (16.70%), relative water content (1.77%) and chlorophyll 'a' content on leaf (4.86%) was recorded from wild rice genotype *Poterecia coaractata* (V<sub>10</sub>) under drought stress condition. The increase of root dry weight hill<sup>-1</sup> (92.08%), increase of total dry weight hill<sup>-1</sup> (13.08%) and increase of grain fertility percentage (3.12%) was counted from wild rice genotype *Porterecia coaractata* (V<sub>10</sub>) under drought stress condition. The minimum decrease of normal leaf length (2.17%) and flag leaf breadth (0.79%) was counted from rice genotype FR13A (Check variety as drought tolerant) (V<sub>7</sub>) under drought stress condition.

The increase of nodes plant<sup>-1</sup> (3.69%), increase of flag leaf length (5.02%) and maximum increase of proline content (36.93%) was counted from rice genotype FR13A (Check variety as drought tolerant) (V<sub>7</sub>) under drought stress condition. The increase of normal leaf breadth (0.99%) and increase of flag leaf ratio (12.89%) was counted from wild rice genotype *O. alta* (V<sub>9</sub>) under drought stress condition. The minimum decrease of grains panicle<sup>-1</sup> (3.03%) and carotenoids content (7.45%) was obtained from wild rice genotype *O. officinalis* (V<sub>12</sub>) under drought stress condition. And the minimum increase of water saturation deficit (26.63%) was also obtained from wild rice genotype *O. officinalis* (V<sub>12</sub>) under drought stress condition. The minimum decrease filled grains panicle<sup>-1</sup> (2.06%) and maximum increase of water saturation deficit (48.75%) was obtained from wild rice genotype *O. longistaminata* (V<sub>5</sub>) under drought stress condition. The minimum decrease of water retention capacity (22.95%) and water uptake capacity (5.39%) was obtained from wild rice genotype *O. glaberrima* (V<sub>6</sub>) under drought stress condition. The tested genotypes performed variably against drought stress.

Among the tested genotypes *O. punctata* (V<sub>2</sub>) and *O. barthii* (V<sub>4</sub>) showed more susceptibility under drought stress on the other hand *O. latifolia* (V<sub>11</sub>), *O. nivara* (V<sub>3</sub>), *Potericia coaractata* (V<sub>10</sub>), *O. officinalis* (V<sub>12</sub>), FR13A (Check variety as drought tolerant) (V<sub>7</sub>) showed more tolerance capability against drought stress.

The 4<sup>th</sup> experiment was comprised of two factors; Factor A: 12 rice genotypes viz., V<sub>1</sub>= *O. rufipogon*, V<sub>2</sub>= *O. barthii*, V<sub>3</sub>=*O. nivara*, V<sub>4</sub>= *O. latifolia*, V<sub>5</sub>= *Potericia coaractata*, V<sub>6</sub>= *O. glaberrima*, V<sub>7</sub>= *O. longistaminata*, V<sub>8</sub>= *O. officinalis*, V<sub>9</sub>= *O. punctata*, V<sub>10</sub>= *O. alta*, V<sub>11</sub>=Pokkali (Check variety) and V<sub>12</sub>=BRRI Dhan 29 (Check variety) and Factor B: 3 salinity levels viz., S<sub>1</sub>= 0 mM NaCl (Control) , S<sub>2</sub>=50 mM NaCl and S<sub>3</sub>=100 mM NaCl.

At 50 mM NaCl concentration it was observed that rice genotypes *O. barthii* (V<sub>2</sub>), *O. glaberrima* (V<sub>6</sub>) and BRRI Dhan 29 (Check variety as salt sensitive) (V<sub>12</sub>) did not survive and at 100 mM NaCl concentration *O. rufipogon* (V<sub>1</sub>), *O. barthii* (V<sub>2</sub>), *O. nivara* (V<sub>3</sub>), *O. glaberrima* (V<sub>6</sub>), Pokkali (Check variety as salt tolerant)(V<sub>11</sub>) and V<sub>12</sub>=BRRI Dhan 29 (Check variety as salt sensitive) (V<sub>12</sub>) did not survive. Among survival genotypes the maximum decrease of plant height (69.24%), leaves plant<sup>-1</sup> (69.23 %), normal leaf ratio (69.46%), flag leaf length (68.31%), flag leaf area (70.14%), flag leaf ratio (68.13%), root length (70.27%), shoot dry weight hill<sup>-1</sup> (71.12%), total dry weight hill<sup>-1</sup> (68.88%), tillers hill<sup>-1</sup> (73.33%), effective tillers hill<sup>-1</sup> (71.65%), non-effective tillers hill<sup>-1</sup> (75.89%), panicle length (72.24%), grains panicle<sup>-1</sup> (68.83%), filled grains panicle<sup>-1</sup> (68.57%), unfilled grains panicle<sup>-1</sup> (69.32%), thousand grain weight (67.52%), biological yield hill<sup>-1</sup> (70.50%), Ch ‘a’ content on leaf (77.00%), Ch ‘b’ content on leaf (73.86%), carotenoid content on leaf (75.63%), proline content on leaf (55.74%), relative water content on leaf (69.87%), water retention capacity (85.02%) and water uptake capacity (79.05%) was observed in *O. punctata* (V<sub>9</sub>) at 100 mM NaCl concentration. The maximum nodes plant<sup>-1</sup> decrease (69.86%), normal leaf length (67.58%), normal leaf breadth (68.25%), normal leaf area (67.74%), flag leaf breadth (76.49%), root dry weight hill<sup>-1</sup> (68.51%), grain yield hill<sup>-1</sup> (67.73%), harvest index (65.24%) and maximum increase of water saturation deficit (89.05%) was recorded from *O. longistaminata* (V<sub>7</sub>) at 100 mM NaCl concentration.

Among the survival wild rice genotypes the minimum decrease of plant height (2.12%), leaves plant<sup>-1</sup> (8.16%) shoot dry weight hill<sup>-1</sup> (5.38%), total dry weight hill<sup>-1</sup> (7.18%), panicle length (12.64%), thousand grain weight (0.53%), grain yield hill<sup>-1</sup> (14.83%), biological yield hill<sup>-1</sup> (5.80%), relative water content on leaf (2.78%) and increase of water saturation deficit (35.62%) attained by wild rice genotype *O. latifolia* (V<sub>4</sub>) at 100 mM NaCl concentration. The minimum decrease of nodes plant<sup>-1</sup> (10.00%), normal leaf length (4.55%), normal leaf breadth (4.42%), normal leaf area (2.17%), flag leaf length (7.02%), flag leaf breadth (5.44%), flag leaf area (2.27%), root length (4.82%), tillers hill<sup>-1</sup> (5.99%), effective tillers hill<sup>-1</sup> (4.45%), non-effective tillers hill<sup>-1</sup> (9.12%), unfilled grains panicle<sup>-1</sup> (7.14%), harvest index (2.76%), water retention capacity (48.50%) and water uptake capacity (19.84%) was recorded from *Potericia coaractata* (V<sub>5</sub>) at 100 mM NaCl concentration. The minimum decrease of normal leaf ratio (6.53%), flag leaf ratio (6.75%), grains panicle<sup>-1</sup> (8.68%), filled grains panicle<sup>-1</sup> (7.62%), Ch 'a' content on leaf (11.57%), Ch 'b' content on leaf (8.05%), carotenoid content on leaf (15.29%) and increase proline content on leaf (29.73%) observed in *O. alta* (V<sub>10</sub>) at 100 mM NaCl concentration. *O. longistaminata* (V<sub>7</sub>) and *O. punctata* (V<sub>9</sub>) rice genotypes required (66.55%) less days to 1<sup>st</sup> flowering compare to control treatment (no salt stress) where *Potericia coaractata* (V<sub>5</sub>) rice genotype required (1.71%) more days to 1<sup>st</sup> flowering compare to control treatment (no salt stress). *O. longistaminata* (V<sub>7</sub>) rice genotype required (0.74%) less days to complete its life cycle comparing to control treatment (no salt stress) and *O. punctata* (V<sub>9</sub>) rice genotype required (0.57%) more days to complete its life cycle comparing to control treatment (no salt stress).

The maximum decrease (%) of plant growth, yield, yield contributing traits and physiological traits was observed in *O. punctata* (V<sub>9</sub>) followed by *O. longistaminata* (V<sub>7</sub>). On the other hand the less decrease (%) of plant growth and yield, yield contributing traits was observed in *O. latifolia* (V<sub>4</sub>), *Potericia coaractata* (V<sub>5</sub>) and *O. alta* (V<sub>10</sub>) wild rice genotypes; among them *O. latifolia* (V<sub>4</sub>) and *Potericia coaractata* (V<sub>5</sub>) showed more tolerance in maximum yield traits of wild rice genotypes.

In the 5<sup>th</sup> experiment allelic diversity analysis of wild rice accession has been done for salinity tolerance. Under this present piece of work molecular characterization of the



12 wild rice genotypes was done to determine the genetic relationship among the genotypes for breeding purposes and to make DNA fingerprinting and genetic relationship among these genotypes using SSR markers. Microsatellites are considered appropriate for species identification because of their ability to detect large numbers of distance alleles repeatedly, accurately and efficiently (Smith and Helentjaris, 1996). From the analysis, it was found that a total of 24 alleles were detected with an average number of 2 alleles per locus. The PIC value of each primer pair ranged from 0.16 (*O. rufipogon*) to 0.37 (*O. alta*, *O. latifolia*, *O. officinalis*, *Portericia coactata* and *O. nivara*) with an average of 0.31. This result revealed that *O. alta*, *O. latifolia*, *O. officinalis*, *Portericia coactata* and *O. nivara* would be the best salt tolerant wild rice genotypes among 12 wild rice genotypes. According to Nei *et al.* (1983) the highest level of genetic diversity (0.50) was observed in genotypes *Oryza alta*, *Oryza barthii*, *Oryza latifolia*, *Oryza officinalis* and *Oryza nivara* and the lowest level of genetic diversity (0.17) was observed in genotype *Oryza rufipogon* with a mean diversity of 0.43. From the above the study, the following recommendations can be made: *O. alta*, *O. latifolia*, *O. officinalis*, *Portericia coactata* and *O. nivara* the best salt tolerant and *Oryza rufipogon* lowest salt tolerant wild rice genotypes among the 12 wild rice genotypes. These genotypes could be utilized to develop salt tolerant rice varieties with all desirable characters. So this research can be used to identify traditional more land races from saline prone region of Bangladesh. This molecular characterized information could be helpful to the breeders for further planning of rice breeding program to improve breeding rice for salinity tolerance.

The polymorphism was detected among the genotypes can be used in breeding program to maximize the use of genetic resources as well as to develop salt tolerant varieties. The genotype pairs which showed genetic distance can be used in further breeding program.

Form the above results of allelic diversity analysis it may be concluded that the PIC value of each primer pair ranged from 0.16 (*O. rufipogon*) to 0.37 (*O. alta*, *O. latifolia*, *O. officinalis*, *Portericia coactata* and *O. nivara*) with an average of 0.31. This result revealed that *O. alta*, *O. latifolia*, *O. officinalis*, *Portericia coactata* and *O. nivara* would be the best salt tolerant wild rice genotypes among 12 wild rice genotypes.

## Conclusion

Undoubtedly the wild rice genotypes are very much important sources for the introgression of desirable traits to the modern developed rice cultivar. In this study some of the wild rice genotypes performed better under salinity and drought stress conditions than the others. Under drought stress, the tested genotypes responded differently. The grain yield reduction was higher (22.78%) in *O. latifolia* whereas *O. nivara* wild rice genotype showed less reduction (6.20%) of grain yield under drought stress condition (40-45% field capacity). Among the tested genotypes *O. punctata* and *O. barthii* showed more susceptibility under drought stress. On the other hand, *O. latifolia*, *O. nivara*, *Poterecia coaractata*, *O. officinalis* and FR13A showed more tolerance capability against drought stress. Under salt stress, the wild rice genotype *O. longistaminata* showed most susceptibility in respect of production and decreased grain yield (67.73%) compared to control treatment, and *O. latifolia* wild rice genotypes showed more tolerance to salt stress in respect of grain yield and decreased only (14.83%) grain yield at 100 mM NaCl concentration. After allelic diversity analysis the findings revealed that *O. alta*, *Potericia coaractata*, *O. latifolia*, *O. officinalis* and *O. nivara* would be the potential salt tolerant wild rice genotypes among tested one. Though grain yield is the ultimate goal for crop producer but for breeding program other wild rice genotypes could be resourceful for introgression of desirable traits into a modern rice cultivar for obtaining higher yield under salinity or drought stress condition.

### **Recommendation**

Development of modern high yielding rice cultivars with better yield potential under drought and salinity stress condition is highly necessary in Bangladesh. The specific traits of the wild rice genotypes conferring salinity and drought tolerance as appeared in the study could be a valuable resource. Molecular analysis of the identified traits of the wild species of rice for salinity and drought tolerance should further be explored. These experiments were in pots trails, so for mre clarification mre field research should be carried out. The desirable traits from the wild rice species could be considered for their better integration into the modern rice cultivars.

## REFERENCES

- Abbad, H., Jaafari, S. E., Bort, J. and Araus, J. L. (2004). Comparison of flag leaf and ear photosynthesis with grain yield of durum wheat under various water conditions and genotypes. *Agron. J.*, 24: 19-28.
- Abbas, A., Khan, S., Hussain, N., Hanjra, M. A. and Akbar, S. (2013). Characterizing soil salinity in irrigated agriculture using a remote sensing approach. *Phys. Chem. Earth, Parts A/B/C* 55-57, pp.43-52.
- Abdullah, H. M. and Rahman, M. M. (2015). Initiating rain water harvest technology for climate change induced drought resilient agriculture: scopes and challenges in Bangladesh. *J. Agric. Environ. Int. Dev.*, 109(2): 189-208.
- Abdullah, Z., Khan, M. A. and Flowers, T. J. (2018). Causes of sterility in seed set of rice under salinity stress. *J. Agron. Crop Sci.*, 187: 25-32.
- Abdullah, Z., Khan, M. A. and Flowers, T. Z. (2001). Causes of sterility in seed set of rice under salinity stress. *J. Agron. Crop Sci.*, 167(1): 25-32.
- Abeer, H., Abd-Allah, E. F., Alqarawi, A. A., Alwhibi-Mona, S., Alenazi, M. M., Egamberdieva, D., and Ahmad, P. (2015). Arbuscular mycorrhizal fungi mitigates NaCl induced adverse effects on *Solanum lycopersicum* L. *Pakistan J. Bot.*, 47(1): 327-340.
- Abo, M. E., Sy, A. A. and Alegbejo, M. D. (1998). Rice yellow mottle virus (RYMV) in Africa: Evolution, distribution and economic significance on sustainable rice production and management strategies. *J. Sust. Agric.*, 11(2-3): 85-111.
- Abramavicius, D. and Valkunas, L. (2016). Role of coherent vibrations in energy transfer and conversion in photosynthetic pigment-protein complexes. *Photosynth. Res.*, 127: 33-47.
- Africa Rice. (2013). New breeding directions at AfricaRice: beyond NERICA. [http://www.africarice.org/publications/Beyond\\_NERICA.pdf](http://www.africarice.org/publications/Beyond_NERICA.pdf).

- Agarwal, P., Parida, S. K., Raghuvanshi, S., Kapoor, S., Khurana, P., Khurana, J. P. and Tyagi, A. K. (2016). rice improvement through genome-based functional analysis and molecular breeding in India. *Rice*, 9: 1.
- Aghaleh, M., Niknam, V., Ebrahimzadeh, H. and Razavi, K. (2009). Salt stress effects on growth, pigments, proteins and lipid peroxidation in *Salicornia persica* and *S. europaea*. *Biol. Plant*, 53: 243-248.
- Ahmadikhah, A. and Marufinia, A. (2016). Effect of reduced plant height on drought tolerance in rice. *3 Biotech.*, 6: 1-9.
- Ahmed, Q. N. (2006). Influence of different cultivation methods on growth and yield of hybrid and inbred rice. M.S. Thesis. Dept. of Agronomy, Sher-e-Bangla Agricultural University, Dhaka.
- Ai, N. S. (2011). Biomass and concentration of total chlorophyll on ginger leaf under water deficit. *J. Ilmiah Sains*, 11(1): 45-53.
- Aidy, E. A. N., Emery, E. M. I., Draz, A. E. and Badawi, A. T. (2000). Chemical and morphological characters of some local rice genotypes. *Egyptian J. Agric. Res.*, 78(2): 693-716.
- Akbar, M. and Yabuno, Y. (1974). Breeding for saline-resistant varieties of rice. II. Comparative performance of some rice varieties to salinity during early developing stages. *Japan J. Breed.*, 25: 176-181.
- Akcin A. and Yalcin, E. (2016). Effect of salinity stress on chlorophyll, carotenoid content, and proline in *Salicornia prostrata* Pall. and *Suaeda prostrata* Pall. subsp. prostrate (*Amaranthaceae*). *Brazil J. Bot.*, 39(1): 101-106.
- Akimoto, M., Shimamoto, Y. and Morishima, H. (1998). Genetic differentiation in *Oryza glumaepatula* and its phylogenetic relationships with other AA genome species. *Rice Genet. Newsl.* 14: 37-39.
- Akram, H. M., Ali, A., Sattar, A., Rehman, H. S. U. and Bibi, A. (2013). Impact of water deficit stress on various physiological and agronomic traits of three basmati rice cultivars. *J. Anim. Plant Sci.*, 23(5): 1415-1423.

- Akram, N. A. and Ashraf, M. (2011). Pattern of accumulation of inorganic elements in sunflower (*Helianthus annuus* L.) plants subjected to salt stress and exogenous application of 5-aminolevulinic acid. *Pakistan J. Bot.*, 43: 521-530.
- Alam, M. J., Kanako, S. and Rahman, M. M. (2015). The Decreasing Trend of Agricultural Land in Bangladesh: Myth and Facts. *The Jahangirnagar Econ. Rev.*, 26: 85-96.
- Alamgir, A. N. M. and Ali, M. Y. (2006). Effects of NaCl salinity on leaf characters and physiological growth attributes of different genotypes of rice. *Bangladesh J. Bot.*, 35(2): 99-107.
- Aldesuquy, H. S., Abo-Hamed, S. A., Abbas, M. A. and Elhakem, A. H. (2009). Effect of glycine betaine and salicylic acid on growth and productivity of droughted wheat cultivars. I. Osmolytes in relation to osmotic adjustment and grain yield. *J. Environ. Sci. Mansoura Univ.*, 37: 13-33.
- Aldesuquy, H. S., Baka, Z. A., El-Shehaby, O. A. and Ghanem, H. E. (2012). Varietal differences in growth vigor, water relations, protein and nucleic acids content of two wheat varieties grown under seawater stress. *J. Stress Physiol. Biochem.*, 8: 24-47.
- Ali, A. (2009). Influence of silicon on wheat grown under saline environments. Doctoral thesis, University of Agriculture, Faisalabad, Pakistan.
- Almeselmani, M., Saud, A., Al-Zubi, K., Abdullah, F., Hareri, F., Nassan, M., Ammar, M. A. and Kanbar, O. (2012). Physiological performance of different durum wheat varieties grown under rainfed condition. *Global J. Sci. Front. Res.*, 12: 55-63.
- Amin, M. R., Hamid, A., Choudhury, R. U., Raquibullah, S. M. and Asaduzzaman, M. (2006). Nitrogen fertilizer effect on tillering, dry matter production and yield of traditional varieties of rice. *Int. J. Sustain. Crop Prod.*, 1(1): 17-20.
- Angeles, E. R., Cabunagan, R. C., Tiongco, E. R., Azzam, O., Teng, P. S., Khush, G. S. and Chancellor, T. C. B. (1998). Advanced breeding lines with resistance to rice tungro viruses. *Int. Rice Res. Notes*, 23(1): 17-18.

- Anjaneyulu, M., Reddy, D. R. and Reddy, K. H. P. (2010). Genetic variability, heritability and genetic advance in rice. *Res. Crops*, 11(2): 415-416.
- Anjum, S. A., Xie, X., Wang, L., Saleem, M. F., Man, C. and Lei, W. (2011). Morphological, physiological and biochemical responses of plants to drought stress. *African J. Agric. Res.*, 6(9): 2026-2032.
- Apel, K. and Hirt, H. (2004). Reactive oxygen species: metabolism, oxidative stress, and signal transduction. *Annu. Rev. Plant Biol.*, 55: 373-399.
- Araus, J. L., Slafer, G. A., Reynolds, M. P. and Royo, C. (2002). Plant breeding and drought in C<sub>3</sub> cereals: what should we breed for? *Ann. Bot.*, 89: 925-940.
- Aref, F. (2013). Effect of saline irrigation water on yield and yield components of rice. *African J. Biotechnol.*, 12(22): 3503-3513.
- Arnon, D. I. (1949). Copper enzymes in isolated chloroplasts polyphenoloxidase in *Beta vulgaris*. *Plant physiol.*, 24(1): 1-15.
- Asch, F., Dingkuhn, M., Wittstock, C. and Doerffling, K. (1999). Sodium and potassium uptake of rice panicles as affected by salinity and season in relation to yield and yield components. *Plant Soil*, 207(2): 133-145.
- Ashraf, M. (2009). Biotechnological approach of improving plant salt tolerance using antioxidants as markers. *Biotechnol. Adv.*, 27: 84-93.
- Ashraf, M. and Foolad, M. R. (2007). Roles of glycine betaine and proline in improving plant abiotic stress resistance. *Environ. Expt. Bot.*, 59(2): 206-216.
- Ashraf, M. Y., Azmi, A. R., Khan, A. H. and Ala, S. A. (1994). Effect of water stress on total phenols, peroxidase activity and chlorophyll content in wheat. *Acta Physiol. Plant*, 16(3): 185-191.
- Ashrafuzzaman, M. (2006). Influence of tiller separation days on yield and yield attributes of inbred and hybrid rice. M.S. Thesis. Dept. of Agronomy, Sher-e-Bangla Agricultural University, Dhaka.

- Atwell, B. J., Wang, H. and Scafaro, A. P. (2014). Could abiotic stress tolerance in wild relatives of rice be used to improve *Oryza sativa*? Plant Sci., 215(16): 48-58.
- Ayerbe, L. and Tenorio, J. L. (1998). Turgor maintenance, osmotic adjustment and soluble sugar and proline accumulation in 49 pea cultivars in response to water stress. Field crop Res., 59: 225-235.
- Baker, N. R. (2008). Chlorophyll fluorescence: a probe of photosynthesis in vivo. Annu. Rev. Plant Biol., 59: 89-113.
- Baksha, M. M., Huq, A. M. and Khan, M. S. (1979). Taxonomic studies in the monocotyledonous weeds of the paddy fields of Dacca. Dacca Univ. Stud., 27(2): 147-160.
- Bala, B., Mallik, M., Saclain, S. and Islam, M. S. (2017). Genetic variation in wild and hatchery populations of giant fresh water prawn (*Macrobrachium resenbergtii*) revealed by randomly amplified polymorphic DNA markers. J. Genet. Eng. Biotechnol., pp.1523-1530.
- Bansal, K. C. and Nagarajan, S. (1986). Leaf water content, stomatal conductance and proline accumulation in leaves of potato in response to water stress. Indian J. Plant Physiol., 29: 397-404.
- Banu, M. N. A., Hoque, M. A., Sugimoto-Watanabe, M., Islam, M. M., Uraji, M., Mastuoka, K., Nakamura, Y., Shimoishi, Y. and Murata, Y. (2010). Proline and glycinebetaine ameliorated NaCl stress via scavenging of hydrogen peroxide and methylglyoxal but not superoxide or nitric oxide in tobacco cultured cells. Biosci. Biotech. Biochem., 74: 2043-2049.
- Bao, Y., and Ge, S. (2004). Origin and phylogeny of *Oryza* species with the CD genome based on multiple-gene sequence data. Plant Syst. Evol. 249: 55-66.
- Baque, M. A., Faijunnahar, M., Habib, M. A. and Motmainna, M. (2018). PEG induced germination, seedling growth and water relation behavior of wheat genotypes under salt stress condition. Univ. J. Plant Sci., 6(3): 21-31.



- Baque, M. A., Karim, M. A. and Hamia, A. (2002). Role of potassium on water relation behavior of *Triticum astivum* L. under water stress conditions. *Prog. Agric.*, 13(1&2): 71-75.
- Baque, M. A., Karim, M. A., Hamid, A. and Tetsushi, H. (2006). Effect of fertilizer potassium on growth, yield and nutrient uptake of wheat under water stress conditions. *South Pacific Stud.*, 27: 25-36.
- Basra, S. M. A., Farooq, M., Afzal, I. and Hussain, M. (2006). Influence of osmopriming on the germination and early seedling growth of coarse and fine rice. *Int. J. Agri. Boil.*, 8(1): 19-22.
- Batjuka, A., Škute, N. and Petjukevičs, A. (2016). The influence of antimycin a on pigment composition and functional activity of photosynthetic apparatus of wheat under high temperature. *Photosynthetica*, 55: 1-14.
- BBS (2022). Yearbook of Agricultural Statistics-2021. Bangladesh Bureau of Statistics. Statistics and Informatics Division. Ministry of Planning. Government of the People's Republic of Bangladesh. pp. 51-69.
- Beinsan, C., Camen, D., Sumalan, R. and Babau, M. (2009). Study concerning salt stress effect on leaf area dynamics and chlorophyll contain in four bean local landraces from Banat area. In: Florijancić T, Luzaic R (eds) 44<sup>th</sup> Croatian and 4<sup>th</sup> international symposium on agriculture, 16–20 February, pp. 416-419.
- Bhavyasree, R. K., Joe, A.J., Jeyaprakash, P. and Raveendran, M. (2019). The effect of induced drought stress on seedling vigour and antioxidant enzymes in wild and cultivated *Oryza* species. *Intl. J. Crop Sci.*, 7(3): 1078-1081.
- Bhusan, D., Das, D. K., Hossain, M., Murata, Y. and Hoque, M. A. (2016). Improvement of salt tolerance in rice by increasing antioxidant defense systems using exogenous application of proline. *Australian J. Crop Sci.*, 10(1): 50-56.
- Bisne, R. and Sarawgi, A. K. (2008). Agro-morphological and quality characterization of badshah bhog group from aromatic rice germplasm of Chhattisgarh. *BangladeshJ. Agric. Res.*, 33(3): 479-492.

- Biswal, A. K. and Kohli, A. (2013). Cereal flag leaf adaptations for grain yield under drought: Knowledge status and gaps. *Mol. Breed.*, 31(4): 749-766.
- Biswal, B. (1995). Carotenoid catabolism during leaf senescence and its control by light. *J. Photochem. Photobiol. Biol.*, 30: 3-13.
- Blatt, M. R. and Armstrong, F. (1993). K<sup>+</sup> channels for stomatal guard cells, abscisic acid evoked control of outward rectifier mediated by cytoplasmic pH. *Planta*, 191: 330-341.
- Blum, A. (1988). Salinity resistance in plant breeding for stress environments. CRC Press, Florida. pp. 163- 179.
- Blum, A. (2005). Drought resistance, water-use efficiency, and yield potential-are they compatible, dissonant, or mutually exclusive? *Crop Pasture Sci.*, 56: 1159-1168.
- Blum, A. (2011). Drought tolerance: Is it a complex trait? *Funct. Plant Biol.*, 38(10): 753-757.
- Blumwald, E. (2000). Sodium transport and salt tolerance in plants. *Curr. Opin. Cell Biol.*, 12(4): 431-434.
- Bota, J., Medrano, H. and Flexas, J. (2004). Is photosynthesis limited by decreased Rubisco activity and RuBP content under progressive water stress? *New Phytol.*, 162(3): 671-681.
- Botwright A. T. L., Latte, H. R. and Wade, L. J. (2008). Genotype and environment interactions for grain yield of upland rice backcross lines in diverse hydrological environments. *Field Crops Res.*, 108(2): 117-125.
- Bouman, B. A. M. and Toung, T. P. (2001). Field water management to save water and increase its productivity in irrigated lowland rice. *Agric. Water Manag.*, 49: 11-30.
- Bouvier, F., Isner, J. C., Dogbo, O. and Camara, B. (2005). Oxidative tailoring of carotenoids: A prospect towards novel functions in plants. *Trends Plant Sci.*, 10: 187-194.

- Brar, D. S. and Khush, G. S. (2018). Wild relatives of rice: a valuable genetic resource for genomics and breeding research in compendium of plant genomes: The wild *Oryza* genomes, eds Mondal, T. K. and Henry, R. J. (Berlin: Springer-Verlag), pp. 1-25.
- Brown, R. H. (1994). Growth of the green plant. Physiological basis of crop growth and development. Teasar, M. B. (Ed.). Madison, Wisconsin, pp. 153-173.
- BRRI (Bangladesh Rice Research Institute). 2022. Total Rice (Aus, Aman and Boro) Area (000'ha), Production (000'ton) and Yield (ton/ha) of Bangladesh.
- Bunnag, S. and Pongthai, P. (2013). Selection of rice cultivars tolerant to drought stress at the vegetative stage under field conditions. *American J. Plant Sci.*, 4(9): 1701-1708.
- Cal, A. J., Sanciango, M. and Rebolledo, M.C. (2018). Leaf morphology, rather than plant water status, underlies genetic variation of rice leaf rolling under drought. *Plant Cell Environ.*, 42: 1532-1544.
- Campos, M. D., Nogales, A., Cardoso, H. G., Campos, C., Grzebelus, D., Velada, I. and Arnholdt-Schmitt, B. (2016). Carrot plastid terminal oxidase gene (dcptox) responds early to chilling and harbors intronic pre-mirnas related to plant disease defense. *Plant Gene*, 7: 21-25.
- Cannella, D., Möllers, K.B., Frigaard, N. U., Jensen, P. E., Bjerrum, M. J., Johansen, K. S. and Felby, C. (2016). Light-driven oxidation of polysaccharides by photosynthetic pigments and a metalloenzyme. *Natl. Commun.*, 7: 111-134.
- Centritto, M., Lauteri, M., Monteverdi, M. C. and Serraj, R. (2009). Leaf gas exchange, carbon isotope discrimination, and grain yield in contrasting rice genotypes subjected to water deficits during the reproductive stage. *J. Expt. Bot.*, 60(8): 2325-2339.
- Cerqueira, F. B., Erasmo, E. A. L., Silva, J. I. C., Nunes, T. V., Carvalho, G. P. and Silva, A. A. (2013). Competition between drought-tolerant upland rice cultivars and weeds under water stress condition. *PlantaDaninha*, 31(2): 291-302.

- Chamely, S. G., Islam, N., Hoshain, S., Rabbani, M. G., Kader, M. A. and Salam, M. A. (2015). Effect of variety and nitrogen rate on the yield performance of *boro* rice. *Prog. Agril.*, 26(1): 6-14.
- Channa, G. S., Mahar, A. R., Rajpar, I., HafeezMemon, A., Saand, M. A., Mirbahar, A. A., Majid, A., Lal, S. and Sirohi, M. H. (2019). Effect of salinity on growth, yield and ion contents of rice genotypes. *Int. J. Biosci.*, 14(5): 192-204.
- Cha-um, S., Vejchasarn, P. and Kirdmanee, C. (2007). An effective defensive response in Thai aromatic rice varieties to salinity. *J. Crop Sci. Biotech.*, 10: 257-264.
- Cha-um, S., Yooyongwech, S. and Supaibulwatana, K. (2010). Water deficit stress in the reproductive stage of four indica rice genotypes. *Pakistan J. Bot.*, 42(5): 3387-3398.
- Cheabu, S., Panichawong, N., Rattanamettha, P., Wasuri, B., Kasemsap, P., Arikitt, S., Vanavichit, A. and Malumpong, C. (2019). Screening for spikelet fertility and validation of heat tolerance in a large rice mutant population. *Rice Sci.*, (in press).
- Chelah, M. K. B., Nordin, M. N. B., Musliania, M. I., Khanif, Y. M. and Jahan, M. S. (2011). Composting increases bris soil health and sustains rice production on bris soil. *Sci.Asia*, 37: 291-295.
- Chen, Z., Cuin, T. A., Zhou, M., Twomey, A., Naidu, B. P. and Shabala, S. (2007). Compatible solute accumulation and stress-mitigating effects in barley genotypes contrasting in their salt tolerance. *J. Expt. Bot.*, 58(15/16): 4245-4255.
- Cherian, S. and Reddy, M. P. (2000). Salt tolerance in halophyte *Scaedanu deflora*. Effect of NaCl on growth, ion accumulation and oxidative enzymes. *Indian J. Plant Physiol.*, 5(1): 32-37.

- Chopart, J. L., Le-Mézo, L. and Mézino, M. (2008). Software application for processing root data from impact counts on soil profiles. User Guide, Technol. Document. pp. 26-28.
- Choudhury, A. K. (2009). Water stress tolerance of French bean (*Phaseolus vulgaris* L.), Ph.D. Dissertation. Department of Agronomy. Bangabandhu Sheikh Mujibur Rahaman Agricultural University, Gazipur, Bangladesh.
- Chouhan, S. K., Singh, A. K., Aparajita, S., Ram, M., Singh, P. K. and Singh, N. K. (2014b). Characterization and evaluation of *Oryza Nivara* and *Oryza Rufipogon*. The bioscan, 9(2): 853-858.
- Chouhan, S. K., Singh, A. K., Singh, A., Singh, S. P., Singh, N. K. and Singh, P. K. (2014a). Agro-morphological diversity in wild rice accessions of eastern Indo-gangetic region of India. Bangladesh J. Bot., 43(3): 337-344.
- Chunthaburee, S. (2016). Physiological and biochemical parameters for evaluation and clustering of rice cultivars differing in salt tolerance at seedling stage. Saudi J. Biol. Sci., 23(4): 467-477.
- Chutia, J. and Borah, S. P. (2012). Water stress effects on leaf growth and chlorophyll content but not the grain yield in traditional rice genotypes of Assam, India. II. Protein and Proline Status in Seedlings under PEG Induced Water Stress. American J. Plant Sci., 3(7): 971-980.
- Chutipaijit, S. (2011). High contents of proline and anthocyanin increase protective response to salinity in *Oryza sativa* L spp *indica*. Australian J. Crop Sci., 5: 1191-1198.
- Clark, L. J., Price, A. H., Steele, K. A. and Whalley, W. R. (2008). Evidence from near-isogenic lines that root penetration increases with root diameter and bending stiffness in rice. Funct. Plant Biol., 35(11): 1163-1171.
- Clayton, W. D. (1970). Gramineae (Part 1). In: Milne-Redhead E, Polhill RM, eds. Flora of Tropical East Africa. London, UK: Crown Agents for Oversea Governments and Administrations.

- Coloquio, E., Cabunagan, R. C. and Azzam, O. (1998). Potential sources of resistance against RGSV-2 in wild rice germplasm. *Int. Rice Res. Notes*, 23(3): 14-16.
- Comas, L. H., Becker, S. R., Cruz, V. M., Byrne, P. F. and Dierig, D. A. (2013). Root traits contributing to plant productivity under drought. *Front. Plant Sci.*, 4: 442.
- Cominelli, E., Conti, L., Tonelli, C. and Galbiati, M. (2013). Challenges and perspectives to improve crop drought and salinity tolerance. *New Biotechnol.*, 30: 355-361.
- Cornic, G. (2000). Drought stress inhibits photosynthesis by decreasing stomatal aperture- not by affecting ATP synthesis. *Trends Plant Sci.*, 5: 187- 198.
- Cuin, T. A. and Shabala, S. (2005). Exogenously supplied compatible solutes rapidly ameliorate NaCl-induced potassium efflux from barley roots. *Plant Cell Physiol.*, 46(12): 1924-1933.
- Daiz, M. G. Q., Bebing, N. N., Villegas, M. J. and Manuel, M. C. (2002). Cell biology, Laboratory Manual (Fifth Edition): Genetics and molecular biology division. Philippines. Univ. Philippines, p. 47.
- Dalal, V. K. and Tripathy, B. C. (2012). Modulation of chlorophyll biosynthesis by water stress in rice seedlings during chloroplast biogenesis. *Plant Cell Environ.* 35: 1685-1703.
- Dangi, K., Singh, S. K., Malviya, D. K., Gautam, A., Kanapuriya, N. and Kumar, B. (2017). Effect of rice varieties on growth, yield and economics at varying levels of nitrogen under direct seeded upland condition Rewa region. *Intl. J. Curr. Microbiol. Appl. Sci.*, 6(9): 2313-2318.
- Datir, S., Kulkarni, B. and Patil, N. (2018). differential responses of rice cultivars to NaCl in relation to physiological and biochemical parameters at seedling stage. *Acta Sci. Agric.*, 2(2): 2-7.

- Datta, J. K., Nag, S., Banerjee, A. and Mondal, N. K. (2009). Impact of salt stress on five varieties of wheat cultivars under laboratory condition. *J. Appl. Sci. Environ.*, 13(3): 93-97.
- Dawit, A. (2010). Screening of rice genotypes against salinity for yield and yield component. Dissertation, Hawassa University.
- de Souza, T. C., de Castro, E. M., Magalhães, P. C., Lino, L. D. O., Alves, E. T. and de Albuquerque, P. E. P. (2013). Morphophysiology, morphoanatomy and grain yield under field conditions for two maize hybrids with contrasting response to drought stress. *Acta Physiol. Plant*, 35: 3201-3211.
- De, S. (2021). Strategies of plant biotechnology to meet the increasing demand of food and nutrition in India. *Intl. Annals Sci.* 10(1): 7-15.
- Debnath, A. (2010). Influence of planting material and variety on yield of boro rice. M.S. Thesis. Dept. of Agronomy, Sher-e-Bangla Agricultural University, Dhaka.
- Debnath, A., Biswas, P. K., Sardar, M. S. A. and Rahman, A. (2012). Influence of mother and clonal tillers on yield and performance of inbred and hybrid *boro* rice. *Bangladesh Agron. J.*, 15(1): 1-7.
- Delauney, A. J. and Verma, D. P. S. (1993). Proline biosynthesis and osmoregulation in plants. *Plant J.*, 4(2): 215-223.
- Deltoro, V. I., Calatayud, A., Gimeno, C., Abadía, A. and Barreno, E. (1998). Changes in chlorophyll a fluorescence, photosynthetic CO<sub>2</sub> assimilation and xanthophyll cycle interconversions during dehydration in desiccation-tolerant and intolerant liverworts. *Planta*, 207: 224-228.
- Demiral, T. and Türkan, I. (2005). Comparative lipid peroxidation, antioxidant defense systems and proline content in roots of two rice cultivars differing in salt tolerance. *Environ. Expt. Bot.*, 53(3): 247-257.

- Demiral, T. and Türkan, I. (2006). Exogenous glycinebetaine affects growth and proline accumulation and retards senescence in two rice cultivars under NaCl stress. *Environ. Expt. Bot.*, 56: 72-79.
- Dhanwani, R. K., Sarawgi, A. K., Solanki, A. and Tiwari, J. K. (2013). Genetic variability analysis for various yield attributing and quality traits in rice. *Bioscan*, 8(4): 1403-1407.
- Dien, D. C., Mochizuki, T. and Yamakawa, T. (2017). Morphology and dry matter accumulation in rice seedlings under drought conditions. *J. Fac. Agric. Kyushu Univ.*, 62(2): 309-322.
- Dien, D. C., Mochizuki, T. and Yamakawa, T. (2019). Effect of various drought stresses and subsequent recovery on proline, total soluble sugar and starch metabolisms in rice varieties. *Plant Prod. Sci.*, 22(4): 530-545.
- Dijkstra, P. and Lambers, H. (1986). Photosynthesis and respiration of growth rate. In: Marcelle, R., Clijsters, H. and Van Poucke, M. (eds). *Biological Control of Photosynthesis*, Martinus Nijhoff Publishers, The Hague, pp. 251-255.
- Dingkuhn, M., Audebert, A., Jones, M. P., Etienne, K. and Sow, A. (1998). Control of stomatal conductance and leaf rolling in *O. sativa* and *O. glaberrima* upland rice. *Field Crops Res.*, 61: 223-236.
- Duan, J., Li, J., Guo, S. and Kang, Y. (2008). Exogenous spermidine affects polyamine metabolism in salinity-stressed *Cucumis sativus* roots and enhances short-term salinity tolerance. *J. Plant Physiol.*, 165: 1620-1635.
- Eizenga, G. C., Lee, F. N. and Jia, Y. (2004). Identification of blast resistance genes in wild relatives of rice (*Oryza* spp.) and newly introduced rice (*O. sativa*) lines. *Res. Series - Arkansas Agril. Expt. Stat.*, 517: 29-36.
- Eynard, A., Lal, R. and Wiebe, K. (2005). Crop response in salt-affected soils. *J. Sustain. Agric.*, 27: 5-50.



- Fabre, D., Siband, P. and Dingkuhn, M. (2005). Characterizing stress effects on rice grain development and filling using grain weight and size distribution. *Field Crop Res.*, 92: 11-16.
- Fageria, N. K. and Moreira, A. (2011). The role of mineral nutrition on root crop growth of crop plants. *Adv. Agron.*, 110: 251-331.
- Falk, S., Maxwell, D. P., Laudenbach, D. E., Huner, N. P. A. and Baker, N. R. (1996). Photosynthesis and the Environment. In: *Advances in photosynthesis*, Kluwer Academic Publishers, Dordrecht, 5: 367-385.
- Fang, Y. J. and Xiong, L. Z. (2015). General mechanisms of drought response and their application in drought resistance improvement in plants. *Cell Mol. Life Sci.*, 72(4): 673-689.
- Farooq, M., Hussain, M., Wahid, A. and Siddique, K. H. M. (2012). Drought Stress in Plants: An Overview. In: Aroca, R. (Ed). *Plant Responses to Drought Stress*. Springer-Verlag, Heidelberg, pp. 1-33.
- Farooq, M., Kobayashi, N., Ito, O., Wahid, A. and Serraj, R. (2010). Broader leaves result in better performance of indica rice under drought stress. *J. Plant Physiol.*, 167(13): 1066-1075.
- Farooq, M., Wahid, A. and Lee, D. J. (2009a). Exogenously applied polyamines increase drought tolerance of rice by improving leaf water status, photosynthesis and membrane properties. *Acta Physiol. Plant*, 31(5): 937-945.
- Farooq, M., Wahid, A., Lee, D. J., Ito, O. and Siddique, K. H. M. (2009b). Advances in drought resistance of rice. *Crit. Rev. Plant Sci.*, 28: 199-217.
- Farooq, S., Asghar, M., Iqbal, N. and Shah, T. M. (1992). Variability in salt tolerance of accessions of wild rice species *Oryza punctata* and *O. officinalis*. *Intl. Rice Res. Newsl.*, 17(6): 16.
- Farooq, S., Shah, T. M., Arif, M. and Iqbal, N. (1996). Inheritance of RAPD markers in the F<sub>1</sub> interspecific hybrids of rice. *Pakistan J. Bot.*, 28(1): 51-59.

- Farshid, A. and Hassan, E. R. (2012). Physiological characterization of rice under salinity stress during vegetative and reproductive stages. *Indian J. Sci. Technol.*, 5: 2578-2586.
- Fen, L. L., Ismail, M. R., Zulkarami, B., Rahman, M. S. A., Islam, M. R. (2015). Physiological and molecular characterization of drought responses and screening of drought tolerant rice varieties. *Biosci. J. Uberlândia*, 31(3): 709-718.
- Feng, F., Xu, X., Du, X., Tong, H., Luo, L. and Mei, H. (2012). Assessment of drought resistance among wild rice accessions using a protocol based on single-tiller propagation and PVC-tube cultivation. *American J. Crop Sci.*, 6(7): 1204-1211.
- Flexas, J., Diaz-Espejo, A., Galmés, A., Kaldenhoff, J., Medrano, R. and Ribas-Carbo, H. (2007). Rapid variations of mesophyll conductance in response to changes in CO<sub>2</sub> concentration around leaves. *Plant Cell Environ.* 30: 1284-1298.
- Flower, T. J., Salma, F. M. and Yeo, A. R. (1998). Water use efficiency in rice in relation to plant. *Plant cell Environ.*, 11: 453-459.
- Flowers, T. J. and Yeo, A. R. (1981). Variability in the resistance of sodium chloride salinity within rice varieties. *New Phytol.*, 88: 363-373.
- Flowers, T. J., Flowers, S. A., Hajibagheri, M. A. and Yeo, A. R. (1990). Salt tolerance in the halophytic wild rice, *Porteresia coarctata* Tateoka. *New Phytol.*, 114: 675-684.
- Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., Johnston, M., Mueller, N. D., O'Connell, L. C., Ray, D. K. and West, P. C. (2011). Solutions for a cultivated planet. *Nat.*, 478: 337-342.
- Foyer, C. H., Descourvieres, P. and Kunert, K. J. (1994). Photo oxidative stress in plants. *Plant Physiol.*, 92: 696-717.

- Funakawa, S., Reiji, S., Elmira, K., Takashi, K. and Norio, I. (2000). Salt affected soils under rice-based irrigation agriculture in southern Kazakhstan. *Geoderma*, 97: 61-685.
- Futakuchi, K., Sié, M. and Saito, K. (2012). Yield potential and physiological and morphological characteristics related to yield performance in *Oryza glaberrima* Steud. *Plant Prod. Sci.* 15: 151-163.
- Gadallah, M. A. A. (1999). Effects of proline and glycinebetaine on *Vicia faba* responses to salt stress. *Biol. Plant.*, 42: 249-257.
- Gangashetty, P., Salimath, P. and Hanamaratti, N. (2013). Genetic variability studies in genetically diverse non-basmati local Aromatic genotypes of rice. *Rice Genomics Genet.*, 4(2): 4-8.
- Ganji Arjenaki, F., Jabbari, R. and Morshedi, A. (2012). Evaluation of drought stress on relative water content, chlorophyll content and mineral elements of wheat varieties. *Intl. J. Agric. Crop Sci.*, 4(11): 726-729.
- García-Plazaola, J. I., Portillo-Estrada, M., Fernández-Marín, B., Kännaste, A. and Niinemets, Ü. (2017). Emissions of carotenoid cleavage products upon heat shock and mechanical wounding from a foliose lichen. *Environ. Exp. Bot.*, 133: 87-97.
- GBIF (Global Biodiversity Information Facility). (2013). Global Biodiversity Information Facility. <http://data.gbif.org/species/>.
- Gewaily, E. E., Ghoneim, A. M. and Osman, M. M. (2018). Effects of nitrogen levels on growth, yield and nitrogen use efficiency of some newly released Egyptian rice genotypes. *Open Agric.*, 3(1): 310-318.
- Ghosh, S. C. and Sharma, D. (2012). Genetic parameters of agromorpho-physiological traits in rice. *Electron. J. Plant Breed.*, 3(1): 711-714.
- Ghoulam, C., Foursy, A. and Fares, K. (2002). Effects of salt stress on growth, inorganic ions and proline accumulation in relation to osmotic adjustment in five sugar beet cultivars. *Environ. Expt. Bot.*, 47: 39-50.

- Gireesh, C. (2018). *Ryza alta* swollen. In: Mondal, T., Henry, R. (eds). The wild oryza genomes. Compendium of plant genomes. Springer, Cham.
- Gohain, T. (2014). Performance of local rice cultivars under aerobic ecosystem of Nagaland. *Ann. Plant Soil Res.*, 16(4): 342-345.
- Gomes, F. B., Olivia, M. A., Nielke, M. S., de Almeida, A. F., Leite, H. G. and Aquine, L. A. (2008). photosynthetic limitations in leaves of young brazilian green dwarf coconut (*Cocos nucifera* L. 'nana') palm under well-watered conditions and recovering from drought stress. *Environ. Expt. Bot.*, 62: 195-204.
- Gomez, K. A. and Gomez, A. A. (1984). Statistical procedures for agricultural research (2 ed.). John wiley and sons, NewYork. p. 680.
- Gong, H. J., Randall, D. P. and Flowers, T. J. (2006). Silicon deposition in the root reduces sodium uptake in rice seedlings by reducing bypass flow. *Plant Cell Environ.*, 29: 1970-1979.
- Gowda, V. R. P., Henry, A., Yamauchi, A., Shashidhar, H. E. and Serraj, R. (2011). Root biology and genetic improvement for drought avoidance in rice. *Field Crops Res.*, 122(1): 1-13.
- Gravois, K. A. and McNew, R. W. (1993). Genetic relationship among and selection for rice yield and yield components. *Crop Sci.*, 33: 249-252.
- Greenway, H. and Munns, R. (1980). Mechanism of salt tolerance in non-halophytes. *Ann. Rev. Plant Physio.*, 31: 139-168.
- Guo, P. and Li, R. (2000). Effects of high nocturnal temperature on photosynthetic organization in rice leaves. *Acta Bot. Sin.*, 42: 13-18.
- Gupta, B. and Huang, B. (2014). Mechanism of salinity tolerance in plants: Physiological, biochemical, and molecular characterization. *Int. J. Genomics*, 1: 701-796.

- Hakim, M. A., Juraimi, A. S., Begum, M., Hanafi, M. M., Ismail, M. R. and Selamat, A. (2010). Effect of salt stress on germination and early seedling growth of rice. *African J. Biotechnol.* 9(13): 1911-1918.
- Hakim, M. A., Juraimi, A. S., Hanafi, M. M., Ali, E., Ismail, M. R., Selamat, A. and Karim, S. M. (2014). Effect of salt stress on morpho-physiology, vegetative growth and yield of rice. *J. Environ.Biol.*, 35: 317-326.
- Hall, D. (1990). *Oryza rufipogon* in the Florida Everglades. *Flora North America News*, 4: 2-4.
- Hanson, A. D., Nelsen, C. E. and Everson, E. H. (1977). Evaluation of free proline accumulation as an index of drought resistance using two contrasting barley cultivars. *Crop Sci.*, 17: 720-726.
- Haque, M. A. and Haque, M. M. (2016). Growth, yield and nitrogen use efficiency of new rice variety under variable nitrogen rates. *American J. Plant Sci.*, 7(3): 612-622.
- Haque, S. A. (2006). Salinity problems and crop production in coastal regions of Bangladesh. *Pakistan J. Bot.*, 38(5): 1359-1365.
- Hare, P. D. and Cress, W. A. (1997). Metabolic implications of stress-induced proline accumulation in plants. *Plant Growth Regul.*, 21(2): 79-102.
- Hare, P. D., Cress, W. A. and Staden, J. V. (2002). Dissecting the roles of osmolyte accumulation during stress. *Plant Cell Environ.*, 21: 535-553.
- Haritha, G., Malathi, S. Divya, B., Swamy, B. P. M., Mangrauthia, S. K. and Sarla, N. (2018). Mondal, Tapan K.; Henry, Robert J. (eds.), "Oryzanivara Sharma et Shastry", *The Wild Oryza Genomes, Compendium of Plant Genomes*, Cham: Springer International Publishing, pp. 207-238.
- Harlan, J. R. (1989). Wild-grass seed harvesting in the Sahara and sub-Sahara of Africa. *Foraging and farming: the evolution of plant exploitation* [ed. by Harris, D.R.\Hillman, G.C.]. London, UK: Unwin Hyman, pp.79-98.

- Hasamuzzaman, M., Fujita, M., Islam, M. N., Ahamed, K. U. and Nahar, K. (2009). Performance of four irrigated rice varieties under different levels of salinity stress. *Intl. J. Integr. Biol.*, 6(2): 85-90.
- Hasan, M. K., Islam, M. S., Islam, M. R., Ismaan, H. N., Sabagh, A. E. L., Barutçular, C., Meena, R. S. and Saneoka, H. (2019). Water relations and dry matter accumulation of black gram and mungbean as affected by salinity. *Thailand J. Agric. Sci.*, 52(1): 54-67.
- Hasan, M. M., Baque, M. A., Habib, M. A., Yeasmin, M. and Hakim, M. A. (2017). Screening of salt tolerance capability of wheat genotypes under salt stress condition. *Univ. J. Agril. Res.*, 5(4): 235-249.
- Hasanuzzaman, M., Alam, M. M., Rahman, A., Hasanuzzaman, M., Nahar, K. and Fujita, M. (2014). Exogenous proline and glycine betaine mediated upregulation of antioxidant defense and glyoxalase systems provides better protection against salt-induced oxidative stress in two rice varieties. *Biomed. Res. Int.* DOI:10.1155/2014/757219.
- Hasegawa, P. M., Bressan, R. A., Zhu, J. K. and Bohnert, H. J. (2000). Plant cellular and molecular responses to high salinity. *Annu. Rev. Plant Physiol. Plant Mol. Biol.*, 51: 463-499.
- Hassan, M. S., Khair, A. and Haque, M. M. (2009). Genotypic variation in traditional rice varieties for Chlorophyll content, SPAD value and nitrogen use efficiency. *Bangladesh J. Agril. Res.*, 34: 505-515.
- Hassanein, R. A., Hashem, H. A. and Khalil, R. R. (2012). Stigmasterol treatment increases salt stress tolerance of faba bean plants by enhancing antioxidant systems. *Plant Omics*, 5(5): 476.
- Hayat, S. (2012). Role of proline under changing environments. *Plant Signal. Behav.*, 7(11): 1456-1466.
- Hayat, S., Hayat, Q., Alyemeni, M. N., Wani, A. S., Pichtel, J. and Ahmad, A. (2012). Role of proline under changing environments: A Rev. *Plant Signal Behav.*, 7(11): 1456-1466.

- Heenan, D. P. and Lewin, L. G. (1988). Salinity tolerance in rice varieties at different growth stages. *Australian J. Expt. Agric.*, 28(3): 343-349.
- Heinrichs, E. A., Viajante, V. D. and Romena, A. M. (1985). Resistance of wild rices, *Oryza* spp., to the whorl maggot *Hydrellia philippina* Ferino (Diptera: Ephydriidae). *Environ. Entomol.*, 14(4): 404-407.
- Henry, A., Gowda, V. R. P., Torres, R. O., McNally, K. L. and Serraj, R. (2011). Variation in root system architecture and drought response in rice (*Oryza sativa*): phenotyping of the *Oryza* SNP panel in rainfed lowland fields. *Field Crops Res.*, 120: 205-214.
- Hichem, H., Mounir, D. and Naceur, E. A. (2009). Differential responses of two maize varieties to salt stress: changes on polyphenols composition of foliage and oxidative damages. *Indian Crops Prod.*, 30: 144-151.
- Hien, D. T., Jacobs, M., Angenon, G., Hermans, C., Thu, T. T., Van Son, L. and Roosens, N. H. (2003). Proline accumulation and  $\Delta^1$ -pyrroline-5-carboxylate synthase gene properties in three rice cultivars differing in salinity and drought tolerance. *Plant Sci.*, 165(5): 1059-1068.
- Hirt, H. and Shinozaki, K. (2004). *Plant responses to abiotic stress*. Springer, Berlin.
- Hoang, T. M. L., Tran, T. N., Nguyen, T. K. T., Williams, B., Wurm, P., Bellairs, S. and Mundee, S. (2016). Improvement of salinity stress tolerance in rice: challenges and opportunities. *Agron.*, 6: 1-23.
- Holt, N. E., Zigmantas, D., Valkunas, L., Li, X. P., Niyogi, K. K. and Fleming, G. R. (2005). Carotenoid cation formation and the regulation of photosynthetic light harvesting. *Sci.*, 307: 433-436.
- Hoogenboom, G., Huck, M. G. and Peterson, C. M. (1987). Root growth rate of soybean as affected by drought stress. *Agron J.*, 79: 607-614.
- Hossain, M. A. (2001). Growth and yield performance of some boro rice cultivars under different soil moisture regimes. M.S. Thesis, Dep. Crop Bot. Bangladesh Agric. Univ., Mymensingh.

- Hossain, M. A., Hoque, M. A., Burritt, D. J. and Fujita, M. (2014b). Proline protects plants against abiotic oxidative stress: biochemical and molecular mechanisms. In: Ahmad P (ed) Oxidative damage to plants. Elsevier Inc, San Diego.
- Hossain, M. M., Islam, M. M., Hossain, H., Ali, M. S., Teixeira da Silva, J. A., Komamine, A. and Prodhan, S. H. (2012). Genetic diversity analysis of aromatic landraces of rice by microsatellite markers. *Genes, Genomes and Genomics*. 6(2): 42-47.
- Hossain, M. M., Sultana, F. and Rahman, A. H. M. A. (2014a). A comparative screening of hybrid, modern varieties and local rice cultivar for brown leaf spot disease susceptibility and yield performance. *Arch. Phytopathol. Plant Prot.*, 47(7): 795-802.
- Hossain, M. Z., Rasel, I. U. and Samad, R. (2016). Soil moisture effects on the growth of lentil (*Lens culinaris* Medik.) varieties in Bangladesh. *Mol.*, 16: 30-40.
- Hossain, M. Z., Sikder, S., Husna, A., Sultana, S., Akhter, S., Alim, A. and Joardar, J. C. (2020). Influence of water stress on morphology, physiology and yield contributing characteristics of rice SAARC *J. Agric.*, 18(1): 61-71.
- Hou, X., Xie, K., Yao, J., Qi, Z. and Xiong, L. (2009). A homolog of human ski-interacting protein in rice positively regulates cell viability and stress tolerance. *Proc. Natl. Acad. Sci. USA*, 106: 6410-6415.
- Houborg, R., McCabe, M., Cescatti, A., Gao, F., Schull, M. and Gitelson, A. (2015). Joint leaf chlorophyll content and leaf area index retrieval from landsat data using a regularized model inversion system (regflec). *Remote Sens. Environ.*, 159: 203-221.
- Hu, H. and Xiong, L. (2014). Genetic engineering and breeding of drought-resistant crops. *Annu. Rev. Plant Biol.*, 65: 715-741.
- Huang, C. J., Wei, G., Jie, Y.C., Xu, J. J., Zhao, S. Y., Wang, L. C. and Anjum, S. A. (2015). Responses of gas exchange, chlorophyll synthesis and ros-scavenging



- systems to salinity stress in two ramie (*Boehmeria nivea* L.) cultivars. *Photosynthetica*, 53: 455-463.
- Hunt, R. (1978). The fitted curve in plant growth studies. *Mathematics and Plant Physiology*. Rose, D. A. and Edwards, D. A. C. (eds.). Aca. Press. London, pp. 283-298.
- Hussain, M., Malik, M. A., Farooq, M., Ashraf, M. Y. and Cheema, M. A. (2008). Improving drought tolerance by exogenous application of glycinebetaine and salicylic acid in sunflower. *J. Agron. Crop Sci.*, 194: 193-199.
- Hussain, S., Jun-hua, Z., Chu, Z., Lian-feng, Z., Xiao-chuang, C., Sheng-miao, Y. U., James, A. B., Ji-jie, H. and Qian-yu J. (2017). Effects of salt stress on rice growth, development characteristics, and the regulating ways: A rev. *J. Integr. Agric.*, 16(11): 2357-2374.
- IRRI (International Rice Research Institute) (1996). Standard Evaluation System for Rice. International Rice Research Institute, Los Banos, Manila, Philippines. p. 52.
- Islam, A. K. M. S., Rana, M. S., Rahman, M. M., Mian, M. J. A., Rahman, M. M., Rahman, M. A. and Naher, N. (2016). Growth, yield and nutrient uptake capacity of rice under different sulphur levels. *Turkish J. Agric. Food Sci. Technol.*, 4(7): 557-565.
- Islam, M. R., Akther, H., Afroz, M. and Bilkis, S. (2013). Effect of nitrogen from organic and inorganic sources on the yield and nitrogen use efficiency of BRRI dhan28. *Bangladesh J. Prog. Sci. Technol.*, 11(2): 179-184.
- Islam, M. R., Salam. M. A., Hassan, L., Collard, B. C. Y., Singh, R. K. and Gregorio, G. B. (2011). QTL mapping for salinity tolerance at seedling stage in rice. *Emir. J. Food Agric.*, 23: 137-146.
- Islam, M. S. (2001). Morpho-physiology of black gram and mungbean as influenced by salinity. MS thesis, Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur, Bangladesh.

- Islam, M. S. (2008). Water stress tolerance of mungbean genotypes as influenced by plant growth regulators. A Ph. D. Dissertation, Dept. of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh.
- Islam, M. T., Islam, M. T. and Salam, M. A. (1994a). Growth and yield performance of some rice genotypes under different soil moisture regimes. Bangladesh J. Trg. Dev., 7(2): 57-62.
- Islam, M. T., Salam, M. A. and Kauser, M. (1994b). Effect of soil water stress at different growth stages of rice on yield components and yield. Prog. Agric., 5(20): 151-156.
- Islam, M. Z. and Mia, B. M. A. (2007). Effect of different saline levels on growth and yield attributes of mutant rice. J. Soil. Natl., 1(2): 18-22.
- Ivens, G. W. (1989). East African weeds and their control, Nairobi, Kenya: Oxford University Press.
- Jahan, A., Islam, A., Sarkar, M. I. U., Iqbal, M., Ahmed, M. N. and Islam, M. R. (2020). Nitrogen response of two high yielding rice varieties as influenced by nitrogen levels and growing seasons. Geol. Ecol. Landscap., pp.1-8.
- Jahan, M. S., Nordin, M. N. B., Lah, M. K. B. C. and Khanif, Y. M. (2013). Effects of water stress on rice production: bioavailability of potassium in soil. J. Stress Physiol. Biochem., 9(2): 97-107.
- Jahan, M. S., Nozulaidi, M. B. N., Moneruzzaman, M. K., Ainun, A. and Husna, N. (2014). Control of plant growth and water loss by a lack of light-harvesting complexes in photosystem-II in Arabidopsis thaliana chl-1 mutant. Acta Physiol. Plant, 36(7): 1627-1635.
- Jain, R. K., Mishra, M. D. and Singh, J. (1989). *Oryza barthii* - a promising resistance source to rice tungro virus. Indian Phytopathol., 42(4): 551-552.
- Jaleel, C. A., Manivannan, P., Wahid, A., Farooq, M., Al-Juburi, H. J., Somasundaram, R. and Panneerselvam, R. (2009). Drought stress in plants: A

- review on morphological characteristics and pigments composition. *Int. J. Agric. Biol.*, 11(1): 100-105.
- Jamil, M., Bae, L. D., Yong, J. K., Ashraf, M., Chun, L. S. and Shik, R. E. (2006). Effect of salt (NaCl) stress on germination and early seedling growth of four vegetables species. *J. Cent. European Agric.*, 7: 273-282.
- Jarne, P. and Lagoda, P. J. L. (1996). Microsatellites, from molecules to populations and back. *Trends Ecol. Evol.*, 11(10): 424-429.
- Jeong, J. S., Kim, Y. S., Baek, K. H., Jung, H., Ha, S. H. and Do Choi, Y. (2010). Root-specific expression of OsNAC10 improves drought tolerance and grain yield in rice under field drought conditions. *Plant Physiol.*, 153: 185-97.
- Ji, K. X., Wang, Y. Y., Sun, W. N., Lou, Q. J., Mei, H. W., Shen, S. H. and Chen, H. (2012). Drought-responsive mechanisms in rice genotypes with contrasting drought tolerance during reproductive stage. *J. PlantPhysiol.*, 169(4): 336-344.
- Jiang, X. J., Zhang, S., Miao, L., Tong, T., Liu, Z. and Sui, Y. (2010). Effect of salt stress on rice seedling characteristics, effect of salt stress on root system at seedling stage of rice. *North Rice*, 40: 21-24.
- Jones, M., Heinrichs, E., Johnson, D. and Riches, C. (1994). Characterization and utilization of *Oryza glaberrima* in the upland rice breeding program. In: WARDA, Annual report 1993. *Bouaké, Côte d'Ivoire*. pp. 3-13.
- Joseph, B., Jini, D. and Sujatha, S. (2010). Biological and physiological perspectives of specificity in abiotic salt stress response from various rice plants. *Asian J. Agric. Sci.*, 2(3): 99-105.
- Kabir, M. E., Karim, M. A. and Azad, M. A. K. (2004). Effect of potassium on salinity tolerance of mungbean (*Vigna radiata* L. Wilczek). *J. Biol. Sci.*, 4: 103-110.
- Kabir, M. S., Salam, M. U., Chowdhury, A. Rahman, N. M. F., Iftekharuddaula, K. M., Rahman, M. S., Rashid, M. H., Dipti, S. S., Islam, A., Latif, M. A., Islam, A. K. M. S., Hossain, M. M., Nessa, B., Ansari, T. H., Ali, M. A. and Biswas,

- J. K. (2015). Rice Vision for Bangladesh: 2050 and Beyond . Bangladesh Rice J., 19(2): 1-18.
- Kabir, S. M. H. (2012). Rice. In: Islam, Sirajul; Jamal, Ahmed A. (eds.). Banglapedia: National Encyclopedia of Bangladesh (Second ed.). Asiatic Society of Bangladesh.
- Kaiser, W. M. (1987). Effect of water deficit on photosynthetic capacity. Plant Physiol., 7: 142-149.
- Kamal, M. Z. U., Yamaguchi, M., Azuchi, F., Kinose, Y., Wada, Y., Funada, R. and Izuta, T. (2015). Effects of ozone and soil salinity, singly and in combination, on growth, yield and leaf gas exchange rates of two Bangladeshi wheat cultivars. Asian J. Atmos. Environ., 9(2): 173-186.
- Kamoshita, A., Rofriguez, R., Yamauchi, A. and Wade, L. (2004). Genotypic variation in response of rainfed lowland to prolonged drought and rewatering. Plant Prod. Sci., 7: 406- 420.
- Kanawapee, N., Sanitchon, J., Lontom, W. and Threerakulpisut, P. (2012). Evaluation of salt tolerance at the seedling stage in rice genotypes by growth performance, ion accumulation, proline and chlorophyll content. Plant Soil, 358: 235-249.
- Kang, D. J. and Futakuchi, K. (2019). Effect of moderate drought-stress on flowering time of interspecific hybrid progenies (*Oryza sativa* L. × *Oryza glaberrima* Steud.). J. Crop Sci. Biotechnol., 22(1): 75-81.
- Kartika, K., Sakagami, J., Laktan, B., Yabuta, S., Wijaya, A., Kadir, S., Widur, I.L., Siaga, E. and Nako, Y. (2020). Morpho-physiological response of *Oryza glaberrima* to gradual soil drying. Rice Sci., 27(1): 67-74.
- Kassa, B., Libois, R. and Sinsin, B. (2008). Diet and food preference of the waterbuck (*Kobus ellipsiprymnus defassa*) in the Pendjari National Park, Benin. African J. Ecol., 46(3): 303-310.

- Kastura, K. and Nakaide, Y. (2011). Factors that determine grain weight in rice under high yielding aerobic culture: The importance of husk size. *Field Crops Res.*, 123: 266-272.
- Kaushal, P. and Ravi, P. (1998). Crossability of wild species of *Oryza* with *O. sativa* cvs PR 106 and Pusa Basmati 1 for transfer of bacterial leaf blight resistance through interspecific hybridization. *J. Agril. Sci.*, 130(4): 423-430.
- Kaushal, P. and Sidhu, J. S. (1998). Screening of wild *Oryza* species against bacterial leaf blight (*Xanthomonas oryzae* pv. *oryzae*) pathotypes of Punjab (India). *Plant Breed.*, 117(5): 491-493.
- Kaushal, P., Ravi and Sidhu, J. S. (1998). Screening of wild *Oryza* species against bacterial leaf blight (*Xanthomonas oryzae* pv. *oryzae*) pathotypes of Punjab (India). *Plant Breed.*, 117(5): 491-493.
- Kavar, T., Maras, M., Kidric, M., Sustar-Vozlic, J. and Meglic, V. (2007). Identification of genes involved in the response of leaves of *Phaseolus vulgaris* to drought stress. *Mol. Breed.*, 21: 159-172.
- Kaya, M. D., Okçub, G., Ataka, M., Çıkılıç, Y. and Kolsarıcı, Ö. (2006). Seed treatments to overcome salt and drought stress during germination in sunflower (*Helianthus annuus* L.). *European J. Agron.*, 24: 291-295.
- Kemble, A. R. and MacPherson, H. T. (1954). Liberation of amino acids in perennial rye grass during wilting. *Biochem. J.*, 58: 46-49.
- Keyvan, S. (2010). The effects of drought stress on yield, relative water content, proline, soluble carbohydrates and chlorophyll of bread wheat cultivars. *J. Anim. Plant Sci.*, 8(3): 1051-1060.
- Khairi, M., Nozulaidi, M., Afifah, A. and Jahan, M. S. (2015). Effect of various water regimes on rice production in lowland irrigation. *Australian J. Crop Sci.*, 9(2): 153-159.
- Khan, A. L., Hamayun, M., Kim, Y. H., Kang, S. M. and Lee, I. J. (2011). Ameliorative symbiosis of endophyte (*Penicillium funiculosum* LHL06) under

salt stress elevated plant growth of *Glycine max* L. Plant Physiol. Biochem., 49: 852-861.

Khan, F., Upreti, P., Singh, R., Shukla, P. K. and Shirke, P. A. (2017). Physiological performance of two contrasting rice varieties under water stress. Physiol. Mol. Biol. Plants, 23(1): 85-97.

Khan, M. A. A. (1981). The Effect of CO<sub>2</sub> environment on the pattern of growth and development in rice and mustard. PhD Dissertation. Royal Vet. and Agril. Univ. Copenhagen, p. 104.

Khan, M. B., Hussain, N. and Iqbal, M. (2001). Effect of water stress on growth and yield components of maize variety YHS 202. J. Res. Sci., 12: 15-18.

Khan, M. S. A., Hamid, A. and Karim, M. A. (1997). Effect of sodium chloride on germination and seedling characters of different types of rice. J. Agron. Crop Sci., 179: 163-169.

Khan, Z. R., Rueda, B. P. and Caballero, P. (1989). Behavioural and physiological responses of rice leaffolder *Cnaphalocrocis medinalis* to selected wild rices. Entomol. Exp. Appl., 52(1): 7-13.

Khanam, T., Akhtar, N., Halim, M. A. and Hossain, F. (2018). Effect of irrigation salinity on the growth and yield of two Aus rice cultivars of Bangladesh. Jahangirnagar Univ. J. Biol. Sci., 7(2): 1-12.

Khatun, S. and Flowers, T. J. (1995). Effects of salinity on seed set in rice. Plant Cell Environ., 18(1): 61-67.

Khatun, S. and Rizzo, C. A. (1995). Genotypic variation in the effect of salinity on fertility in rice. Plant Soil., 173(2): 239-250.

Khayatnezhad, M. (2012). The effect of drought stress on leaf chlorophyll content and stress resistance in maize cultivars. African J. Microbiol. Res., 6(12): 2844-2848.

Khedr, A. H. A., Abbas, M. A., Wahid, A. A. A., Quick, W. P. and Abogadallah, G. M. (2003). Proline induces the expression of salt-stressresponsive proteins and

- may improve the adaptation of *Panocratium maritimum* L. to salt-stress. J. Exp. Bot., 54 (392): 2553-2562.
- Khush, G. S. (1997). Origin, dispersal, cultivation and variation of rice. Plant Mol. Biol., 35(1-2): 25-34.
- Kijoji, A. A., Nchimbi-Msolla, S., Kanyeka, Z. L., Klassen, S. P., Serraj, R. and Henry, A. (2013). Water extraction and root traits in *Oryza sativa* × *Oryza glaberrima* introgression lines under different soil moisture regimes. Funct. Plant Biol., 40(1): 54-66.
- Kikuta, M., Makihara, D., Arita, N., Miyazaki, A. and Yamamoto, Y. (2019). Effects of different water management practices on the dry matter production process and characteristics in NERICAs. Plant Prod. Sci., 22(2): 168-179.
- Kiran, T. V., Rao, Y. V., Subrahmanyam, D., Rani, N.S., Bhadana, V. P., Rao, P. R. and Voleti, S. R. (2013). Variation in leaf photosynthetic characteristics in wild rice species. Photosynthetica, 51(3): 350-358.
- Kirk, J. T. O. and Allen, R. L. (1965). Dependence of chloroplast pigments synthesis on protein synthetic effects on actilon. Biochemistry and Biophysics, Research, 27: 523-530.
- Kishor, P .B. K., Sangam, S., Amrutha, R. N., Axmi, S., Naidu, K. R., Rao, K. R. S. S., Rao, S., Reddy, K. J., Theriappan, P. and Sreenivasulu, N. (2005). Regulation of proline biosynthesis, degradation, uptake and transport in higher plants: its implications in plant growth and abiotic stress tolerance. Crit. Rev. Curr. Sci., 88: 424-438.
- Kishor, P. B. K. and Sreenivasulu, N. (2014). Is proline accumulation per se correlated with stress tolerance or is proline homeostasis a more critical issue? Plant Cell Environ., 37: 300-311.
- Knowledge bank. (2013). Rice Knowledge Bank. Wild rice taxonomy. <http://www.knowledgebank.irri.org/extension/oryza-barthii-a-chev.html>.

- Kocks, P., Ross, J. and Björkman, O. (1995). Thermodynamic efficiency and resonance of photosynthesis in a C<sub>3</sub> plant. *J. Phys. Chem.*, 99: 16483-16489.
- Koffler, B. E., Luschin-Ebengreuth, N., Stabentheiner, E., Müller, M. and Zechmann, B. (2014). Compartment specific response of antioxidants to drought stress in *Arabidopsis*. *Plant Sci.*, 227: 133-144.
- Kronzucker, J. K. and Britto, T. D. (2011). Sodium transport in plants: A critical review. *New Phytol.*, 189: 54-81.
- Kulich, J. and Kaluba, E. M. (1985). Pasture research and development in Zambia. In: Pasture improvement research in Eastern and Southern Africa [ed. by Kategile, J.A.]. Ottawa, Canada: International Development Research Centre, pp. 163-179.
- Kumar, A., Bandhu, P. and Das, A. (2005). Salt tolerance and salinity effects on plants: a review. *Ecotoxicol. Environ. Saf.*, 60: 324-349.
- Kumar, A., Dixit, S., Ram, T., Yadaw, R. B., Mishra, K. K. and Mandal, N. P. (2014b). Breeding high-yielding drought-tolerant rice: Genetic variations and conventional and molecular approaches. *J. Exp. Bot.*, 65(21): 6265-6278.
- Kumar, S., Dwivedi, S. K., Singh, S. S., Bhatt, B. P., Mehta, P., Elanchezhian, R., Singh, V. P. and Singh, O. N. (2014a). Morphophysiological traits associated with reproductive stage drought tolerance of rice genotypes under rain-fed condition of eastern Indo-Gangetic Plain. *Indian J. Plant Physiol.*, 19(2): 87-93.
- Kumar, S., Kour, S., Gupta, M., Kachroo, D. and Singh, H. (2017). Influence of rice varieties and fertility levels on performance of rice and soil nutrient status under aerobic conditions. *J. Appl. Natl. Sci.*, 9(2): 1164-1169.
- Lakitan, B., Alberto, A., Lindiana, L., Kartika, K., Herlinda, S. and Kurnianingsih, A. (2018). The benefits of bichar on growth and yield in tropical riparian wetland, South Sumatera, Indonesia. *CMUJ Nat. Sci.*, 17(2): 111-126.



- Larkunthod, P., Nounjan, N., Siangliw, J. L., Toojinda, T., Sanitchon, J., Jongdee, B. and Theerakulpisut, P.(2018). Physiological responses under drought stress of improved drought- tolerant rice lines and their parents. Not. Bot. Hort. Agrobot., 46(2): 679-687.
- Lauteri, M., Haworth, M., Serraj, R., Monteverdi, M. C. and Centritto, M. (2014). Photosynthetic diffusional constraints affect yield in drought stressed rice cultivars during flowering. PLoS One, 9(10): e109054.
- Lawlor, D. W. and Cornic, G. (2002). Photosynthetic carbon assimilation and associated metabolism in relation to water deficits in higher plants. Plant Cell Environ., 25: 275-294.
- Le Rudulier, D. (2005). Osmoregulation in rhizobia: The key role of compatible solutes. Grain Legu., 42: 18-19.
- Leishman, M. R. and Westoby, M. (1994). The role of seed size in seedling establishment in dry soil conditions -experimental evidence from semi-arid species. J. Ecol., 82(2): 249-258.
- Levitt, J. (1980). Responses of plant to environmental stress chilling, freezing, and high temperature stresses, 2<sup>nd</sup> eds. Academic, New York.
- Li, N., Chen, S., Zhou, X., Li, C., Shao, J., Wang, R., Fritz, E., Hüttermann, A. and Polle, A. (2008). Effect of NaCl on photosynthesis, salt accumulation and ion compartmentation in two mangrove species, *Kandelia candel* and *Bruguiera gymnorhiza*. Aquat. Bot., 88: 303-310.
- Li, P. H., Wang, Z. L., Zhang, H. and Wang, B. S. (2004). Cloning and expression analysis of the B subunit of V-H<sup>+</sup>-ATPase in the leaves of Suaeda salsa under NaCl stress. Acta Bot. Sin., 46: 93-99.
- Linares, O. F. (2002). African rice (*Oryza glaberrima*): history and future potential. Proc. Natl. Acad. Sci. America, 99: 16360-16365.

- Lisar, S. Y. S., Motafakkerazad, R., Hossain, M. M. and Rahman, I. M. M. (2012). Water Stress in Plants: Causes, Effects and Responses. Rijeka, Croatia: InTech., pp. 1-14.
- Liu, K. J. and Muse, S. V. (2005). PowerMarker: an integrated analysis environment for genetic marker analysis. *Bioinform.*, 21: 2128-2129.
- Liu, K., Ye, Y., Tang, C., Wang, Z. and Yang, J. (2008). Responses of ethylene and ACC in rice grains to soil moisture and their relations to grain filling. *Front. Agric. China*, 2: 172-180.
- Liu, L., Lafitte, R. and Guan, D. (2004). Wild *Oryza* species as potential sources of drought adaptive traits. *Euphytica*, 138: 149-161.
- Liu, T. and van Staden, J. (2000). Selection and characterization of sodium chloride tolerant callus of *Glycine max* (L.) Merr cv. Acme. *Plant Growth Regul.*, 31: 195-207.
- Liul, L., Lafitte, R. and Guan, D. (2004). Wild *Oryza* species as potential sources of drought-adaptive traits. *Euphytica*, 138: 149-161.
- Loggini, B., Scartazza, A., Brugnoli, E. and Navari-Izzo, F. (1999). Antioxidative defense system, pigment composition, and photosynthetic efficiency in two wheat cultivars subjected to drought. *Plant Physiol.*, 119: 1091-1100.
- Long, S. P. and Baker, N. R. (1986). Saline terrestrial environments. In: Baker, N. R. and Long, S. P. (Eds.), *Photosynthesis in Contrasting Environments*, Elsevier, Amsterdam. pp. 63-102.
- Lopes, M. S. and Reynolds, M. P. (2010). Partitioning of assimilates to deeper roots is associated with cooler canopies and increased yield under drought in wheat. *Funct. Plant Biol.*, 37: 147-156.
- Ludlow, M. M. and Muchow, R. C. (1990). A critical evaluation of traits for improving crop yields in water-limited environments. *Adv. Agron.*, 43: 107-153.

- Lum, M. S., Hanafi, M. M., Rafii, Y. M. and Akmar, A. S. N. (2014). Effect of drought stress on growth, proline and antioxidant enzymes of upland rice. *J. Anim. Plant Sci.*, 24(5): 1487-1493.
- Lutts, S., Kinet, J. M. and Bouharmont, J. (1996). NaCl-induced senescence in leaves of rice cultivars differing in salinity resistance. *Ann. Bot.*, 78(3): 389-398.
- Lutts, S., Majerus, V. and Kinet, J. M. (1999). NaCl effects on proline metabolism in rice seedlings. *Physiol. Plant*, 105(3): 450-458.
- Mafakheri, A., Siosemardeh, A., Bahramnejad, B., Struik, P. C. and Sohrabi, E. (2010). Effect of drought stress on yield, proline and chlorophyll contents in three chickpea cultivars. *Australian J. Crop Sci.*, 4(8): 580-585.
- Maggio, A. (2002). Does proline accumulation play an active role in stress-induced growth reduction? *Plant J.* 31(6): 699-712.
- Maggio, A., Miyazaki, S., Veronese, P., Fujita, T., Ibeas, J. I., Damsz, B., Narasimhan, M., Hasegawa, P. M., Joly, R. J. and Bressan, R. A. (2002). Does proline accumulation play an active role in stress-induced growth reduction? *Plant J.*, 31(6): 699-712.
- Mahajan, G., Timsina, J., Jhanji, S., Sekhon, N. K. and Singh, K. (2012). Cultivar response, dry matter partitioning and nitrogen use efficiency in direct seeded rice in northwest India. *J. Crop Improv.*, 26: 767-790.
- Mahmood, M., Latif, T. and Khan, M. A. (2009). Effect of salinity on growth, yield and yield components in basmati rice germplasm. *Pakistan J. Bot.*, 41(6): 3033-3045.
- Mahmud, A. A. (2012). Improvement of drought tolerant potato variety. A Ph. D. Dissertation. Dept. of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh.
- Maisura, Chozin, M. A., Lubis, I., Junaedi, A. and Ehara, H. (2014). Some physiological character responses of rice under drought conditions in a paddy system. *J. ISSAAS*, 20(1): 104-114.

- Malumpong, C., Youngkom, P., Vanavichit, A. and Siang-Liw, M. (2019). Variation in tolerance to salinity stress at the reproductive stage in a large fast neutron mutant rice population. *Intl. J. Agril. Technol.*, 15(3): 445-464.
- Manikavelu, A., Nadarajan, N., Ganesh, S. K., Gnanamalar, R. P. and Babu, C. R. (2006). Drought tolerance in rice: Morphological and molecular genetic consideration. *Plant Growth Regul.*, 50(2/3): 121-138.
- Manivannan, P., Jaleel, C. A., Sanker, B., Kishorekumar, A., Somassundaram, R., Alagu Lakshmanan G. M. and Panneerselvam, R. (2007). Growth, biochemical modifications and praline metabolism in *Helianthus annuus* L. as induced by drought stress. *Colloids Surf. Bionierfaces*, 59: 141-149.
- Marie, A. and Vengosh, A. (2001). Sources of salinity in ground water from Jericho area, Jordan Valley. *Ground water*, 39: 240-248.
- Marquardt, J. (1998). Effects of carotenoid-depletion on the photosynthetic apparatus of a *Galdieria sulphuraria* (rhodophyta) strain that retains its photosynthetic apparatus in the dark. *J. Plant Physiol.*, 152: 372-380.
- Martin, M., Micell, F., Morgan, J. A., Scalet, M. and Zerbi, G. (1993). Synthesis of osmotically active substances in winter wheat leaves as related to drought resistance of different genotypes. *J. Agron. Crop Sci.*, 171: 176-184.
- Martinez, C. P., Tohme, J., Lopez, J., Borrero, J., McCouch, S. R., Roca, W., Chatel M. and Guimaraes, E. (1998). Current status of rice improvement through use of wild rice species at CIAT. *Agron. Mesoamericana*, 9(1): 10-17.
- Martinez, J. P., Silva, H., Ledent, J. F. and Pinto, M. (2007). Effect of drought stress on the osmotic adjustment, cell wall elasticity and cell volume of six cultivars of common beans (*Phaseolus vulgaris* L.). *European J. Agron.*, 26: 30-38.
- Mazher, A. M. A., El-Quesni, E. M. F. and Farahat, M. M. (2007). Responses of ornamental and woody trees to salinity. *World J. Agric. Sci.*, 3(3): 386-395.

- Meiri, A. and Poljakoff-Mayber, A. (1970). Effect of various salinity regimes on growth, leaf expansions and transpiration rate of bean plants. *Plant Soil Sci.*, 109: 26-34.
- Menguer, P. K., Sperotto, R. A. and Ricachenevsky, F. K. (2017). A walk on the wild side: *Oryza* species as source for rice abiotic stress tolerance. *Genet. Mol. Biol.*, 40(1): 238-252.
- Merah, O. (2001). Potential importance of water status traits for durum wheat improvement under Mediterranean conditions. *J. Agril. Res.*, 137: 139-145.
- Merzlyak, M. N., Gitelson, A. A., Chivkunova, O. B. and Rakitin, V. Y. (1999). Non-destructive optical detection of pigment changes during leaf senescence and fruit ripening. *Physiol. Plant*, 106: 135-141.
- Mia, M. A. B. and Shamsuddin, Z. H. (2011). Physio-morphological appraisal of aromatic fine rice in relation to yield potential. *Int. J. Bot.*, 7: 223-229.
- Miller, G. (2018). Reactive oxygen signaling in plants. *Annu. Plant Rev.*, pp.189-201.
- Miller, G., Suzuki, N., Ciftci-Yilmaz, S. and Mittler, R. (2010). Reactive oxygen species homeostasis and signalling during drought and salinity stresses. *Plant Cell Environ.*, 33: 453-467.
- Mishra, S., Singh, B., Misra, P., Rai, V. and Singh, N. K. (2016). Haplotype distribution and association of candidate genes with salt tolerance in Indian wild ricegermplasm. *Plant Cell Rep.*, 35: 2295-2308.
- Misra, A. N., Sahu, S. M., Misra, M., Singh, P., Meera, I., Das, N., Kar, M. and Sahu, P. (1997). Sodium chloride induced changes in leaf growth, and pigment and protein contents in two rice cultivars. *Biol. Plant.*, 39(2): 257-262.
- Molazem, D., Qurbanov, E. M. and Dunyamaliyev, S. A. (2010). Role of proline, Na and chylrophyll content in salt tolerance of corn. *American-Eurasian J. Agric. Environ. Sci.* 9(3): 319-324.

- Momayezi, M. R., Zaharah, A. R., Hanafi, M. M. and Razi, M. I. (2009). Agronomic characteristics and proline accumulation of Iranian rice genotypes at early seedling stage under sodium salts stress. *Malaysian J. Soil Sci.*, 13: 59- 75.
- Mondal, M., Puteh, A., Malek, M. and Rafi, M. (2013). Salinity induced morphophysiological characters and yield attributes in rice genotypes. *J. Food Agric. Environ.*, 11: 610-614.
- Moonmoon, S., Fakir, M. S. A. and Islam, M. T. (2017). Effect of drought stress on grain dry weight, photosynthesis and chlorophyll in six rice genotypes. *Sch. J. Agric. Vet. Sci.*, 4(1):13-17.
- Moradi, F. and Ismail, A. M. (2007). Responses of photosynthesis, chlorophyll fluorescence and ROS-scavenging systems to salt stress during seedling and reproductive stages in rice. *Ann. Bot.*, 99: 1161-1173.
- Morgan, P. W. (1990). Effects of abiotic stresses on plant hormone systems. In: *Stress Responses in plants: adaptation and acclimation mechanisms*, Wiley-Liss, Inc., pp. 113-146.
- Morishima, H., Sano, Y. and Oka, H. I. (1984). Differentiation of perennial and annual types due to habitat conditions in the wild rice *Oryza perennis*. *Plant Syst. Evol.* 144: 119-135.
- Morita, S., Yonemaru, J. and Takanashi, J. (2005). Grain growth and endosperm cell size under high night temperatures in rice. *Ann. Bot.*, 95: 695-701.
- Mostajeran, A. and Eichi, V. R. (2009). Effects of drought stress on growth and yield of rice cultivars and accumulation of proline and soluble sugars in sheath and blades of their different ages leaves. *American-European J. Agric. Environ. Sci.*, 5(2): 264-272.
- Moud, A. M. and Maghsoudi, K. (2008). Salt stress effects on respiration and growth of germinated seeds of different wheat cultivars. *World J. Agril. Sci.*, 4(3): 351-358.

- Moukoubi, Y. D., Sie, M., Vodouhe, R., N'dri, B., Toulou, B., Ogunbayo, S. A. and Ahanchede, A. (2011). Assessing phenotypic diversity of interspecific rice varieties using agro-morphological characterization. *J. Plant Breed. Crop Sci.*, 3(5): 74-86.
- Muhammad, A. and Majid, R. F. (2013). Crop breeding for salt tolerance in the era of molecular markers and marker-assisted selection. *Plant Breed.*, 132: 10-20.
- Munns, R. (2002). Comparative physiology of salt and water stress. *Plant Cell Environ.*, 25: 239-250.
- Munns, R. (2005). Genes and salt tolerance: bringing them together. *New Phytol.*, 167: 645-663.
- Munns, R. (2006). Approaches to increasing the salt tolerance of wheat and other cereals. *J. Expt. Bot.*, 57(5): 1025-1043.
- Munns, R. and Tester, M. (2008). Mechanisms of salinity tolerance. *Annu. Rev. Plant Biol.*, 59: 651-681.
- Munns, R., James, R. A. and Lauchli, A. (2006). Approaches to increasing the salt tolerance of wheat and other cereals. *J. Expt. Bot.*, 57: 1025-1043.
- Nagy, L., Kiss, V., Brumfeld, V., Osvay, K., Börzsönyi, Á., Magyar, M., Szabó, T., Dorogi, M. and Malkin, S. (2015). Thermal effects and structural changes of photosynthetic reaction centers characterized by wide frequency band hydrophone: Effects of carotenoids and terbutryn. *Photochem. Photobiol.*, 91: 1368-1375.
- Nascimento, W. F., Silva, E. F. and Veasey, E. A. (2011). Agro-morphological characterization of upland rice accessions. *Science Agric.*, 68(6): 652-660.
- Ndaeyo, N. U., Iboko, K. U., Harry, G. I. and Edem, S. O. (2008). Growth and yield performance of some upland rice cultivars as influenced by varied rates of NPK fertilizer on an ultisol. *J. Trop. Agric. Food Environ. Ext.*, 7(3): 249-255.

- Ndayiragije, A. and Lutts, S. (2006). Do exogenous polyamines have an impact on the response of a salt-sensitive rice cultivar to NaCl? *J. Plant Physiol.*, 163: 506-516.
- Ndjiondjop, M.N., Seck, P.A., Lorieux, M., Futakuchi, K., Yao, N., Djedatin, G., Sow, M., Bocco, R., Cisse, F. and Fatondji, B.(2012). Effect of drought on oryza glaberrima rice accessions and oryza glaberrima derived-lines. *Asian J. Agril. Res.* 6: 144-157.
- Neelam, K., Sahi, G. K., Kumar, K. and Singh, K. (2018). Identification of drought stress tolerance in wild species germplasm of rice based on leaf and root morphology *Plant Genet. Resour.*, 16(4): 289-295.
- Neelam, K., Sahil, G., K., Kumar, K. and Singh, K. (2017). Identification of drought stress tolerance in wild species germplasm of rice based on leaf and root morphology. *Plant Gen. Resour.*, 16(4): 289-295.
- Negawo, A.T., Jorge, A., Hanson, J., Teshome, A., Muktar, M. S., Azevedo, A. L. S., Ledo, F. J., Machado, J. C. and Jones, C. (2018). Molecular markers as a tool for germplasm acquisition to enhance the genetic diversity of a napier grassm collection. *Trop. Grasslands Forrajes Trop.*, 6(2): 58-69.
- Nei, M., Tajima, F. and Tateno, Y. (1983). Accuracy of estimated phylogenetic trees from molecular data. *J. Mol. Evol.*, 19(2): 153-170.
- Netondo, G. W., Onyango, J. C. and Beck, E. (2004). Sorghum and salinity. Response of growth, water relations and ion accumulation to NaCl salinity. *Crop Sci.*, 44: 797-805.
- Nguyen, H. T., Babu, R. C. and Blum, A. (1997). Breeding for drought resistance in rice: Physilogy and molecular genetics considerations, *Crop Sci.*, 37: 1426-1434.
- Nguyen, H. T., Das Bhowmik, S. S., Long, H., Cheng, Y., Mundree, S.G. and Hoang, L.T. (2021). Rapid accumulation of proline enhances salinity tolerance in australian wild rice *Oryza australiensis* Domin. *Plants*, 10: 45-53.



- Nicolas, M. E., Lambers, H., Simpson, R. J. and Dalling, M. J. (1985). Effect of drought on metabolism and partitioning of carbon in two wheat varieties differing in drought-tolerance. *Ann. Bot.*, 55: 727-742.
- Nicolas, M. E., Munns, R., Samarakoon, A. B. and Gifford, R. M. (1994). Elevated CO<sub>2</sub> improves the growth of wheat under salinity. *Australian J. Plant Physiol.*, 20: 349-360.
- Nikolaeva, M. K., Maevskaya, S. N., Shugaev, A. G. and Bukhov, N. G. (2010). Effect of drought on chlorophyll content and antioxidant enzyme activities in leaves of three wheat cultivars varying in productivity. *Russian J. Plant Physiol.*, 57: 87-95.
- Nobuhiro, S., Ludmila, R., Hongjian, L., Joel, S., Vladimir, S. and Ron, M. (2005). Enhanced tolerance to environmental stress in transgenic plants expressing the transcriptional coactivator multiprotein bridging factor 1c. *Plant Physiol.*, 139: 1313-1322.
- Noctor, G. and Foyer, C. H. (1998). Ascorbate and glutathione: keeping active oxygen under control. *Annu. Rev. Plant Physiol. Plant Mol. Biol.*, 49: 249-279.
- Nonami, H. (1998). Plant water relations and control of cell elongation at low water potentials. *J. Plant Res.*, 111: 373-382.
- Nounjan, N. and Theerakulpisut, P. (2012). Effects of exogenous proline and trehalose on physiological responses in rice seedlings during salt-stress and after recovery. *Plant Soil Environ.*, 58: 309-315.
- Nunes, C., de Sousa, S., da Silva, J. M., Fevereiro, M. P. and da Silva, A. B. (2008). Physiological responses of the legume model *Medicago truncatula* cv. Jemalong to water deficit. *Environ. Exp. Bot.* 63: 289-296.
- Nyoka, G. C. (1983). Weed problems and control practices in deepwater and floating rice in Mali. In: Deat, M. and Marnotte, P. eds. *Proceedings of the Second Biannual Conference*. Abidjan, Côte d'Ivoire: West African Weed Sci. Soc., pp. 146-157.

- O'Toole, J. C. and Moya, T. B. (1981). Water deficit and yield in upland rice. *Field Crops Res.*, 4(3): 247-259.
- Ochiai, K. and Matoh, T. (2002). Characterization of the Na<sup>+</sup> delivery from roots to shoots in rice under saline stress: Excessive salt enhances apoplastic transport in rice plants. *Soil Sci. Plant Nutri.*, 48: 371-378.
- Orcutt, D. M. and Nilsen, E. T. (2000). *The Physiology of Plants Under Stress*. John Wiley and Sons, Inc., 605 Third Avenue, New York, NY 10158-0012, USA.
- Ouyang, W. J., Struik, P. C., Yin, X. Y. and Yang, J. C. (2017). Stomatal conductance, mesophyll conductance, and transpiration efficiency in relation to leaf anatomy in rice and wheat genotypes under drought. *J. Exp. Bot.*, 68(18): 5191-5205.
- Pandey, R. M. and Singh, R. (2010). Genetic studies for biochemical and quantitative characters in grain amaranth (*Amaranthus hypochondriacus* L.). *Plant Omics J.*, 3(4): 129-134.
- Pandey, V. and Shukla, A. (2015). Acclimation and tolerance strategies of rice under drought stress. *Rice Sci.*, 22(4): 147-161.
- Pantuwan, G., Fukai, S., Cooper, M., Rajatasereekul, S. and O'Toole, J. C. (2002). Yield response of rice genotypes to drought under rainfed lowlands: 2. Selection of drought resistant genotypes. *Field Crops Res.*, 73: 169-180.
- Pantuwan, G., Fukai, S., Cooper, M., Rajatasereekul, S. and O'Toole, J. C. (2000). Field screening for drought resistance. In: *Increased lowland rice production in the Mekong region. Proceedings of International Workshop* (Vientiane, Laos), pp. 69-77.
- Parashivamurthy, S., Prashad, R., Lakshmi, J. and Rama-chandra, C. (2012). Influence of varieties and fertilizer levels on growth, seed yield and quality of rice under aerobic conditions. *Mysore J. Agril. Sci.*, 46(3): 602-609.

- Pastori, G. M and Trippi, V. S. (1992). Oxidative stress induces high rate of glutathione reductase synthesis in a drought resistant maize strain. *Plant cell Physiol.*, 33: 957- 961.
- Patra, B. C and Dhua, S. R. (2003). Agro-morphological diversity scenario in upland rice germplasm of Jeypore tract. *Genet. Resour. Crop Evol.*, 50: 825-828.
- Peng, S., Khush, G. S. and Cassman, K. G. (1994). Evaluation of a new plant ideotype for increased yield potential. In: Cassman, K.G. (Ed.), *Breaking the Yield Barrier: Proceedings of a Workshop on rice Yield Potential in Favorable Environments*, Los Banos, Philippines. 29 Nov-4 Dec., 1994. *Int. Rice Res. Inst. Los Banos, Philippines*, pp.5-20.
- Pessarkli, M. (1999). *Hand book of plant and crop stress*. Marcel Dekker Inc., p. 697.
- Petersen, L. and Shireen, S. (2001). Soil and water salinity in the coastal area of Bangladesh. *Soil Resources Development Institute, Dhaka, Bangladesh*. Viewed 11 February, 2018. <http://ageconsearch.umn.edu/bitstream/198012/2/16-160-AJARD-658-667>.
- Phan, P. D. T., Kageyama, H., Ishikawa, R. and Ishii, T. (2012). Estimation of the outcrossing rate for annual Asian wild rice under field conditions. *Breed. Sci.*, 62(3): 256-262.
- Piegu, B., Guyot, R., Picault, N., Roulin, A., Saniyal, A. and Kim, H. (2006). Doubling genome size without polyploidization: dynamics of retrotransposition-driven genomic expansions in *Oryza australiensis*, a wild relative of rice. *Genome Res.* 16: 1262-1269.
- Polash, M. A. S., Sakil, M. A., Tahjib-Ul-Arif, M. and Hossain, M. A. (2018). Effect of salinity on osmolytes and relative water content of selected rice genotypes. *Trop. Plant Res.*, 5(2): 227-232.
- Polivka, T. and Frank, H. A. (2010). Molecular factors controlling photosynthetic light harvesting by carotenoids. *Accounts chem. Res.*, 43: 1125-1134.

- Poorter, H. (1989). Interspecific differences in relative growth rate: On ecological causes and physiological consequences. In: Lambers, H., Cambridge, M. L., Konings, H. and Pons, T. L. (eds). *Causes and Consequences of Variation in Growth Rate and Productivity in Plants*, SPB Academic Publishing, The Hague, pp. 45-68.
- Poorter, H. and Remkes, C. (1990). Leaf area ratio and net assimilation rate of 24 wild species differing in relative growth rate. *Oecologia*, 83: 553-559.
- Poustini, K., Siosemardeh, A. and Ranjbar, M. (2007). Proline accumulation as a response to salt stress in 30 wheat cultivars differing in salt tolerance. *Genet. Resour. Crop Evol.*, 54(5): 925-934.
- Prasad, B. and Eizenga, G. C. (2008). Rice sheath blight disease resistance identified in *Oryza* spp. accessions. *Plant Dis.*, 92(11):1503-1509.
- Prusty, M.R., Kim, S. R., Vinarao, R., Entila, F., Egdane, J., Diaz, M. G. Q. and Jena, K. K. (2018). Newly identified wild rice accessions conferring high salt tolerance might use a tissue tolerance mechanism in leaf. *Front. Plant Sci.*, 9: 417.
- Puvanitha, S. and Mahendran, S. (2017). Effect of salinity on plant height, shoot and root dry weight of selected rice cultivars. *Sch. J. Agric. Vet. Sci.*, 4(4): 126-131.
- Qadir, M., Quillerou, V., Nangia, G., Murtaza, M., Singh, R. J., Thomas, P., Dreschel, and Noble, A. D. (2014). Economics of salt-induced land degradation and restoration. *Nat. Resour. Forum*, 38: 382-295.
- Quampah, A., Wang, R. M., Shamsi, I. H., Jilani, G., Zhang, Q., Hua, S. and Xu, H. (2011). Improving water productivity by potassium application in various rice genotypes. *Intl. J. Agric. Biol.*, 13: 9-17.
- Quintero, J. M., Fournier, J. M., Benlloch, M. and Rodriguez-Navarro, A. (2008). Na<sup>+</sup> accumulation in root symplast of sunflower plants exposed to moderate salinity is transpiration-dependent. *J. Plant Physiol.*, 165: 1248-1254.

- Radford, P. J. (1967). Growth analysis formulae, their use and abuse. *Crop Sci.*, 7: 181-175.
- Radi, A. A., Farghaly, F. A. and Hamada, A. M. (2013). Physiological and biochemical responses of salt-tolerant and salt-sensitive wheat and bean cultivars to salinity. *J. Biol. Earth Sci.* 3(1): 72-88.
- Rahman, M. M., Haque, M. A., Nihad, A. I. S., Akand, M. H. M. and Howlader, M. R. A. (2016). Morpho-physiological response of *Acacia auriculiformis* as influenced by seawater induced salinity stress. *Forest System*, 25(3): 62-71.
- Rahman, M. M., Syed, M. A., Adil, M., Ahmad, H. and Rashid, M. M. (2012). Genetic variability, correlation and path coefficient analysis of some physiological traits of transplanted Aman rice. *Middle East J. Sci. Res.*, 11: 563-566.
- Rahman, S., Jahan, T., Rahman, S. M. M., Rahman, M., Haque, M. M. and Khan, M. A. A. (2018). Evaluation of some transplanted aus rice genotypes for morphology, yield and disease incidence. *European Acad. Res. Bangladesh*, p. 295.
- Raman, A., Verulkar, S. B., Mandal, N. P., Variar, M., Shukla, V. D., Dwivedi, J. L., Singh, B. N., Singh, O. N., Swain, P., Mall, A. K., Robin, S., Chandrababu, R., Jain, A., Ram, T., Hittalmani, S., Haefele, S., Piepho, H. P. and Kumar, A. (2012). Drought yield index to select high yielding rice lines under different drought stress severities. *Rice*, 5(31): 1-12.
- Ramanjaneyulu, A. V., Gourishankar, V., Neelima, T. L. and Shashibhushan, D. (2014). Genetic analysis of rice genotypes under aerobic conditions on alfisols. *SA-BRAO J. Breed. Genet.*, 46(1): 99-111.
- Ranathunge, K., Steudle, E. and Lafitte, R. (2005). Blockage of apoplastic bypass-flow of water in rice roots by insoluble salt precipitates analogous to a Pfeffer cell. *Plant Cell Environ.*, 28: 121-133.

- Rangan, L., Sankararamasubramanian, H. M., Radha, R. and Swaminathan, M. S. (2002). Genetic relationship of *Porteresia coarctata* Tateoka using molecular markers". *Plant Biosystems*, 136(3): 339-348.
- Ranganayakulu, G. S., Sudhakar, C. and Reddy, S. P. (2015). Effect of water stress on proline metabolism and leaf relative water content in two high yielding genotypes of groundnut (*Arachis hypogaea* L.) with contrasting drought tolerance. *J. Expt. Biol. Agric. Sci.*, 3(1): 2320-8694.
- Ranjbarfordoei, A., Samson, R., Damne, P. V. and Lemeur, R. (2000). Effects of drought stress induced by polyethylene glycol on pigment content and photosynthetic gas exchange of *Pistacia khinjak* and *P. mutica*. *Photosynthetica*, 38(3): 443–447.
- Ratnayaka, H. H., Molin, W. T. and Sterling, T. M. (2003). Physiological and antioxidant responses of cotton and spurred anoda under interference and mild drought. *J. Exp. Bot.*, 54: 2293-2305.
- Reddy, T. Y. and Redd, G. H. (1997). *Principle of Agronomy*. Kalyani Publication, New Delhi, India, p. 515.
- Rees, W. A. (1978). The ecology of the Kafue lechwe: the food supply. *J. Appl. Ecol.*, 15(1): 177-191.
- Reimers, P. J., Consignades, B. and Nelson, R. J. (1993). Wild species of *Oryza* with resistance to rice blast (B1). *Int. Rice Res. Notes*, 18(2): 5.
- Ren, X., Jiang, H. Z., Yan, Y., Chen, X., Zhou, L. and Huang. (2014). Genetic diversity and population structure of the major peanut cultivars grown in China by SSR markers. *PLOS One*, 9: e88091.
- Reversat, G. and Destombes, D. (1998). Screening for resistance to *Heterodera sacchari* in the two cultivated rice species, *Oryza sativa* and *O. glaberrima*. *Fundam. Appl. Nematol.*, 21(4): 307-317.

- Rhodes, D. and Samaras, Y. (1994). Genetic control of osmoregulation in plants. In: Strange, S. K., Cellular and Molecular Physiology of Cell Volume Regulation. Boca Raton: CRC Press, pp. 347-361.
- Ritchie, S. W., Nguyen, H. T. and Holaday, A. S. (1990). Leaf water content and gas exchange parameters of two wheat genotypes differing in drought resistance. Crop Sci., 30: 105-111.
- Rodrigues, M. L., Pacheco, C. M. A. and Chaves, M. M. (1995). Soil-plant water relations, root distribution and biomass partitioning in *Lupinus albus* L. under drought conditions. J. Exp. Bot., 46: 947-956.
- Roetman, E. and Sterk, A. A. (1986). Growth of microspecies of different sections of *Taraxacum* in climatic chambers. Acta. Bot. Neerl., 35: 5-22.
- Roy, S. K., Ali, M. Y., Jahan, M. S., Saha, U. K., Ahmad-Hamdani, M. S., Hasan. M. M. and Alam, M. A. (2014b). Evaluation of growth and yield attributing characteristics of indigenous *Boro* rice varieties. Life Sci. J., 11(4): 122-126.
- Roy, S., Banerjee, A., Mawkhlieng, B., Misra, A. K., Pattanayak, A., Harish, G. D., Singh, S. K., Ngachan, S. V. and Bansal, K. C. (2015). Genetic diversity and population structure in aromatic and quality rice landraces from North-Eastern India. Plos One, 0129607.
- Roy, T. S., Pulok, M. A. I., Rahman, M. M., Hussain, M. A. and Khatun, S. (2014a). Effect of varieties and row spacing on the growth and yield of aus rice. Bangladesh Res. Pub. J., 10(2): 138-144.
- RRDI (Rice Research and Development Institute). (1999). Netscape –Effect of water deficit. Dept. Agric., Batalagoda, Ibbagamuwa, Srilanka.
- Rubel, M. H., Hassan, L., Islam, M. M., Robin, A. H. K. and Alam, M. J. (2014). Evaluation of rice genotypes under salt stress at the seedling and reproductive stages using phenotypic and molecular markers. Pakistan J. Bot., 46(2): 423-432.

- Sabouri, H. and Sabouri. A. (2008). New evidence of QTLs attributed to salinity tolerance in rice. *African J. Biotechnol.*, 7: 4376-4383.
- Saeedipour, S. (2012). Effect of post-anthesis water deficit on yield and some physiological parameters on two wheat cultivars. *African J. Agric. Res.*, 7: 3446-3452.
- Saeedipour, S. (2014). Effects of salinity stress on growth, chlorophyll content and ion accumulation in two indica rice cultivars differing in salinity tolerance. *Int. J. Biosci.*, 4(4): 33-40.
- Saha, P., Sade, N., Arzani, A., Rubio Wilhelmi, M. D. M., Coe, K. M., Li, B. and Blumwald, E. (2016a). Effects of abiotic stress on physiological plasticity and water use of *Setaria viridis* (L.). *Plant Sci.*, 251: 128-138.
- Saha, S., Begum, H. H. and Nasrin, S. (2019). Effects of drought stress on growth and accumulation of proline in five rice varieties. *J. Asiat. Soc. Bangladesh Sci.*, 45(2): 241-247.
- Saha, S., Samad, R., Rashid, P. and Karmoker, J. L. (2016b). Effects of sulphur deficiency on growth, sugars, proline and chlorophyll content in mungbean (*Vigna radiata* L. var. BARI Mung-6). *Bangladesh J. Bot.*, 45: 405-410.
- Sajib, A. M., Musharaf, M. H., Mosnaz, A. T. M. J., Hossain, H., Islam, M. M., Ali, M. S. and Prodhan, S. H. (2012). SSR marker-based molecular characterization and genetic diversity analysis of aromatic landraces of rice. *J. BioSci. Biotech.*, 1(2): 107-116.
- Salih, O. M. and Nour, A. M. (1992). Nutritional quality of uncultivated cereal grains utilised as famine foods in western Sudan as measured by chemical analysis. *J. Sci. Food Agric.*, 58(3): 417-424.
- Samson, B. K., Hasan, H. and Wade, L. J. (2002). Penetration of hardpans by rice lines in the rainfed lowlands. *Field Crop Res.*, 76: 175-188.



- Sanchez, D. H., Siahpoosh, M. R., Roessner, U., Udvardi, M. and Kopka, J. (2008). Plant metabolomics reveals conserved and divergent metabolic responses to salinity. *Physiol. Plant*, 132(2): 209-219.
- Sanchez, P. L., Wing, R. A., and Brar, D. S. (2014). The wild relative of rice: genomes and genomics, in *Genetics and genomics of rice*. Springer, pp. 9-25.
- Sangakkara, U. R., Hartwig, U. A. and Nosberger, J. (1996). Response of root branching and shoot water potentials of french bean (*Phaseolus vulgaris* L.) to soil moisture and fertilizer potassium. *J. Agron. Crop Sci.*, 177: 165-173.
- Santabarbara, S., Casazza, A. P., Ali, K., Economou, C. K., Wannathong, T., Zito, F., Redding, K. E., Rappaport, F. and Purton, S. (2013). The requirement for carotenoids in the assembly and function of the photosynthetic complexes in *chlamydomonas reinhardtii*. *Plant Physiol.*, 161: 535-546.
- Santo, C. V. (2004). Regulation of chlorophyll biosynthesis and degradation by salt stress in sunflower leaves. *Sci. Hortic.*, 103: 93-99.
- Saqib, Z. A., Akhtar, J., Ul-Haq, M. A. and Ahmad, I. (2012). Salt induced changes in leaf phenology of wheat plants are regulated by accumulation and distribution pattern of Na<sup>+</sup> ion. *Pakistan J. Agri. Sci.*, 49: 141-148.
- Sarawgi, A. K., Subba Rao, L. V., Parikh, M., Sharma, B. and Ojha, G. C. (2011). Assessment of variability of rice germplasm using agromorphological characterization. *J. Rice Res.*, 6(1): 15-28.
- Sarijeva, G., Knapp, M. and Lichtenthaler, H. K. (2007). Differences in photosynthetic activity, chlorophyll and carotenoid levels, and in chlorophyll fluorescence parameters in green sun and shade leaves of ginkgo and fagus. *J. Plant Physiol.*, 164: 950-955.
- Sarker, B. C., Zahan, M., Majumder, U. K., Islam, M. A. and Roy, B. (2013). Growth and yield potential of some local and high yielding *Boro* rice cultivars. *J. Agric. Environ.*, 7(1): 107-110.

- Sarvestani, Z. T., Pirdashti, H., Sanavy, S. A. and Balouchi, H. (2008). Study of water stress effects in different growth stages on yield and yield components of different rice cultivars. *Pakistan J. Biol. Sci.*, 11(10): 1303-1309.
- Schafleitner, R., Gaudin, A., Rosales, R. O. G., Aliaga, C. A. A. and Bonierbale, M. (2007). Proline accumulation and real time PCR expression analysis of genes encoding enzymes of proline metabolism in relation to drought tolerance in Andean potato. *Acta Physiol. Plant*, 29: 19-26.
- Schlemmer, M. R., Francis, D. D., Shanahan, J. F. and Schepers, J. S. (2005). Remotely measuring chlorophyll content in corn leaves with differing nitrogen levels and relative water content. *Agron. J.*, 97: 106-112.
- Schuppler, U., He, P. H., John, P. C. L. and Munns, R. (1998). Effects of water stress on cell division and cell-division-cycle-2-like cell-cycle kinase activity in wheat leaves. *Plant Physiol.*, 117: 667-678.
- Seckin, B., Turkan, I., Sekmen, A. H. and Ozfidan, C. (2010). The role of antioxidant defense systems at differential salt tolerance of sea barley grass (*Hordeum marinum*) and cultivated barley (*Hordeum vulgare* L.). *Environ. Exp. Bot.*, 69: 76-85.
- Seeman, J. R. and Sharkey, J. D. (1986). Salinity and Nitrogen effects on photosynthesis, Ribulose-1, 5 bisphosphate carboxylase and metabolites pool size in *Phaseolus vulgaris* L. *Plant physiol.*, 82: 555-560.
- Sen, T. T. H., Nhi, P. T. P. and Sen, T. T. (2017). Salinity effect at seedling and flowering stages of some rice lines and varieties. *J. Agril. Sci. Technol.*, 7: 32-39.
- Senanayake, R. M. N. H., Herath, H. M. V. G., Wickramesinghe, I. P., Udawela, U. A. K. S. and Sirisena, D. N. (2017). Phenotypic screening of rice varieties for tolerant to salt stress at seed germination, seedling and maturity stages. *Trop. Agril. Res.*, 29(1): 90-100.

- Sengupta, S. and Majumder, A.L. (2010). *Porteresia coarctata* (Roxb.) Tateoka, a wild rice: a potential model for studying salt-stress biology in rice. *Plant Cell Environ.*, 33: 526-542.
- Sengupta, S. (2014). The possible overlap between salinity and mechanical challenges in *Porteresia coarctata*. *Proc. Indian Nat. Sci. Acad.*, 80(5): 1013-1023.
- Serraj, R. and Sinclair, T. R. (2002). Osmolyte accumulation: Can it really help increase crop yield under drought conditions? *Plant, Cell Environ.*, 25: 333-341.
- Serraj, R., McNally, K. L., Slamet-Loedin, I., Kohli, A., Haefele, S. M., Atlin, G. and Kumar, A. (2011). Drought resistance improvement in rice: An integrated genetic and resource management strategy. *Plant Prod. Sci.*, 14(1): 1-14.
- Serrano, R. and Gaxiola, R. (1994). Microbial models and salt stress tolerance in plants. *Crit. Rev. Plant Sci.*, 13: 121-138.
- Shabala, S. and Cuin, T. A. (2008). Potassium transport and plant salt tolerance. *Physiol. Plant*, 133: 651-659.
- Shabala, S. N. (2000). Ionic and osmotic components of salt stress specifically modulate net ion fluxes from bean leaf mesophyll. *Plant Cell Environ.*, 23: 825-837.
- Shabala, S. N. (2003). Regulation of potassium transport in leaves: from molecular to tissue level. *Ann. Bot.*, 92: 627-634.
- Shah, S. H., Houborg, R. and McCabe, M. F. (2017). Response of chlorophyll, carotenoid and SPAD-502 measurement to salinity and nutrient stress in wheat. *Agron.*, 61: 1-21.
- Shahryari, R., Gurbanov, E., Gadimov, A. and Hassanpanah, D. (2008). Tolerance of 42 bread wheat genotypes to drought stress after anthesis. *Pakistan J. Biol. Sci.*, 11(10): 1330-1335.
- Shaibu, A. A. (2018). Screening african rice (*Oryza glaberrima*) for tolerance to abiotic stresses: II. lowland drought. *Crop Sci.*, 58(1): 133-142.

- Shalhevet, J. (1995). Root and shoot growth responses to salinity in maize and soybean. *Agron J.*, 87:512-516.
- Shao, H. B., Chu, L. Y., Shao, M. A., Jaleel, C. A. and Mi, H. M. (2008). Higher plant antioxidants and redox signaling under environmental stresses. *Comp. Rend. Biol.*, 331: 433-441.
- Sharma, S. S. and Dietz, K. J. (2006). The significance of amino acids and amino acid-derived molecules in plant responses and adaptation to heavy metal stress. *J. Exp. Bot.*, 57: 711-526.
- Shiyam, J. O., Binang, W. B. and Ittah, M. A. (2014). Evaluation of growth and yield attributes of some lowland Chinese hybrid rice varieties in the coastal humid forest zone of Nigeria. *J. Agric. Vet. Sci.*, 7(2): 70-73.
- Shrestha, J., Subedi, S., Kushwaha, U. K. S. and Maharjan, B. (2021). Evaluation of growth and yield traits in rice genotypes using multivariate analysis. *Heliyon*, pp.1-6.
- Shumbe, L., Bott, R. and Havaux, M. (2014). Dihydroactinidiolide, a high light-induced-carotene derivative that can regulate gene expression and photoacclimation in arabidopsis. *Mol. Plant*, 7: 1248-1251.
- Siaga, E., Lakitan, B., Hasbi, Bernas, S. M., Wijaya, A., Lisda, R., Ramadhani, F., Widuri, L. I., Kartika, K. and Meihana, M. (2018). Application of floating culture system in chili pepper (*Capsicum annum* L.) during prolonged flooding period at riparian wetland in Indonesia. *Australian J. Crop Sci.*, 12(5): 808-816.
- Siddiq, S., Aamer, A. A., Sattar, A. and Yaseen, M. M. A. (2011). Response of different rice cultivars to different NPK levels in the central cropping zone of Punjab. *Agril. Sci. Digest*, 3(3): 155-160.
- Siddique, M. R. B., Hamid, A. and Islam, M. S. (2000). Drought stress effects on water relations of wheat. *Bot. Bull. Acad. Sin.* 41: 35-39.

- Siddique, M. R. B., Hamid, A., Islam, M. S. (2001). Drought stress effects on water relations of wheat, Bot. Bull. Acad. Sinica 41: 35-39.
- Sinclair, T. and Ludlow, M. (1985). Who taught plants thermodynamics? The unfulfilled potential of plant water potential. Australian J. Plant Physiol., 12: 213-217.
- Singh, A. K., Prakash, V. and Sastry, E. V. D. (2000). Effect of salinity stress on seed germination and seedling growth of wheat. Agric. Sci. Digestion, 20(2): 96-98.
- Singh, A., Sengar, K. and Sengar, R. S. (2013b). Gene regulation and biotechnology of drought tolerance in rice. Int. J. Biotechnol. Bioeng. Res., 4(6): 547-552.
- Singh, C. M., Babu, G. S., Kumar, B. and Mehandi, S. (2013a). Analysis of quantitative variation and selection criteria for yield improvement in exotic germplasm of upland rice (*Oryza sativa* L.). Bioscan, 8(2): 485-492.
- Singh, D., and Kumar, A. (2014). Effect of sources of nitrogen growth yield and uptake of nutrients in rice. Ann. Plant Soil Res., 16(1): 359-361.
- Singh, K., Neelam, K., Kaur, A. and Kaur, K. (2016a). Rice. In: Singh, M. and Kumar, S. (eds), Broadening the Genetic Base of Grain Cereals. Berlin: Springer, pp. 27-65.
- Singh, R., Pandey, N., Naskar, J. and Shirke, P. A. (2015). Physiological performance and differential expression profiling of genes associated with drought tolerance in contrasting varieties of two *Gossypium species*. Protoplasma, 252: 423-438.
- Singh, R., Singh, Y., Xalaxo, S., Verulkar, S., Yadav, N., Singh, S., Singh, N., Prasad, K. S. N., Kondayya, K., Ramana Rao, P. V., Girija Rani, M., Anuradha, T., Suraynarayana, Y., Sharma, P. C., Krishnamurthy, S. L., Sharma, S. K., Dwivedi, J. L., Singh, A. K., Singh, P. K., Nilanjay, Singh, N. K., Kumar, R., Chetia, S. K., Ahmad, T., Rai, M., Perraju, P., Pande, A., Singh, D. N., Mandal, N. P., Reddy, J. N., Singh, O. N., Katara, J. L., Marandi, B., Swain, P., Sarkar, R. K., Singh, D. P., Mohapatra, T., Padmawathi, G., Ram, T., Kathiresan, R. M., Paramsivam, K., Nadarajan, S., Thirumeni, S., Nagarajan,

- M., Singh, A. K., Vikram, P., Kumar, A., Septiningsih, E., Singh, U. S., Ismail, A. M., Mackill, D. and Singh, N. K. (2016b). From QTL to variety-harnessing the benefits of QTLs for drought, flood and salt tolerance in mega rice varieties of India through a multi-institutional network. *Plant Sci.*, 242: 278-287.
- Singh, S., Prasad, S., Yadav, V., Kumar, A., Jaiswal, B., Kumar, A. and Dwivedi, D. K. (2018). Effect of drought stress on yield and yield components of genotypes. *Int. J. Curr. Microbiol. Appl. Sci.*, 7: 2752-2759.
- Smet, I. D., White, P. J., Bengough, A. G., Dupuy, L., Parizot, B., Casimiro, I., Heidstra, R., Laskowski, M., Lepetit, M., Hochholdinger, F., Draye, X., Zhang, H. M., Broadley, M. R., Peret, B., Hammond, J. P., Fukaki, H., Mooney, S., Lynch, J. P., Nacry, P. and Schurr, U. (2012). Analyzing lateral root development: How to move forward. *Plant Cell*, 24: 15-20.
- Smith, B. N, Giriya, C. and Swamy, P. M. (2002). Interactive effects of sodium chloride and calcium chloride on the accumulation of proline and glycine betaine in peanut. *Environ. Exp. Bot.*, 47: 1-10.
- Smith, S. and Helentjaris, T. (1996). DNA fingerprinting and plant variety protection In: Paterson, A.H. (ed.). *Genome mapping in plants*, Landes Company, Texas, pp. 95-110.
- Soil Resource Development Institute (SRDI), (2010). *Saline Soils of Bangladesh*. Ministry of Agriculture, Bangladesh. pp. 1-60.
- Sokoto, M. B. and Muhammad, A. (2014). Response of rice varieties to water stress in Sokoto, Sudan Savannah, Nigeria. *J. Biosci. Med.*, 2: 68-74.
- Song, N. and Banyo, Y. (2010). Water on plants the concentration of leaf chlorophyll as water-deficit indicator in plants. *J. Ilmiah Sains*, 11(2): 166-173.
- Song, X., Agata, W. and Kawamitsu, Y. (2009). Studies on dry matter and grain production of Fi hybrid rice in China. Characteristics of dry matter production. *Japan J. Crop Sci.*, 59(1): 29-33.

- Subbarao, G. V., Nam, N. H., Chauhan, Y. S. and Johansen, C. (2000). Osmotic adjustment, water relations and carbohydrate remobilization in pigeonpea under water deficits. *J. Plant Physiol.*, 157: 651-659.
- Subudhi, H. N., Das, S., Swain, D. and Singh, O. N. (2011). Variability, correlation and path analysis for quality characters in rice. *Oryza*, 48(4): 319-323.
- Sudhir, P. and Murthy, S. D. S. (2004). Effects of salt stress on basic processes of photosynthesis. *Photosynthetica*, 42: 481-486.
- Sun, H. H., Nong, X. M., Huang, F. X. and Wu, M. X. (1992). Resistance of wild rice collected from Guangxi to bacterial blight. *Acta Phytophyl. Sin.*, 19(3): 237-241.
- Syamsia, Idhan, A., Noerfitryani, Nadir, M., Reta and Kadir, M. (2018). Paddy chlorophyll concentrations in drought stress condition and endophytic fungi application. *IOP Conf. Ser.: Earth Environ. Sci.*, 156: 1-6.
- Szabados, L. and Savoure, A. (2010). Proline: a multifunctional amino acid. *Rev. Trends Plant Sci.*, 15: 89-97.
- Taiz, L. and Zeiger, E. (1991). *Plant physiology*. The Benjamin Cummings Pub.Co. Inc. California. p.782.
- Taiz, L. and Zeiger, E. (2006). *Plant physiology*, 4<sup>th</sup> edition, Sinauer Associates, Sunderland, UK.
- Takeoka, T. (1962). Taxonomic studies of *Oryza*. II. Several species complexes. *Bot. Mag. Tokyo*, 75(894): 455-461.
- Takeoka, T. (1963). Taxonomic studies of *Oryza*. III. Key to species and their enumeration. *Bot. Mag. Tokyo*, 76(899): 165-173.
- Tao, H., Brueck, H., Dittert, K., Kreye, C., Lin, S. and Sattelmacher, B. (2006). Growth and yield formation for rice in the watersaving ground cover rice production system (GCRPS). *Field Crops Res.*, 95: 1-12.

- Tariq, R., Ali, J. and M. Arif, M. (2019). Morphological screening and *saltol* region based ssr markers analysis of rice (*Oryza sativa*) genotypes for salinity tolerance at seedling stage .Intl. J. Agric. Biol., 21: 1. 25-33.
- Tasmina, T., Khan, A. R., Karim, A., Akter, N. and Islam,R. (2016). Physiological changes of wheat varieties under water deficit condition. Bangladesh Agron. J., 19(2): 105-114.
- Tester, M. and Davenport, R. (2003). Na<sup>+</sup> tolerance and Na<sup>+</sup> transport in higher plants. Ann. Bot., 91: 503-527.
- Tester, M. and Langridge, P. (2010). Breeding technologies to increase crop production in a changing world. Sci., 327: 818-822.
- The United Nations Population Fund (UNPF) (2016). Linking Population, Poverty and Development. Available online: <http://www.unfpa.org/pds/trends.htm> (accessed on 8 February 2016).
- Theerakulpisut, P., Bunnag, S. and Kong-ngern. K. (2005). Genetic diversity, salinity tolerance and physiology responses to NaCl of Six rice cultivars. Asian J. Plant Sci., 4(6): 562-573.
- Thomas, N. and Lal, G. M. L. (2012). Genetic divergence in rice genotypes under irrigated conditions. Ann. Plant Soil Res., 14(1): 109-112.
- Thottapilly, G and Rossel, H. W. (1993). Evaluation of resistance to rice yellow mottle virus in *Oryza* species. Indian J. Virol., 9(1): 65-73.
- Timple, S. E., Fiona, R., Mercado, H., Ma, F. O., Borromeo, T. H. and Cruz, P. C. S. (2018). Response of intact seeds of wild rice species to dry heat treatment and dormancy-breaking chemicals. Seed Sci. Technol., 46(1): 157-173.
- Tiwari, S., Tiwari, K., Kumar, S., Zaidi, S. F. A. and Ved, P. (2015). Response of rice to integrated nitrogen management under SRI method of cultivation. Ann. Plant Soil Res., 17(1): 106-108.
- Tripathi, A., Bisen, R., Ahirwal, R. P., Paroha, S., Sahu, R. and Ranganatha, A. R. G. (2013). Study on genetic divergence in sesame (*Sesamum indicum* L.)



- germplasm based on morphological and quality traits. *Bioscan*, 8(4): 1387-1391.
- Tripathy, J. N., Zhang, J. X., Robin, S., Nguyen, T. T. and Nguyen, H. T. (2000). QTLs for cell-membrane stability mapped in rice under drought stress. *Theor. Appl. Genet.*, 100(8): 1197-1202.
- Troll, W. and Lindsley, J. (1955). A photometric method for the determination of proline. *J. Biol. Chem.* 215: 655-660.
- Tropical plants database, Ken fern. [Tropical.theferns.info](http://Tropical.theferns.info). 2023-06-11.
- Tropicos.org. Retrieved 1 February 2015.
- Trovato, M. (2008). Multiple roles of proline in plant stress tolerance and development. *Rendiconti Lincei*, 19(4): 325-346.
- Tseng, S. T. and Oster, J. J. (1994). Registration of 87-Y-550, a rice germplasm line resistant to stem rot disease. *Crop Sci.*, 34(1): 314.
- Tsuda, M. and Takami, S. (1991). Changing in heading date and panicle weight in rice subjected to water stress during the early stage of panicle development. *Japanese J. Crop Sci.*, 60: 2-64.
- Tubur, H. W., Chozin, M. A., Santosa, E. and Junaedi, A. (2012). Rice genotypes responses to drought periods in paddy field rice system. *J. Agron.Indonesia*, 40: 169-175.
- Turner, N. C., Wright, G. C. and Siddique, K. H. M. (2001). Adaptation of grain legumes (pulses) to water-limited environments. *Adv. Agron.*, 71: 123-231.
- Upadhyaya, H. and Panda, S. K. (2019). Drought stress responses and its management in rice, in *advances in rice research for abiotic stress tolerance*. Elsevier, pp. 177-200.
- Usman, M., Raheem, Z. F., Ahsan, T., Iqbal, A., Sarfaraz, Z. N. and Haq, Z. (2013). Morphological, physiological and biochemical attributes as indicators for drought tolerance in rice. *European J. Biol. Sci.*, 5(1): 23-28.

- Vales, M. (1985). Study of complete resistance to *Pyricularia oryzae* of *Oryza sativa*, *Oryza longistaminata* hybrids and their *Oryza longistaminata* parent. *Agron. Trop. Riz et Riziculture et Cultures Vivrieres Trop.*, 40(2): 148-156.
- Van Heerden, P. D. R. and Laurie, R. (2008). Effects of prolonged restriction in water supply on photosynthesis shoot development and storage root yield in sweet potato. *Physiol. Plant*, 134: 99-109.
- Vaughan, D. A. (1989). The genus *Oryza* current status of taxonomy. IRRI research paper series 138. Manilla: IRRI.
- Vaughan, D. A. (1994). The wild relatives of rice, a genetic resources handbook. Intl. Rice Res. Inst., Philippines, p. 147.
- Vaughan, D. A. (1994). The wild relatives of rice, a genetic resources handbook. International Rice Research Institute, Philippines.
- Vaughan, D. A. (1994). The wild relatives of rice: a genetic resources handbook. Los Banos: IRRI, p. 137.
- Vaughan, D. A., Lu, B. R. and Tomooka, N. (2008). The evolving story of rice evolution. *Plant Sci.*, 174(4): 394-408.
- Vaughan, D. A., Morishima, H. and Kadowaki, K. (2003). Diversity in the *Oryza* genus. *Curr. Opin. Plant Mol. Biol.*, 6: 139-146.
- Velusamy, R. (1988). Resistance of wild rices, *Oryza* spp., to the brown planthopper, *Nilaparvata lugens* (Stal) (Homoptera: Delphacidae). *Crop Prot.*, 7(6): 403-408.
- Velusamy, R. (1989). Resistance of wild rices, *Oryza* spp., to the whitebacked planthopper *Sogatella furcifera* (Horvath) (Homoptera: Delphacidae). *Crop Prot.*, 8(4): 265-270.
- Vendruscolo, A. C. G., Schuster, I., Pileggi, M., Scapim, C. A., Molinari, H. B. C., Marur, C. J. and Vieira, L. G. C. (2007). Stress-induced synthesis of proline confers tolerance to water deficit in transgenic wheat. *Plant Physiol.*, 164: 1367-1376.

- Venuprasad, R., Lafitte, H. R. and Atlin, G. N. (2007). Response to direct selection for grain yield under drought stress in rice. *Crop Sci.*, 47(1): 285-293.
- Verbruggen, N. and Hermans, C. (2008). Proline accumulation in plants: A Rev. *Amino Acids*, 35(4): 753-759.
- Verma, R. K., Chetia, S.K., Dey, P. C. , Sen, P. and Modi, M. K. (2018). Breeding for drought tolerance: A major challenge for rice cultivation under water limiting conditions. *J. Pharmacog. Phytochem.*, 7(5): 813-816.
- Verma, S. and Mishra, S. N. (2005). Putrescine alleviation of growth in salt stressed *Brassica juncea* by inducing antioxidative defense system. *J. Plant Physiol.*, 162: 669-677.
- Waheed, A., Ahmad, H. and Abbasi, F. M. (2012). Different treatment of rice seed dormancy breaking, germination of both wild species and cultivated varieties (*Oryza sativa L.*). *J. Mater. Environ. Sci.*, 3(3): 551-560.
- Wahid, A. and Rasul, E. (2005). Photosynthesis in leaf, stem, flower and fruit, in: Pessarakli M. (Ed.), *Handbook of Photosynthesis*, 2<sup>nd</sup> ed., CRC Press, Florida, pp. 479-497.
- Walia, H., Wilson, C., Condamine, P., Liu, X., Ismail, A. M., Zeng, L., Wanamaker, S. I., Mandal, J., Xu, J., Cui, X. and Close, T. J. (2005). Comparative transcriptional profiling of two contrasting rice genotypes under salinity stress during the vegetative growth stage. *Plant Physiol.*, 139: 822-835.
- Wang, F. Z., Wang, Q. B., Kwon, S. Y., Kwak, S. S. and Su, W. A. (2005). Enhanced drought tolerance of transgenic rice plants expressing a pea manganese superoxide dismutase. *J. Plant Physiol.*, 162(4): 465-472.
- Wang, H. and Yamauchi, A. (2006). Growth and function of roots under abiotic stress in soil. In: Huang BR (ed.) *Plant- Environment Interactions*, 3rd edn. New York: CRC Press, pp. 271-320.

- Wang, M., Yu, Y., Haberer, G., Marri, P. R., Fan, C. and Goicoechea, J. L. (2014). The genome sequence of African rice (*Oryza glaberrima*) and evidence for independent domestication. *Nat. Genet.* 46: 982-988.
- Wanichananan, P., Kirdmanee, C. and Vutiyo, C. (2003). Effect of salinity on biochemical and physiological characteristics in correlation to selection of salt-tolerant ability in aromatic rice. *Sci. Asia*, 29: 333-339.
- Wong, S. C., Yiu, P. H., Bong, S. T. W., Lee, H. H., Neohand, P. N. P. and Rajan, A. (2009). Analysis of Sarawak Bario rice diversity using microsatellite markers. *American J. Agric. Biol. Sci.*, 4(4): 298-304.
- Worede, F., Sreewongchai, T., Phumichai, C. and Sripichitt, P. (2014). Multivariate analysis of genetic diversity among some rice genotypes using morpho-agronomic traits. *J. Plant Sci.*, 9(1): 14-24.
- Xie, G., Yang, J., Wang, Z. and Zhi, Q. (2001). Grain filling characteristics of rice and their relationships to physiological activities of grains. *Acta Agron. Sin.*, 27: 557-565.
- Xiong, H., Yu, J., Miao, J., Li, J., Zhang, H., Wang, X., Liu, P., Zhao, Y., Jiang, C., Yin, Z., Li, Y., Guo, Y., Fu, B., Wang, W., Li, Z., Ali, J. and Lia, Z. (2018). Natural variation in *OsLG3* increases drought tolerance in rice by inducing ROS scavenging. *Plant Physiol.*, 178: 451-467.
- Xu, F., Li, L., Huang, X., Cheng, H., Wang, Y. and Cheng, S. (2010). Antioxidant and antibacterial properties of the leaves and stems of *Premna microphylla*. *J. Med. Plant Res.*, 4: 2544-2550.
- Yadav, R. S., Hash, C. T., Bidinger F. R., Devos K. M. and Howarth, C. J. (2004). Genomic regions associated with grain yield and aspects of postflowering drought tolerance in pearl millet across environments and tester background. *Euphytica*, 136: 265-277.
- Yambao, E. B., Ingram, K. T. and Real, J. G. (1992). Root xylem influence on the water relations and drought resistance of rice. *J. Expt. Bot.*, 43(7): 925-932.

- Yang, J., Zhang, J., Wang, Z., Zhu, Q. and Wang, W. (2001). Remobilization of carbon reserves in response to water deficit during grain filling of rice, *Field Crop. Res.*, 71: 47-55.
- Yang, P. M., Huang, Q. C., Qin, G. Y., Zhao, S. P. and Zhou, J. G. (2014). Different drought-stress responses in photosynthesis and reactive oxygen metabolism between autotetraploid and diploid rice. *Photosynthetica*, 52(2): 193-202.
- Yang, X., Wang, B., Chen, L., Li, P. and Cao, C. (2019). The different influences of drought stress at the flowering stage on rice physiological traits, grain yield and quality. *Sci. Rep.*, 9: 37-42.
- Yeo, M. E., Yeo, A. R. and Flowers, T. J. (1994). Photosynthesis and photorespiration in the genus *Oryza*. *J. Expt. Bot.*, 45: 553-560.
- Yesuf, E. and Balcha, A. (2014). Effect of nitrogen application on grain yield and nitrogen efficiency of rice. *Asian J. Crop Sci.*, 6(3): 273-280.
- Yi, Q., Jiapaer, G., Chen, J., Bao, A. and Wang, F. (2014). Different units of measurement of carotenoids estimation in cotton using hyperspectral indices and partial least square regression. *ISPRS J. Photogramm. Remote Sens.*, 91: 72-84.
- Yichie, Y. (2020). Salinity tolerance of wild rice accessions from northern Australia. *Plant Sci.*, 12: 77-86.
- Yichie, Y., Brien, C.J., Berger, B., Roberts, T.H. and Atwell, B.J. (2018). Salinity tolerance in Australian wild *Oryza species* varies widely and matches that observed in *O. sativa*. *Rice*, 11: 32-57.
- Yue, B., Xue, W., Xiong, L., Yu, Q., Luo, L., Cui, K., Jin, D., Xing, Y. and Zhang, Q. (2006). Genetic basis of drought resistance at reproductive stage in rice: Separation of drought tolerance from drought avoidance. *Genet.*, 172: 1213-1228.
- Zahid, A. M., Akhtar, M., Sabrar, M., Anwar, M. and Mushtaq, A. (2005). Interrelationship among yield and economic traits in fine grain rice. In:

- Proceedings of the International Seminar on Rice Crop. Rice Res. Inst. Kala Shah Kaku, Pakistan, pp. 21-24.
- Zain, N. A. M., Ismail, M. R., Mahmood, M., Puteh, A. and Ibrahim, M. H. (2014). Alleviation of water stress effects on MR220 rice by application of periodical water stress and potassium fertilization. *Mol.*, 19: 1795-1819.
- Zakar, T., Laczko-Dobos, H., Toth, T. N. and Gombos, Z. (2016). Carotenoids assist in cyanobacterial photosystem II assembly and function. *Front. Plant Sci.*, 7: 295.
- Zeng, L. and Shannon, M. C. (2000). Effects of salinity on grain yield and yield components of rice at different seeding densities. *Agron. J.*, 92:418-423.
- Zeng, L. and Shannon, M. C. (2003). Salinity effects on seedling growth and yield components of rice. *Crop Sci.*, 40: 996-1003.
- Zeng, L., Lesch, S. M. and Grieve, C. M. (2003a). Rice growth and yield respond to changes in water depth and salinity stress. *Agric. Water Manag.*, 9: 67-75.
- Zeng, L., Poss, J. A., Wilson, C., Draz, A. E., Gregorio, G. B. and Grieve, C. M. (2003b). Evaluation of salt tolerance in rice genotypes by physiological characters. *Euphytica*, 129: 281-292.
- Zhang, J. W., Long, Y., Xue, M. D., Xiao, X. G., Pei, X. W. (2017). Identification of micro RNAs in response to drought in common wild rice (*Oryza rufipogon* Griff.) DOI:10.1371/journal.pone.0170330.
- Zhang, J., Jia, W., Yang, J. and Ismail, A. M. (2006). Role of ABA in integrating plant responses to drought and salt stress. *Field Crops Res.*, 97: 111-119.
- Zhang, J., Zhang, S., Cheng, M., Jiang, H., Zhang, X., Peng, C., Lu, X., Zhang, M. and Jin, J. (2018). Effect of drought on agronomic traits of rice and wheat: A meta-analysis. *Int. J. Environ. Res. Pub. Health*, 15(5): 839.
- Zhang, Q., Wang, C. L., Shi, A. N., Bai, J. F., Ling, S. C., Li, D. Y., Chen, C. B. and Pang, H. H. (1994). Genetic studies on resistance to bacterial blight

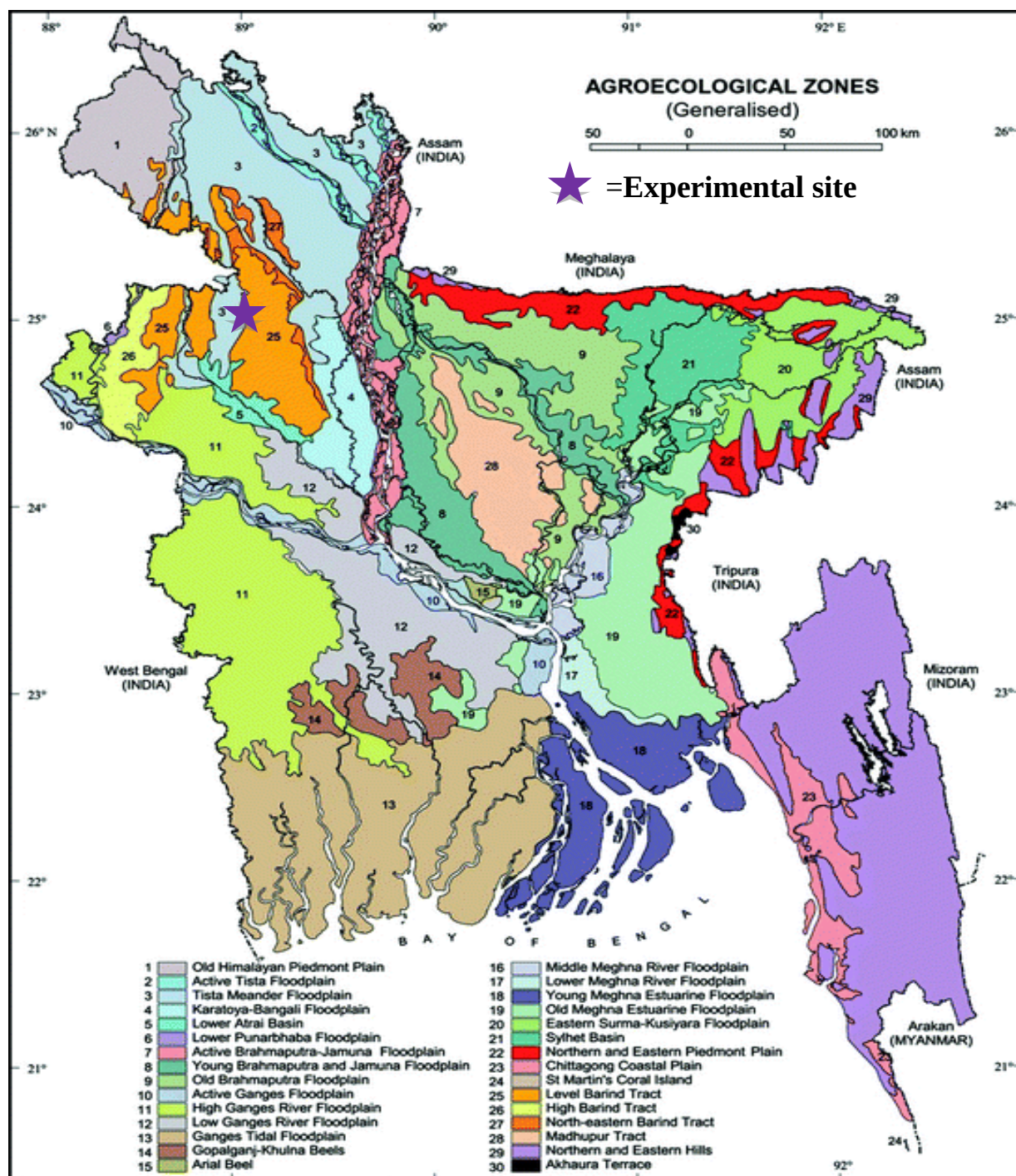
- (*Xanthomonas oryzae* pv. *oryzae* in nine rice cultivars. *Sci. Agric. Sin.*, 27(5): 1-9.
- Zhang, QJ.; Zhu, T.; Xia, EH.; Shi, C.; Liu, YL.; Zhang, Y.; Liu, Y.; Jiang, WK.; et al. (Nov 2014). Rapid diversification of five *Oryza* AA genomes associated with rice adaptation. *Proc. Natl. Acad. Sci. America*, 111(46): 4954-4962.
- Zhang, X. Q., Xie, X. M., Zhou, F. and Zhang, J. M. (2009). Genetic variability and relationship between MT-1 elephant grass and closely related cultivars assessed by SRAP markers. *J. Genet.*, 88(3): 281-290.
- Zhao, M., Ding, Z. and Lafitte, R. (2010). Photosynthetic characteristics in *Oryza* species. *Photosynthetica*, 48: 234-240.
- Zhou, Y., Lam, H. M. and Zhang, J. (2007). Inhibition of photosynthesis and energy dissipation induced by water and high light stresses in rice. *J. Expt. Bot.*, 58(5): 1207-1217.
- Zhu, B., Su, J., Chang, M., Verma, D. P. S., Fan, Y. L. and Wu, R. (1998). Overexpression of a  $\Delta 1$ -pyrroline-5-carboxylate synthetase gene and analysis of tolerance to water- and salt-stress in transgenic rice. *Plant Sci.*, 139: 41-48.
- Zhu, J. K. (2002). Salt and drought stress signal transduction in plants. *Annu. Rev. Plant Biol.*, 53: 247-273.
- Zhu, J. K. (2003). Regulation of ion homeostasis under salt stress. *Curr. Opin. Plant Biol.*, 6: 441-445.
- Zivcak, M., Brestic, M. and Sytar, O. (2016). Osmotic adjustment and plant adaptation to drought stress. In: Hossain, M. A., Wani, S. H., Bhattacharjee, S., Burritt, D. J., Tran, L. S. P. (Eds). *Drought Stress Tolerance in Plants* International Publishing, Switzerland, Springer, 1: 105-143.
- Zu, X., Lu, Y., Wang, Q., Chu, P., Miao, W., Wang, H. and La, H. (2017). A new method for evaluating the drought tolerance of upland rice cultivars. *Crop J.*, 5: 488-498.

Zubaer, M. A., Chowdhury, A. K. M. M. B., Islam, M. Z., Ahmed, T. and Hasan, M. A. (2007). Effects of water stress on growth and yield attributes of aman rice genotypes. *Intl. J. Sustain. Crop Prod.*, 2(6): 25-30.



## APPENDICES

### Appendix I: The Map of the experimental site



**Appendix II. The physical and chemical characteristics of soil of the experimental site as observed prior to experimentation (0-15 cm depth)**

| <b>Soil properties</b>             | <b>Values</b> |
|------------------------------------|---------------|
| <b>Soil texture</b>                | Sandy loam    |
| Sand                               | 28%           |
| Silt                               | 32%           |
| Clay                               | 10%           |
| pH                                 | 5.0           |
| Field capacity                     | 25.8          |
| Wilting point                      | 11.6          |
| Bulk density (g cm <sup>-3</sup> ) | 1.49          |
| Organic matter (%)                 | 0.68          |
| Total N (%)                        | 0.03          |
| P (kg ha <sup>-1</sup> )           | 11.53         |
| K (kg ha <sup>-1</sup> )           | 0.26          |
| Zn (mg kg <sup>-1</sup> )          | 0.88          |
| Ca (mg kg <sup>-1</sup> )          | 1.45          |
| Mg (mg kg <sup>-1</sup> )          | 0.81          |
| B (mg kg <sup>-1</sup> )           | 0.15          |

**Appendix III: Monthly average air temperature, relative humidity and rainfall  
of the experimental site during the study period (March, 2018 to  
December, 2020)**

| Months          | Air temperature (°C) |         | Relative<br>humidity (%) | Total<br>rainfall (mm) |
|-----------------|----------------------|---------|--------------------------|------------------------|
|                 | Maximum              | Minimum |                          |                        |
| March, 2018     | 17.30                | 34.10   | 69                       | 30.00                  |
| April, 2018     | 20.70                | 34.10   | 66                       | 128.80                 |
| May, 2018       | 23.00                | 35.10   | 87                       | 176.00                 |
| June, 2018      | 25.30                | 37.00   | 91                       | 211.40                 |
| July, 2018      | 26.30                | 36.00   | 89                       | 142.00                 |
| August, 2018    | 26.30                | 36.30   | 91                       | 254.60                 |
| September, 2018 | 25.40                | 36.90   | 87                       | 98.20                  |
| October, 2018   | 20.60                | 35.40   | 91                       | 6.00                   |
| November, 2018  | 15.00                | 33.80   | 70                       | 0.00                   |
| December, 2018  | 10.60                | 28.90   | 66                       | 7.80                   |
| January, 2019   | 9.60                 | 26.70   | 77                       | 0.00                   |
| February, 2019  | 13.40                | 26.60   | 79                       | 25.40                  |
| March, 2019     | 15.90                | 30.50   | 71                       | 0.00                   |
| April, 2019     | 21.10                | 31.30   | 81                       | 157.80                 |
| May, 2019       | 23.40                | 32.90   | 85                       | 139.00                 |
| June, 2019      | 25.40                | 33.90   | 86                       | 357.00                 |
| July, 2019      | 26.30                | 32.60   | 90                       | 529.80                 |
| August, 2019    | 27.00                | 34.00   | 85                       | 312.20                 |
| September, 2019 | 25.40                | 36.90   | 88                       | 99.80                  |
| October, 2019   | 22.40                | 30.90   | 91                       | 46.00                  |
| November, 2019  | 18.10                | 30.20   | 86                       | 0.00                   |
| December, 2019  | 11.40                | 23.30   | 87                       | 0.00                   |

### Appendix III: Continued

| Months          | Air temperature (°C) |         | Relative humidity (%) | Total rainfall (mm) |
|-----------------|----------------------|---------|-----------------------|---------------------|
|                 | Maximum              | Minimum |                       |                     |
| January, 2020   | 10.90                | 22.40   | 89                    | 4.80                |
| February, 2020  | 11.90                | 26.00   | 81                    | 7.60                |
| March, 2020     | 17.10                | 30.10   | 79                    | 15.20               |
| April, 2020     | 19.60                | 31.70   | 80                    | 79.00               |
| May, 2020       | 22.20                | 31.50   | 89                    | 334.00              |
| June, 2020      | 25.60                | 33.10   | 92                    | 373.40              |
| July, 2020      | 26.10                | 31.80   | 94                    | 653.80              |
| August, 2020    | 27.00                | 34.00   | 90                    | 242.80              |
| September, 2020 | 25.60                | 31.80   | 96                    | 646.20              |
| October, 2020   | 24.10                | 33.50   | 90                    | 128.40              |
| November, 2020  | 16.30                | 29.80   | 83                    | 0.00                |
| December, 2020  | 12.60                | 25.00   | 89                    | 0.00                |

### Experiment 1

#### Appendix I. Mean square value of plant height, leaves hill<sup>-1</sup>, nodes plant<sup>-1</sup> and chlorophyll content on leaves of wild rice as influenced by different genotypes

| Source of variation | df        | Mean square value of |                           |                           |                               |
|---------------------|-----------|----------------------|---------------------------|---------------------------|-------------------------------|
|                     |           | Plant height         | Leaves hill <sup>-1</sup> | Nodes plant <sup>-1</sup> | Chlorophyll content on leaves |
| <b>Replication</b>  | <b>2</b>  | 32.87                | 0.12                      | 0.11                      | 2.64                          |
| <b>Species (A)</b>  | <b>39</b> | 1637.56*             | 3.27*                     | 5.82*                     | 34.41*                        |
| <b>Error</b>        | <b>78</b> | 53.47                | 0.39                      | 0.26                      | 5.65                          |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix II. Mean square value of length of normal leaf, breadth of normal leaf, length breadth ratio of normal leaf and normal leaf area of wild rice as influenced by different genotypes**

| Source of variation | df        | Mean square value of  |                        |                                     |                  |
|---------------------|-----------|-----------------------|------------------------|-------------------------------------|------------------|
|                     |           | Length of normal leaf | Breadth of normal leaf | Length breadth ratio of normal leaf | Normal leaf area |
| <b>Replication</b>  | <b>2</b>  | 2.83                  | 0.001                  | 1.22                                | 14.65            |
| <b>Species (A)</b>  | <b>39</b> | 377.55*               | 0.96*                  | 49.09*                              | 2311.75*         |
| <b>Error</b>        | <b>78</b> | 3.47                  | 0.014                  | 1.88                                | 8.11             |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix III. Mean square value of length of flag leaf, breadth of flag leaf, length breadth ratio of flag leaf and flag leaf area of wild rice as influenced by different genotypes**

| Source of variation | df        | Mean square value of |                      |                                   |                |
|---------------------|-----------|----------------------|----------------------|-----------------------------------|----------------|
|                     |           | Length of flag leaf  | Breadth of flag leaf | Length breadth ratio of flag leaf | Flag leaf area |
| <b>Replication</b>  | <b>2</b>  | 1.28                 | 0.01                 | 0.10                              | 0.50           |
| <b>Species (A)</b>  | <b>39</b> | 198.20*              | 1.93*                | 24.22*                            | 1487.12*       |
| <b>Error</b>        | <b>78</b> | 1.62                 | 0.02                 | 0.82                              | 2.63           |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix IV. Mean square value of length of root, root dry weight hill<sup>-1</sup>, shoot dry weight hill<sup>-1</sup> and total dry weight hill<sup>-1</sup> of wild rice as influenced by different genotypes**

| Source of variation | df        | Mean square value of |                                    |                                     |                                     |
|---------------------|-----------|----------------------|------------------------------------|-------------------------------------|-------------------------------------|
|                     |           | Length of root       | Root dry weight hill <sup>-1</sup> | Shoot dry weight hill <sup>-1</sup> | Total dry weight hill <sup>-1</sup> |
| <b>Replication</b>  | <b>2</b>  | 1.07                 | 62.58                              | 156.90                              | 1139.93                             |
| <b>Species (A)</b>  | <b>39</b> | 264.63*              | 7881.73*                           | 6532.12*                            | 26770.55*                           |
| <b>Error</b>        | <b>78</b> | 3.80                 | 77.67                              | 59.85                               | 213.49                              |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix V. Mean square value of days to 1<sup>st</sup> flowering, growth duration, tillers hill<sup>-1</sup>, effective tillers hill<sup>-1</sup> and non-effective tillers hill<sup>-1</sup> of wild rice as influenced by different genotypes**

| Source of variation | df        | Mean square value of              |                 |                            |                                      |                                          |
|---------------------|-----------|-----------------------------------|-----------------|----------------------------|--------------------------------------|------------------------------------------|
|                     |           | Days to 1 <sup>st</sup> flowering | Growth duration | Tillers hill <sup>-1</sup> | Effective tillers hill <sup>-1</sup> | Non-effective tillers hill <sup>-1</sup> |
| <b>Replication</b>  | <b>2</b>  | 0.41                              | 0.00            | 56.93                      | 43.86                                | 3.96                                     |
| <b>Species (A)</b>  | <b>39</b> | 5227.59*                          | 6861.11*        | 1898.70*                   | 1107.30*                             | 266.29*                                  |
| <b>Error</b>        | <b>78</b> | 1.40                              | 0.00            | 20.24                      | 11.93                                | 5.86                                     |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix VI. Mean square value of panicle length, grains panicle<sup>-1</sup>, filled grains panicle<sup>-1</sup> and unfilled grains panicle<sup>-1</sup> of wild rice as influenced by different genotypes**

| Source of variation | df        | Mean square value of |                              |                                     |                                       |
|---------------------|-----------|----------------------|------------------------------|-------------------------------------|---------------------------------------|
|                     |           | Panicle length       | Grains panicle <sup>-1</sup> | Filled grains panicle <sup>-1</sup> | Unfilled grains panicle <sup>-1</sup> |
| <b>Replication</b>  | <b>2</b>  | 6.70                 | 82.81                        | 18.26                               | 37.32                                 |
| <b>Species (A)</b>  | <b>39</b> | 258.47*              | 34285.17*                    | 4956.92*                            | 23940.05*                             |
| <b>Error</b>        | <b>78</b> | 2.26                 | 79.37                        | 25.13                               | 30.09                                 |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix VII. Mean square value of 1000 grain weight, grain yield hill<sup>-1</sup>, biological yield hill<sup>-1</sup> and harvest index of wild rice as influenced by different genotypes**

| Source of variation | df        | Mean square value of |                                |                                     |               |
|---------------------|-----------|----------------------|--------------------------------|-------------------------------------|---------------|
|                     |           | 1000 grain weight    | Grain yield hill <sup>-1</sup> | Biological yield hill <sup>-1</sup> | Harvest index |
| <b>Replication</b>  | <b>2</b>  | 0.06                 | 3.52                           | 356.43                              | 3.56          |
| <b>Species (A)</b>  | <b>39</b> | 181.90*              | 1775.70*                       | 9818.02*                            | 380.63*       |
| <b>Error</b>        | <b>78</b> | 0.88                 | 12.13                          | 91.06                               | 3.01          |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

## Experiment 2

### Appendix I. Mean square value of plant height of wild rice as influenced by different genotypes at different days after transplanting

| Source of variation | df        | Plant height at different days after transplanting (DAT) |         |          |          |          |
|---------------------|-----------|----------------------------------------------------------|---------|----------|----------|----------|
|                     |           | 25                                                       | 50      | 75       | 100      | Harvest  |
| <b>Replication</b>  | <b>2</b>  | 31.13                                                    | 8.60    | 54.86    | 5.30     | 123.25   |
| <b>Variety (A)</b>  | <b>9</b>  | 487.59*                                                  | 765.15* | 1257.03* | 1977.70* | 2305.23* |
| <b>Error</b>        | <b>18</b> | 18.79                                                    | 37.09   | 30.15    | 48.04    | 64.00    |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

### Appendix II. Mean square value of normal leaf length, breadth, length breadth ratio, area of wild rice as influenced by different genotypes

| Source of variation | df        | Mean square value of |                     |                      |                  |
|---------------------|-----------|----------------------|---------------------|----------------------|------------------|
|                     |           | Normal leaf length   | Normal leaf breadth | length breadth ratio | Normal leaf area |
| <b>Replication</b>  | <b>2</b>  | 2.89                 | 0.002               | 0.36                 | 3.77             |
| <b>Variety (A)</b>  | <b>9</b>  | 365.72*              | 1.09*               | 53.99*               | 2770.05*         |
| <b>Error</b>        | <b>18</b> | 4.00                 | 0.01                | 2.02                 | 5.81             |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

### Appendix III. Mean square value of flag leaf length, breadth, length breadth ratio, area of wild rice as influenced by different genotypes

| Source of variation | df        | Mean square value of |                   |                    |                |
|---------------------|-----------|----------------------|-------------------|--------------------|----------------|
|                     |           | Flag leaf length     | Flag leaf breadth | Flag breadth ratio | Flag leaf area |
| <b>Replication</b>  | <b>2</b>  | 0.55                 | 0.001             | 0.75               | 1.36           |
| <b>Variety (A)</b>  | <b>9</b>  | 325.96*              | 2.48*             | 35.90*             | 2024.52*       |
| <b>Error</b>        | <b>18</b> | 1.83                 | 0.01              | 0.75               | 3.25           |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix IV. Mean square value of leaves hill<sup>-1</sup>, nodes plant<sup>-1</sup>, days to 1<sup>st</sup> flowering and growth duration of wild rice as influenced by different genotypes**

| Source of variation | df        | Mean square value of      |                           |                                   |                 |
|---------------------|-----------|---------------------------|---------------------------|-----------------------------------|-----------------|
|                     |           | Leaves hill <sup>-1</sup> | Nodes plant <sup>-1</sup> | Days to 1 <sup>st</sup> flowering | Growth duration |
| <b>Replication</b>  | <b>2</b>  | 0.76                      | 0.20                      | 2.43                              | 1.03            |
| <b>Variety (A)</b>  | <b>9</b>  | 3.27*                     | 4.19*                     | 6131.35*                          | 7296.67*        |
| <b>Error</b>        | <b>18</b> | 0.38                      | 0.23                      | 26.25                             | 1.70            |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**AppendixV. Mean square value of leaf area hill<sup>-1</sup> of wild rice as influenced by different genotypes at different days after transplanting**

| Source of variation | df        | Leaf areahill <sup>-1</sup> at different days after transplanting (DAT) |             |             |             |             |
|---------------------|-----------|-------------------------------------------------------------------------|-------------|-------------|-------------|-------------|
|                     |           | 25                                                                      | 50          | 75          | 100         | Harvest     |
| <b>Replication</b>  | <b>2</b>  | 188.57                                                                  | 10805.16    | 48438.91    | 39097.43    | 21828.46    |
| <b>Variety (A)</b>  | <b>9</b>  | 20753.97*                                                               | 1084495.79* | 3167026.73* | 3631029.41* | 2558965.23* |
| <b>Error</b>        | <b>18</b> | 267.59                                                                  | 19853.06    | 63913.81    | 82177.26    | 10547.68    |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix VI. Mean square value of leaf area index of wild rice as influenced by different genotypes at different days after transplanting**

| Source of variation | df        | Leaf areaindex at different days after transplanting (DAT) |       |       |       |         |
|---------------------|-----------|------------------------------------------------------------|-------|-------|-------|---------|
|                     |           | 25                                                         | 50    | 75    | 100   | Harvest |
| <b>Replication</b>  | <b>2</b>  | 0.000                                                      | 0.02  | 0.03  | 0.10  | 0.01    |
| <b>Variety (A)</b>  | <b>9</b>  | 0.055*                                                     | 2.86* | 8.36* | 9.59* | 6.76*   |
| <b>Error</b>        | <b>18</b> | 0.001                                                      | 0.05  | 0.17  | 0.18  | 0.06    |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix VII. Mean square value of chlorophyll content on leaf of wild rice as influenced by different genotypes at different days after transplanting**

| Source of variation | df        | Chlorophyll content on leaf at different days after transplanting (DAT) |        |        |        |         |
|---------------------|-----------|-------------------------------------------------------------------------|--------|--------|--------|---------|
|                     |           | 25                                                                      | 50     | 75     | 100    | Harvest |
| <b>Replication</b>  | <b>2</b>  | 2.21                                                                    | 2.03   | 3.51   | 1.26   | 6.47    |
| <b>Variety (A)</b>  | <b>9</b>  | 36.81*                                                                  | 31.09* | 24.21* | 30.21* | 13.95*  |
| <b>Error</b>        | <b>18</b> | 1.94                                                                    | 4.29   | 5.55   | 5.42   | 5.17    |



\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix VIII. Mean square value of shoot dry weight hill<sup>-1</sup>, root dry weight hill<sup>-1</sup> and total dry weight hill<sup>-1</sup> of wild rice as influenced by different genotypes**

| Source of variation | df        | Mean square value of                |                                    |                                     |
|---------------------|-----------|-------------------------------------|------------------------------------|-------------------------------------|
|                     |           | Shoot dry weight hill <sup>-1</sup> | Root dry weight hill <sup>-1</sup> | Total dry weight hill <sup>-1</sup> |
| <b>Replication</b>  | <b>2</b>  | 28.55                               | 33.88                              | 264.40                              |
| <b>Variety (A)</b>  | <b>9</b>  | 9232.15*                            | 7705.74*                           | 34134.79*                           |
| <b>Error</b>        | <b>18</b> | 70.51                               | 61.14                              | 552.00                              |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix IX. Mean square value of dry matter weight hill<sup>-1</sup> of wild rice as influenced by different genotypes at different days after transplanting**

| Source of variation | df        | Dry matter weight hill <sup>-1</sup> at different days after transplanting (DAT) |          |          |           |           |
|---------------------|-----------|----------------------------------------------------------------------------------|----------|----------|-----------|-----------|
|                     |           | 25                                                                               | 50       | 75       | 100       | Harvest   |
| <b>Replication</b>  | <b>2</b>  | 4.59                                                                             | 11.10    | 23.12    | 98.96     | 346.17    |
| <b>Variety (A)</b>  | <b>9</b>  | 159.04*                                                                          | 2090.58* | 9198.85* | 29542.89* | 34135.70* |
| <b>Error</b>        | <b>18</b> | 1.70                                                                             | 13.45    | 74.84    | 329.34    | 582.89    |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix X. Mean square value of crop growth rate of wild rice as influenced by different genotypes at different days after transplanting**

| Source of variation | df        | Crop growth rate at different days after transplanting (DAT) |          |          |                |
|---------------------|-----------|--------------------------------------------------------------|----------|----------|----------------|
|                     |           | 25-50                                                        | 50-75    | 75-100   | 100-at harvest |
| <b>Replication</b>  | <b>2</b>  | 1.89                                                         | 1.86     | 6.11     | 6.86           |
| <b>Variety (A)</b>  | <b>9</b>  | 472.82*                                                      | 1142.81* | 2487.95* | 224.98*        |
| <b>Error</b>        | <b>18</b> | 1.59                                                         | 9.49     | 12.37    | 1.90           |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix XI. Mean square value of relative growth rate of wild rice as influenced by different genotypes at different days after transplanting**

| Source of variation | df        | Relative growth rate at different days after transplanting (DAT) |        |        |                |
|---------------------|-----------|------------------------------------------------------------------|--------|--------|----------------|
|                     |           | 25-50                                                            | 50-75  | 75-100 | 100-at harvest |
| <b>Replication</b>  | <b>2</b>  | 1.94                                                             | 0.08   | 0.05   | 0.03           |
| <b>Variety (A)</b>  | <b>9</b>  | 34.41*                                                           | 46.12* | 29.32* | 2.04*          |
| <b>Error</b>        | <b>18</b> | 1.93                                                             | 0.50   | 0.37   | 0.02           |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix XII. Mean square value of net assimilation rate of wild rice as influenced by different genotypes at different days after transplanting**

| Source of variation | df        | Net assimilation rate at different days after transplanting (DAT) |        |        |                |
|---------------------|-----------|-------------------------------------------------------------------|--------|--------|----------------|
|                     |           | 25-50                                                             | 50-75  | 75-100 | 100-at harvest |
| <b>Replication</b>  | <b>2</b>  | 0.000                                                             | 0.000  | 0.000  | 0.000          |
| <b>Variety (A)</b>  | <b>9</b>  | 0.002*                                                            | 0.001* | 0.001* | 0.000*         |
| <b>Error</b>        | <b>18</b> | 0.000                                                             | 0.000  | 0.000  | 0.000          |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix XIII. Mean square value of leaf area duration of wild rice as influenced by different genotypes at different days after transplanting**

| Source of variation | df        | Leaf area duration at different days after transplanting (DAT) |            |            |                |
|---------------------|-----------|----------------------------------------------------------------|------------|------------|----------------|
|                     |           | 25-50                                                          | 50-75      | 75-100     | 100-at harvest |
| <b>Replication</b>  | <b>2</b>  | 191.08                                                         | 185.69     | 1340.00    | 460.07         |
| <b>Variety (A)</b>  | <b>9</b>  | 21820.44*                                                      | 123922.07* | 212061.19* | 177415.24*     |
| <b>Error</b>        | <b>18</b> | 370.02                                                         | 1689.68    | 3401.90    | 1677.01        |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix XIV. Mean square value of absolute growth rate of wild rice as influenced by different genotypes at different days after transplanting**

| Source of variation | df        | Absolute growth rate at different days after transplanting (DAT) |        |        |                |
|---------------------|-----------|------------------------------------------------------------------|--------|--------|----------------|
|                     |           | 25-50                                                            | 50-75  | 75-100 | 100-at harvest |
| <b>Replication</b>  | <b>2</b>  | 0.006                                                            | 0.002  | 0.004  | 0.001          |
| <b>Variety (A)</b>  | <b>9</b>  | 0.140*                                                           | 0.172* | 0.449* | 0.030*         |
| <b>Error</b>        | <b>18</b> | 0.002                                                            | 0.003  | 0.005  | 0.001          |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix XV. Mean square value of specific leaf area of wild rice as influenced by different genotypes at different days after transplanting**

| Source of variation | df        | Specific leaf area at different days after transplanting (DAT) |         |         |                |
|---------------------|-----------|----------------------------------------------------------------|---------|---------|----------------|
|                     |           | 25-50                                                          | 50-75   | 75-100  | 100-at harvest |
| <b>Replication</b>  | <b>2</b>  | 6.34                                                           | 8.82    | 1.04    | 0.05           |
| <b>Variety (A)</b>  | <b>9</b>  | 1054.17*                                                       | 459.75* | 134.80* | 14.19*         |
| <b>Error</b>        | <b>18</b> | 12.46                                                          | 11.26   | 2.51    | 0.25           |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix XVI. Mean square value of yield contributing characters of wild rice as influenced by different genotypes**

| Source of variation | df        | Mean square value of       |                                      |                                         |                |
|---------------------|-----------|----------------------------|--------------------------------------|-----------------------------------------|----------------|
|                     |           | Tillers hill <sup>-1</sup> | Effective tillers hill <sup>-1</sup> | Non-effectivetillers hill <sup>-1</sup> | Panicle length |
| <b>Replication</b>  | <b>2</b>  | 6.63                       | 3.43                                 | 5.43                                    | 1.23           |
| <b>Variety (A)</b>  | <b>9</b>  | 1064.67*                   | 905.72*                              | 240.16*                                 | 251.32*        |
| <b>Error</b>        | <b>18</b> | 18.78                      | 6.95                                 | 4.40                                    | 3.30           |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix XVII. Mean square value of yield contributing characters of wild rice as influenced by different genotypes**

| Source of variation | df        | Mean square value of         |                                     |                                       |                       |
|---------------------|-----------|------------------------------|-------------------------------------|---------------------------------------|-----------------------|
|                     |           | Grains panicle <sup>-1</sup> | Filled grains panicle <sup>-1</sup> | Unfilled grains panicle <sup>-1</sup> | Thousand grain weight |
| <b>Replication</b>  | <b>2</b>  | 49.63                        | 15.83                               | 15.41                                 | 0.28                  |
| <b>Variety (A)</b>  | <b>9</b>  | 36631.20*                    | 4638.24*                            | 25865.89*                             | 159.63*               |
| <b>Error</b>        | <b>18</b> | 70.78                        | 32.87                               | 18.98                                 | 0.98                  |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix XVIII. Mean square value of yield characters of wild rice as influenced by different genotypes**

| Source of variation | df        | Mean square value of           |                                     |               |
|---------------------|-----------|--------------------------------|-------------------------------------|---------------|
|                     |           | Grain yield hill <sup>-1</sup> | Biological yield hill <sup>-1</sup> | Harvest index |
| <b>Replication</b>  | <b>2</b>  | 2.20                           | 120.26                              | 1.53          |
| <b>Variety (A)</b>  | <b>9</b>  | 2891.56*                       | 15473.42*                           | 388.77*       |
| <b>Error</b>        | <b>18</b> | 21.17                          | 106.49                              | 1.87          |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**EXPERIMENT 3**

**Appendix I. Mean square value of growth characters of wild rice as influenced by different genotypes and drought stress**

| Source of variation                     | df        | Mean square value of |                            |                           |             |
|-----------------------------------------|-----------|----------------------|----------------------------|---------------------------|-------------|
|                                         |           | Plant height         | Leaves plant <sup>-1</sup> | Nodes plant <sup>-1</sup> | Root length |
| <b>Replication</b>                      | <b>2</b>  | 58.01                | 0.42                       | 0.39                      | 4.52        |
| <b>Variety (A)</b>                      | <b>11</b> | 5551.77*             | 1.48*                      | 1.20*                     | 546.62*     |
| <b>Drought stress (B)</b>               | <b>1</b>  | 356.45 <sup>NS</sup> | 6.36*                      | 4.16*                     | 113.00*     |
| <b>Variety (A) X Drought stress (B)</b> | <b>11</b> | 6.29*                | 0.08*                      | 0.29*                     | 7.37*       |
| <b>Error</b>                            | <b>46</b> | 71.84                | 0.16                       | 0.16                      | 3.34        |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix II. Mean square value of leaf characters of wild rice as influenced by different genotypes and drought stress**

| Source of variation                     | df        | Mean square value of |                      |                                  |                  |
|-----------------------------------------|-----------|----------------------|----------------------|----------------------------------|------------------|
|                                         |           | Normal leaf length   | Normal leaf breadth) | Normal leaf length breadth ratio | Normal leaf area |
| <b>Replication</b>                      | <b>2</b>  | 5.21                 | 0.004                | 1.45                             | 18.10            |
| <b>Variety (A)</b>                      | <b>11</b> | 664.00*              | 2.88*                | 121.41*                          | 3109.07*         |
| <b>Drought stress (B)</b>               | <b>1</b>  | 48.25*               | 0.34*                | 0.34 <sup>NS</sup>               | 191.46*          |
| <b>Variety (A) X Drought stress (B)</b> | <b>11</b> | 2.80*                | 0.03*                | 3.11*                            | 11.36*           |
| <b>Error</b>                            | <b>46</b> | 2.58                 | 0.01                 | 1.36                             | 14.46            |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix III. Mean square value of flag leaf characters of wild rice as influenced by different genotypes and drought stress**

| Source of variation                     | df        | Mean square value of |                   |                                |                |
|-----------------------------------------|-----------|----------------------|-------------------|--------------------------------|----------------|
|                                         |           | Flag leaf length     | Flag leaf breadth | Flag leaf length breadth ratio | Flag leaf area |
| <b>Replication</b>                      | <b>2</b>  | 4.76                 | 0.05              | 0.35                           | 3.17           |
| <b>Variety (A)</b>                      | <b>11</b> | 513.77*              | 2.92*             | 66.44*                         | 2964.58*       |
| <b>Drought stress (B)</b>               | <b>1</b>  | 23.04*               | 0.34*             | 0.13 <sup>NS</sup>             | 51.36*         |
| <b>Variety (A) X Drought stress (B)</b> | <b>11</b> | 1.30*                | 0.06*             | 0.52*                          | 1.57*          |
| <b>Error</b>                            | <b>46</b> | 1.18                 | 0.02              | 0.37                           | 2.21           |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix IV. Mean square value of growth characters and phenology of wild rice as influenced by different genotypes and drought stress**

| Source of variation                     | df        | Mean square value of                |                                    |                                     |                                   |                     |
|-----------------------------------------|-----------|-------------------------------------|------------------------------------|-------------------------------------|-----------------------------------|---------------------|
|                                         |           | Shoot dry weight hill <sup>-1</sup> | Root dry weight hill <sup>-1</sup> | Total dry weight hill <sup>-1</sup> | Days to 1 <sup>st</sup> flowering | Growth duration     |
| <b>Replication</b>                      | <b>2</b>  | 18.91                               | 0.64                               | 18.15                               | 2.375                             | 15.13               |
| <b>Variety (A)</b>                      | <b>11</b> | 3097.97*                            | 1750.37*                           | 8880.27*                            | 109.09*                           | 121.59*             |
| <b>Drought stress (B)</b>               | <b>1</b>  | 1651.59*                            | 125.43*                            | 2687.67*                            | 0.000 <sup>NS</sup>               | 0.000 <sup>NS</sup> |
| <b>Variety (A) X Drought stress (B)</b> | <b>11</b> | 33.92*                              | 31.33*                             | 78.56*                              | 0.000*                            | 0.000*              |
| <b>Error</b>                            | <b>46</b> | 36.07                               | 10.64                              | 64.07                               | 3.29                              | 13.95               |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix V. Mean square value of yield contributing characters of wild rice as influenced by different genotypes and drought stress**

| Source of variation                     | df        | Mean square value of       |                                      |                                          |                |
|-----------------------------------------|-----------|----------------------------|--------------------------------------|------------------------------------------|----------------|
|                                         |           | Tillers hill <sup>-1</sup> | Effective tillers hill <sup>-1</sup> | Non-effective tillers hill <sup>-1</sup> | Panicle length |
| <b>Replication</b>                      | <b>2</b>  | 0.10                       | 1.63                                 | 1.245                                    | 4.91           |
| <b>Variety (A)</b>                      | <b>11</b> | 292.47*                    | 176.15*                              | 26.21*                                   | 454.13*        |
| <b>Drought stress (B)</b>               | <b>1</b>  | 256.89*                    | 98.00*                               | 37.70*                                   | 117.56*        |
| <b>Variety (A) X Drought stress (B)</b> | <b>11</b> | 2.28*                      | 2.15*                                | 0.16*                                    | 4.76*          |
| <b>Error</b>                            | <b>46</b> | 3.05                       | 1.47                                 | 0.48                                     | 3.17           |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix VI. Mean square value of yield contributing characters of wild rice as influenced by different genotypes and drought stress**

| Source of variation                     | df        | Mean square value of         |                                     |                                       |                            |                            |
|-----------------------------------------|-----------|------------------------------|-------------------------------------|---------------------------------------|----------------------------|----------------------------|
|                                         |           | Grains panicle <sup>-1</sup> | Filled grains panicle <sup>-1</sup> | Unfilled Grains panicle <sup>-1</sup> | Grain fertility percentage | Grain sterility percentage |
| <b>Replication</b>                      | <b>2</b>  | 28.39                        | 18.01                               | 7.95                                  | 3.86                       | 11.38                      |
| <b>Variety (A)</b>                      | <b>11</b> | 44677.42*                    | 8615.43*                            | 33344.11*                             | 3302.72*                   | 3305.14*                   |
| <b>Drought stress (B)</b>               | <b>1</b>  | 1476.06*                     | 813.39*                             | 98.00 <sup>NS</sup>                   | 8.94 <sup>NS</sup>         | 9.66 <sup>NS</sup>         |
| <b>Variety (A) X Drought stress (B)</b> | <b>11</b> | 37.24*                       | 23.33*                              | 53.30*                                | 11.15*                     | 11.07*                     |
| <b>Error</b>                            | <b>46</b> | 126.94                       | 25.68                               | 36.56                                 | 30.68                      | 6.88                       |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix VII. Mean square value of yield and yield contributing characters of wild rice as influenced by different genotypes and drought stress**

| Source of variation                     | df        | Mean square value of  |                                |                                     |                    |
|-----------------------------------------|-----------|-----------------------|--------------------------------|-------------------------------------|--------------------|
|                                         |           | Thousand grain weight | Grain yield hill <sup>-1</sup> | Biological yield hill <sup>-1</sup> | Harvest index      |
| <b>Replication</b>                      | <b>2</b>  | 0.03                  | 3.14                           | 18.33                               | 0.89               |
| <b>Variety (A)</b>                      | <b>11</b> | 459.64*               | 1059.91*                       | 4722.78*                            | 675.96*            |
| <b>Drought stress (B)</b>               | <b>1</b>  | 0.14 <sup>NS</sup>    | 74.79*                         | 2429.51*                            | 8.11 <sup>NS</sup> |
| <b>Variety (A) X Drought stress (B)</b> | <b>11</b> | 0.02*                 | 2.00*                          | 45.39*                              | 2.03*              |
| <b>Error</b>                            | <b>46</b> | 0.90                  | 2.55                           | 31.89                               | 1.76               |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix VIII. Mean square value of water relation behavior of wild rice as influenced by different genotypes and drought stress**

| Source of variation                     | df        | Mean square value of   |                          |                          |                       |
|-----------------------------------------|-----------|------------------------|--------------------------|--------------------------|-----------------------|
|                                         |           | Relative water content | Water saturation deficit | Water retention capacity | Water uptake capacity |
| <b>Replication</b>                      | <b>2</b>  | 12.45                  | 0.62                     | 0.27                     | 0.00                  |
| <b>Variety (A)</b>                      | <b>11</b> | 42.31*                 | 42.31*                   | 17.78*                   | 0.02*                 |
| <b>Drought stress (B)</b>               | <b>1</b>  | 211.46*                | 212.83*                  | 45.41*                   | 0.03*                 |
| <b>Variety (A) X Drought stress (B)</b> | <b>11</b> | 1.91*                  | 1.93*                    | 1.29*                    | 0.001*                |
| <b>Error</b>                            | <b>46</b> | 6.75                   | 0.84                     | 0.17                     | 0.000                 |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix IX. Mean square value of biochemical traits of wild rice as influenced by different genotypes and drought stress**

| Source of variation                     | df        | Mean square value of          |                               |                     |                 |
|-----------------------------------------|-----------|-------------------------------|-------------------------------|---------------------|-----------------|
|                                         |           | Chlorophyll a content on leaf | Chlorophyll b content on leaf | Carotenoids content | Proline content |
| <b>Replication</b>                      | <b>2</b>  | 3.12                          | 1.92                          | 0.13                | 0.000           |
| <b>Variety (A)</b>                      | <b>11</b> | 15.13*                        | 10.04*                        | 1.61*               | 0.009*          |
| <b>Drought stress (B)</b>               | <b>1</b>  | 273.12*                       | 50.74*                        | 14.82*              | 0.191*          |
| <b>Variety (A) X Drought stress (B)</b> | <b>11</b> | 5.20*                         | 1.02*                         | 0.27*               | 0.002*          |
| <b>Error</b>                            | <b>46</b> | 0.99                          | 0.67                          | 0.04                | 0.000           |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Experiment 4**

**Appendix I. Mean square value of growth and phenological characters of wild rice as influenced by different genotypes and salinity stress**

| Source of variation                      | df        | Mean square value of |                            |                           |                                   |                 |
|------------------------------------------|-----------|----------------------|----------------------------|---------------------------|-----------------------------------|-----------------|
|                                          |           | Plant height         | Leaves plant <sup>-1</sup> | Nodes plant <sup>-1</sup> | Days to 1 <sup>st</sup> flowering | Growth duration |
| <b>Replication</b>                       | <b>2</b>  | 30.51                | 0.48                       | 0.30                      | 18.45                             | 8.44            |
| <b>Variety (A)</b>                       | <b>11</b> | 20269.05*            | 24.06*                     | 19.89*                    | 18289.74*                         | 32440.18*       |
| <b>Salinity stress (B)</b>               | <b>2</b>  | 60077.30*            | 218.64*                    | 165.46*                   | 127810.84*                        | 114378.03*      |
| <b>Variety (A) X Salinity stress (B)</b> | <b>22</b> | 3893.25*             | 13.00*                     | 8.10*                     | 10684.00*                         | 18441.45*       |
| <b>Error</b>                             | <b>70</b> | 36.06                | 0.136                      | 0.102                     | 49.64                             | 6.77            |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix II. Mean square value of leaf characters of wild rice as influenced by different genotypes and salinity stress**

| Source of variation                      | df        | Mean square value of |                     |                   |                  |
|------------------------------------------|-----------|----------------------|---------------------|-------------------|------------------|
|                                          |           | Normal leaf length   | Normal leaf breadth | Normal leaf ratio | Normal leaf area |
| <b>Replication</b>                       | <b>2</b>  | 4.55                 | 0.004               | 1.05              | 1.15             |
| <b>Variety (A)</b>                       | <b>11</b> | 1388.21*             | 4.27*               | 197.13*           | 6862.31*         |
| <b>Salinity stress (B)</b>               | <b>2</b>  | 2553.57*             | 10.76*              | 816.10*           | 5429.37*         |
| <b>Variety (A) X Salinity stress (B)</b> | <b>22</b> | 200.38*              | 0.66*               | 64.96*            | 347.14*          |
| <b>Error</b>                             | <b>70</b> | 1.63                 | 0.007               | 0.95              | 3.66             |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix III. Mean square value of flag leaf characters of wild rice as influenced by different genotypes and salinity stress**

| Source of variation                      | df        | Mean square value of |                   |                 |                |
|------------------------------------------|-----------|----------------------|-------------------|-----------------|----------------|
|                                          |           | Flag leaf length     | Flag leaf breadth | Flag leaf ratio | Flag leaf area |
| <b>Replication</b>                       | <b>2</b>  | 0.35                 | 0.03              | 0.34            | 10.29          |
| <b>Variety (A)</b>                       | <b>11</b> | 1039.04*             | 6.60*             | 112.76*         | 5713.62*       |
| <b>Salinity stress (B)</b>               | <b>2</b>  | 772.23*              | 13.08*            | 269.17*         | 1639.65*       |
| <b>Variety (A) X Salinity stress (B)</b> | <b>22</b> | 47.42*               | 0.76*             | 17.53*          | 83.00*         |
| <b>Error</b>                             | <b>70</b> | 0.79                 | 0.008             | 0.24            | 1.53           |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix IV. Mean square value of growth characters of wild rice as influenced by different genotypes and salinity stress**

| Source of variation                      | df        | Mean square value of |                                     |                                    |                                     |
|------------------------------------------|-----------|----------------------|-------------------------------------|------------------------------------|-------------------------------------|
|                                          |           | Root length          | Shoot dry weight hill <sup>-1</sup> | Root dry weight hill <sup>-1</sup> | Total dry weight hill <sup>-1</sup> |
| <b>Replication</b>                       | <b>2</b>  | 0.80                 | 2.88                                | 7.15                               | 47.27                               |
| <b>Variety (A)</b>                       | <b>11</b> | 1431.88*             | 26804.18*                           | 27041.97*                          | 94125.95*                           |
| <b>Salinity stress (B)</b>               | <b>2</b>  | 2032.72*             | 59959.20*                           | 45395.96*                          | 259851.77*                          |
| <b>Variety (A) X Salinity stress (B)</b> | <b>22</b> | 111.70*              | 4019.99*                            | 3571.06*                           | 19217.45*                           |
| <b>Error</b>                             | <b>70</b> | 1.55                 | 19.58                               | 20.83                              | 112.74                              |



\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix V. Mean square value of yield contributing characters of wild rice as influenced by different genotypes and salinity stress**

| Source of variation                      | df        | Mean square value of       |                                      |                                          |                |
|------------------------------------------|-----------|----------------------------|--------------------------------------|------------------------------------------|----------------|
|                                          |           | Tillers hill <sup>-1</sup> | Effective tillers hill <sup>-1</sup> | Non-effective tillers hill <sup>-1</sup> | Panicle length |
| <b>Replication</b>                       | <b>2</b>  | 41.01                      | 35.20                                | 2.44                                     | 1.60           |
| <b>Variety (A)</b>                       | <b>11</b> | 2150.66*                   | 1062.70*                             | 363.00*                                  | 1083.55*       |
| <b>Salinity stress (B)</b>               | <b>2</b>  | 18903.83*                  | 10551.53*                            | 1349.68*                                 | 2942.57*       |
| <b>Variety (A) X Salinity stress (B)</b> | <b>22</b> | 1199.16*                   | 776.21*                              | 73.91*                                   | 151.67*        |
| <b>Error</b>                             | <b>70</b> | 10.79                      | 7.80                                 | 1.09                                     | 1.27           |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix VI. Mean square value of yield contributing characters of wild rice as influenced by different genotypes and salinity stress**

| Source of variation                      | df        | Mean square value of         |                                     |                                       |                       |
|------------------------------------------|-----------|------------------------------|-------------------------------------|---------------------------------------|-----------------------|
|                                          |           | Grains panicle <sup>-1</sup> | Filled grains panicle <sup>-1</sup> | Unfilled grains panicle <sup>-1</sup> | Thousand grain weight |
| <b>Replication</b>                       | <b>2</b>  | 43.34                        | 0.73                                | 11.76                                 | 0.13                  |
| <b>Variety (A)</b>                       | <b>11</b> | 106506.86*                   | 14107.49*                           | 67315.19*                             | 143.88*               |
| <b>Salinity stress (B)</b>               | <b>2</b>  | 68106.00*                    | 34422.51*                           | 5736.56*                              | 1793.83*              |
| <b>Variety (A) X Salinity stress (B)</b> | <b>22</b> | 5024.40*                     | 2713.75*                            | 745.58*                               | 193.20*               |
| <b>Error</b>                             | <b>70</b> | 26.50                        | 12.96                               | 8.84                                  | 1.16                  |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix VII. Mean square value of yield characters of wild rice as influenced by different genotypes and salinity stress**

| Source of variation                      | df        | Mean square value of           |                                     |               |
|------------------------------------------|-----------|--------------------------------|-------------------------------------|---------------|
|                                          |           | Grain yield hill <sup>-1</sup> | Biological yield hill <sup>-1</sup> | Harvest index |
| <b>Replication</b>                       | <b>2</b>  | 10.10                          | 0.28                                | 0.80          |
| <b>Variety (A)</b>                       | <b>11</b> | 3660.26*                       | 23098.82*                           | 1227.63*      |
| <b>Salinity stress (B)</b>               | <b>2</b>  | 15798.82*                      | 136812.04*                          | 4329.43*      |
| <b>Variety (A) X Salinity stress (B)</b> | <b>22</b> | 1887.31*                       | 9646.59*                            | 564.71*       |
| <b>Error</b>                             | <b>70</b> | 10.96*                         | 49.05*                              | 2.84*         |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix VIII. Mean square value of water relation behavior of wild rice as influenced by different genotypes and salinity stress**

| Source of variation                      | df        | Mean square value of   |                          |                          |                       |
|------------------------------------------|-----------|------------------------|--------------------------|--------------------------|-----------------------|
|                                          |           | Relative water content | Water saturation deficit | Water retention capacity | Water uptake capacity |
| <b>Replication</b>                       | <b>2</b>  | 6.25                   | 2.04                     | 0.24                     | 0.001                 |
| <b>Variety (A)</b>                       | <b>11</b> | 5690.31*               | 1239.43*                 | 39.24*                   | 0.07*                 |
| <b>Salinity stress (B)</b>               | <b>2</b>  | 29448.85*              | 1223.71*                 | 155.18*                  | 0.56*                 |
| <b>Variety (A) X Salinity stress (B)</b> | <b>22</b> | 1844.44*               | 1084.79*                 | 1.46*                    | 0.018*                |
| <b>Error</b>                             | <b>70</b> | 5.17                   | 1.47                     | 0.11                     | 0.001                 |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant

**Appendix IX. Mean square value of biochemical characters of wild rice as influenced by different genotypes and salinity stress**

| Source of variation                      | df        | Mean square value of   |                        |                    |                 |
|------------------------------------------|-----------|------------------------|------------------------|--------------------|-----------------|
|                                          |           | Ch 'a' content on leaf | Ch 'b' content on leaf | Carotenoid content | Proline content |
| <b>Replication</b>                       | <b>2</b>  | 2.76                   | 0.61                   | 0.13               | 0.0001          |
| <b>Variety (A)</b>                       | <b>11</b> | 286.84*                | 149.03*                | 19.23*             | 0.112*          |
| <b>Salinity stress (B)</b>               | <b>2</b>  | 1831.84*               | 978.63*                | 128.51*            | 0.397*          |
| <b>Variety (A) X Salinity stress (B)</b> | <b>22</b> | 72.33*                 | 49.99*                 | 4.91*              | 0.070*          |
| <b>Error</b>                             | <b>70</b> | 0.611                  | 0.56                   | 0.07               | 0.0001          |

\*Significant at 5% level of significance

<sup>NS</sup> Non significant