EFFECT OF IRRIGATION AND FOLIAR SPRAY OF POTASSIUM ON MORPHO-PHYSIOLOGY AND YIELD OF WHEAT

A Dissertation

By

MD. HEDYATUL ISLAM
Student No. 1505162

DOCTOR OF PHILOSOPHY
IN
CROP PHYSIOLOGY AND ECOLOGY

DEPARTMENT OF CROP PHYSIOLOGY AND ECOLOGY
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY
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By
Md. Hedyatul Islam
Student No. 1505162

Submitted to

Approved as to style and contents by

_____

(Professor Dr. Md. Maniruzzaman Bahadur)
Supervisor

_____

(Professor Dr. Md. Abu Hasan)
Co-supervisor

_____

(Professor Dr. Md. Abu Hasan)
Chairman
Examination Committee

DEPARTMENT OF CROP PHYSIOLOGY AND ECOLOGY
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY
DINAJPUR-5200, BANGLADESH

MAY 2020

DEDICATED
TO
BELOVED PARENTS

DECLERATION

I, **Md. Hedyatul Islam**, thereby declared that all the work reported in this dissertation entitled **"Effect of Irrigation and Foliar Spray of Potassium on Morpho-Physiology and Yield of Wheat"** submitted to the Department of Crop Physiology and Ecology, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh, in the fulfilment of the requirements for the degree of **Doctor of Philosophy** in Crop Physiology and Ecology is a record of research designed and carried by me. This work has not been submitted before of this University or any other institution to obtain a degree or any other academic certificate, honor or title.

(Md. Hedyatul Islam)

Professor Dr. Md. Maniruzzaman Bahadur
Department of Crop Physiology and Ecology
Hajee Mohammad Danesh Science and Technology University
Dinajpur-5200, Bangladesh

CERTIFIATE

This is to certify that the work embodied in this thesis is an original research work done by **Md. Hedyatul Islam** under my supervision for the degree of Doctor of Philosophy. The references cited in it have duly been acknowledged. The style and contents of the thesis have been approved and recommended for submission.

(Professor Dr. Md. Maniruzzaman Bahadur)

Supervisor

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The Author

ABSTRACT

The experiment was conducted at the Research Farm and Laboratory of Crop Physiology and Ecology Department, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh during 2015 - 2016 and 2016 - 2017 to study the effect of irrigation levels and yield of wheat and to find out morpho-physiological traits yield of wheat and to find out suitable concentration of potassium for foliar application in alleviating the adverse effect of drought on wheat. Four levels of irrigations (i) I_0 - No irrigation (control), (ii) I_1 - Irrigation with 3200 m^3 ha^{-1} , (iii) I_2 - Irrigation with 3800 m^3 ha^{-1} and (iv) I_3 - Irrigation with 4400 m^3 ha^{-1} water and four levels of potassium such as (i) K_0 - The recommended dose of potassium i.e. 50 kg K ha^{-1} in the form of KCl (control) (ii) K_1-50% of the recommended dose of potassium i.e. 25 kg K ha^{-1} in the form of KCl + Foliar spray with 1% K_2O using K_2SO_4 (iii) K_2-50% of the recommended dose of potassium i.e. 25 kg K ha^{-1} in the form of KCl + Foliar spray with 2% K_2O using K_2SO_4 and (iv) K_3-50% of the recommended dose of potassium i.e. 25 kg K ha^{-1} in the form of KCl + Foliar spray with 3% K_2O using K_2SO_4 were imposed as experimental treatments. Two wheat varieties, namely, BARI Gom 27 and BARI Gom 28 were tested for the above mentioned parameters. The experiment was laid out in a split-split plot design with 3 replications. Irrigation and potassium treatments had significant effects on all the above mentioned parameters in both the years. The plants irrigated with 4400 m^3 ha^{-1} water needed the highest days for attaining their different phenological stages. The highest crop growth, morpho-physiological traits, water consumption, chlorophyll content, yield contributing characters, potassium content of grain and straw and yield of wheat were exhibited in the crops irrigated with 3800 m^3 ha^{-1} water in both the years. With some exceptions, varieties had no significant effects on all the above mentioned parameters in the study. Among the potassium treatments, the highest crop growth, morpho-physiological traits, yield contributing characters, potassium ontent of grain and straw and yield were recorded in treatment K_2 (K_2-50% of the recommended rate of K for the variety i.e. 25 kg K ha^1 in the form of KCl + Foliar spray with 2% K_2O using K_2SO_4) in both the years. Simple correlation coefficients between the yield contributing characters and grain yield for different irrigation and potassium treatments indicated that grain yield was positively correlated with most of the yield components. Wheat cultivation with 3800 m^3 ha^{-1} water and potassium spray with 2% K_2O using K_2SO_4 along with 50% of basal dose of K gave the highest crop growth, morpho-physiological traits, water consumption, yield contributing characters, grain and straw yield which was statistically similar with irrigations with 4400 m^3 ha^{-1} water and potassium spray with 2% K_2O using K_2SO_4 along with 50% of basal dose in both the years.

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ABBREVIATIONS AND ACRONYMS

AEZ	:	Agro Ecologiacl Zone
@	:	At the rate of
Agric.	:	Agriculture
Agril.	:	Agricultural
BARI	:	Bangladesh Agricultural Resarch Institute
BBS	:	Banglladesh Bureau of Statistics
CIMMYT	:	Centro Intermacional de Mejoramiento d maiz y Trigo (International Wheat and Maize Improvement Centre)
cm	:	Centimeter
CRI	:	Crown Root Initiation
CV	:	Co-efficient of Variation
DAA	:	Days After Anthesis
DAS	:	Days After Sowing
Dept.	:	Department
DMRT	:	Duncan's Multiple Range Test
e.g.	:	For example
et al.	:	And other
FAO	:	Food and Agriculture Organization
FW	:	Fresh Weight
g	:	Gram
ha	:	Hectare
HSTU	:	Hajee Mohammad Danesh Science & Technology University
LAI	:	Leaf Area Index
LAR	:	Leaf Area Ratio
LWR	:	Leaf Weight Ratio
RLGR	:	Relative Leaf Growth Rate
SLA	:	Specific Leaf Area
RGR	:	Relative Growth Rate
m	:	Meter
MP	:	Muriate of Potash

NAR	:	Net Assimilation Rate
NARS	:	National Agricultural Research System
No	:	Number
RGR	:	Relative Growth Rate
Sci.	:	Science
SL.	:	Serial
TDM	:	Total Dry Matter
TSP	:	Triple Super Phosphate
UNDP	:	United Nations Development Programme
viz.	:	Namely

CHAPTER 1

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the world's most widely cultivated food crop. It is the most important food grain and ranks first in terms of global consumption and production of food crop known as the king of cereals (Costa, *et al.* 2013) as its cultivation is easier, nutrient content is higher and ecologically suitable. About two thirds of the world population lives on wheat grains. It is eaten in various forms by more than one thousand million human beings in the world. Wheat makes as larger contribution of proteins and calories to man than all other foods or cereal crops. It is the most important source of concentrated carbohydrate for human being and it contains considerable amount of protein, minerals and vitamins. According to the FAO (2018), wheat is the key to the emergence of urban societies for millennia. It is not only used as human food but also as feed for livestock and raw materials for industrial products. Currently about 65% of wheat crop is used for food, 17% for animal feed and 12% in industrial products (FAO, 2013). Wheat starch is used for laundering, paper laminating and corrugating, adhesives, textiles, wallpaper, billboard paste and paper additives. CIMMYT predicted that demand for wheat in the developing world is projected to increase 60% by 2050 from now (CIMMYT, 2013). It contains carbohydrate (69.4%), protein (12.1%), minerals (2.7%), fat (1.7%) and considerable proportion of vitamins (Bakhru 1996). More lands are devoted world-wide to the production of wheat than to any other commercial crop. Wheat is grown across a wide range of environments around the world. Wheat is cool-loving crop and adopted for cultivation in regions with cooler climatic conditions.

Bangladesh has been running shortage of food and the gap between production and requirements is getting wider with the increase in population. Wheat area and production has decreased by 0.43 million hectares and 0.47 million tons, respectively, while yield has increased by 1.7 ton per hectare from 2000 to 2019 (Mundi Index, 2019). So, the possibility of increasing production by intensification of land is practically very little in Bangladesh, the means for increasing crop yields should be explored. Increasing agricultural production per unit area of land is becoming most important step to cope with the present population growth in Bangladesh. Wheat can be a good supplement of rice and it can play a vital role to feed this vast population. From nutritional point of view, wheat is superior to rice for its higher protein content. In Bangladesh, the area under wheat cultivation during 2017-2018 was about 0.35

million ha and producing 1.09 million ton of wheat with an average yields of 3.13 ton ha^{-1} (BBS, 2018). This average yield of wheat is very low compared to the average yield of New Zealand, Netherlands and France (8.95, 8.82 and 6.84 t ha^{-1} respectively) (FAO, 2018). This is as because about one third of the total wheat growing area falls in the rain fed regions where water stress limits plant growth and productivity either of growth or because of unexpected dry periods or due to very low or no rainfall (Khaliq *et al*.1999). At the sane time, consumption rate of wheat is increasing day by day due to its low production cost, good market price and nutrition value. However, horizontal expansion of wheat area is not possible in Bangladesh due to limited land resources and high population density. So, there is an ample opportunity to increase production of wheat per unit area through adoption of modern and improved agronomic practices such as optimum seed rate, timely sowing and judicious application of fertilizer, irrigation and other inputs.

Wheat is the cereal of the temperate regions but is grown at high altitudes in the tropics and also extends into the tropical low lands. Wheat production is concentrated between latitudes 30-60°N and 27-40°S (Nuttonson, 1955). The climate and soil of Bangladesh are quite favorable for the cultivation of wheat during robi season. This is because the optimum temperature for the growth of this crop is 10-20°C (Fisher *et al*. 1998) which eventually prevails in Bangladesh. Wheat can be grown in regions where annual precipitation ranges from 25-175 cm; about three-fourths of the land area based for wheat production receives an average of 37.5-87.5 cm rainfall annually (Briggle and Curtis, 1987). In the tropical climates, irrigation is necessary to produce good yields of wheat when precipitation is less than 20 cm during crop growth. Wheat can be grown on a variety of soils but reasonable drainage and good water holding capacity are preferred. In terms of soil pH, wheat is considered medium acid tolerant (Adams, 1981), but according to Doll (1964) the soil pH range for wheat is 5.5 to 7.0.

Wheat is mostly grown under rain-fed conditions. Rain-fed crop frequently suffers from drought resulting in significant growth and yield loss and decreased revenue with periodic drought affecting 50 and 70% of wheat-growing areas in developing and developed countries, respectively (Trethowan and Pfeiffer, 1999). Supplement irrigation given to wheat improves the development of grain as well as yield (Singh and Singh, 2005). Irrigation frequency has a significant influence on the growth and yield of wheat. With the increase of irrigation frequencies the grain yield of wheat can be increased (Khajanji and Swivedi, 2007). In Bangladesh, the rainfall during *rabi* season in characteristically scanty and uncertain. As such,

wheat gives poor yield under non-irrigated (rain-fed) condition.

Wheat is mainly grown under non-irrigated conditions during the dry winter (November to April) in Bangladesh. Although the vast storage of soil moister resulted from monsoon rain supports the plant growth favorably at the early stages of growth, the plant suffers from water stress at the reproductive stage when the residual moisture depletes (Karim *et al*. 2001). Water deficiency adversely affects plant establishment and thereafter growth and development. Cell enlargement and assimilates partitioning is hindered by the stress. Under extreme condition, it may severally disturb several metabolic processes, which may result in diminished photosynthesis, checked cell enlargement and division and finally cell death (Kramer 1983). Water defiency caused a decline in relative water content (RWC), chlorophyll and carotenoid content, membrane stability and nitrate reductase activity and increases accumulation of abscisic acid (ABA), proline (Chandrasekar *et al*. 2000), soluble sugar (Munns *et al*. 1981; Kameli *et al*. 1993) and leaf and leaf canopy temperature (Siddique *et al*. 2000). Water deficit reduces the interception of solar radiation in the canopy due to early senescence as well as rolling up the leaves (Muller, 2001). Water deficiency at reproductive stage is more harmful to plant process than any other growth stage. This is because water stress at anthesis markedly reduces photosynthesis, reproductive development and finally grain yield (Karim *et al*. 2000 and Araus *et al*. 2002). However, these problem will be further increased due to climate change. Due to raise in world temperature soil losses it's moisture holding capacity as a result drought effect is accelerated. Thus the best option for yield improvement and yield stability of wheat under soil moisture deficit condition is to screen or develop drought tolerant wheat varieties and to ameliorate the adverse effect of water deficit stress using suitable techniques with changing climate.

Wheat is a strategic crop and it is highly responsive to irrigation water during the short winter season between November and March. Application of only one irrigation increase the yield of wheat by more than 40%, whereas two to three irrigations with proper water and fertilizer management practices increase wheat yield by 50-100% (Hossain *et al.,* 2006). Water should be utilized for optimum and economic yield. Modern high yielding crop practices system can be sustained only with good water control and management at the farm level. Optimum water availability to plants during their growth is essential for realizing the full yield production. Every year crop production is essential to increase due to more and more efficient utilization of water through better management practices (Sarker *et al.,* 2007). About 48.64 percent of total wheat growing land of Bangladesh under irrigation facilities and rest of remaining under

rain-fed condition (BBS, 2018). Drought occurs almost every year due to scarcity of rainfall in dry season, which adversely affects the growth and yield of wheat. The growth and yield loss due to drought could be minimized by providing irrigation at least during the critical stage of growth, (Islam *et al.,* 2000). Insufficient water affects the germination of seed and uptake of nutrients from soil. Moreover movement of nutrients through the plant body by physiological activities is also associated with soil water (Tisdale *et al.,* 1985). Sensitivity to moisture stress at different growth stages of wheat, however, varies widely. Singh (1981) found that booting or heading was the most sensitive stage to affect wheat yield for moisture stress. On the other hand, crown root initiation (CRI) stage of wheat was determined by the BARI scientists to be the most sensitive growth stage producing the highest seed yield with one irrigation (BARI, 1990). Crown root initiation in wheat was the most critical stage for irrigation and water shortage at this stage reduced the grain yield by 27% (Mahmood and Ahmad, 2005). Number of tillers improved with irrigation at CRI stage and better grain yield was recorded with irrigation at crown root and boot stage (Mangan *et al.,* 2008). In case of adequate water supply, three irrigations given each at three defined growth stages viz., CRI, maximum tillering and grain filling stages significantly increased seed yield (BARI, 1986). Improper scheduling of irrigation results not only in wastage of water but also decreases the crop growth and yield. Irrigation schedules based on physiological stages have already been worked out for timely sown crop under different situations.

As water demand, plants need mineral nutrient for proper growth, development and yield. Different nutrient including macro and micro nutrients are essential for improving the activity of numeras enzymes and ultimately synthesis of various metabolites which regulates normal growth and development. In addition, these nutrients contribute to give fitness under adverse environments including water deficiency.

Increased agricultural productivity usually comes from effective adoption of improved technologies. Optomun yield comes in a combination of all the production factors and conditions in a given farm condition including fertilizers. Among all factors, in fact, the contribution of fertilizers to increased yield is perhaps the greatest. Fertilizer type, rate and application methods are also important to increase crop production. Farmers use to apply fertilizer usining different methods including foliar spray, broadcasting, deep placement, fertigation, band placement etc. Foliar application is one of the effeciant methods which has

multiple benefit like to meet immediate need of crops, increase production and its quality, less costly and environment frieldly.

Potassium (K) is an essential nutrient and is also the most abundant cation in plants. K plays essential roles in enzyme activation, protein synthesis, photosynthesis, osmoregulation, stomatal movement, energy transfer, phloem transport, cation-anion balance and stress resistance Marschner (2012). K regularizes physiological processes like photosynthesis, translocation of cations into sink organs, regulation of turgor pressure and enzymes activation (Mengel *et al*. 2001). Mohammad *et al*. (2011) documented that K plays vital role in increasing grain and biological yield during water deficit condition. Cakmak (2005) reported that plant suffering from drought stress required more internal K. During stress condition, Reactive Oxygen Species (ROS) formation was induced and oxidative damage to cells occurred and requirement for K was increased (Foyer *et al*. 2002). This enhanced need for K by plants suffering from drought stress showed that K is required for photosynthetic and CO_2 fixation, because water deficit caused stomatal closer and decreased CO_2 fixation. Jiang *et al*. (2002) documented that the limited photosynthesis increased ROS production and carbohydrate metabolism also disturbed. Thus the low grain yield of resulting from water deficit could be overcome by increasing K supply (Damon *et al*. 2007). Witold *et al.* (2013) reported that application of K fertilizer to plants is a simple agronomic practice used to increase crop tolerance to a temporary water shortage. It may be that the improvement of a plant's access to K during mild water-deficiency stress will increase water uptake by the root cells, which in turn increases their osmotic potential and thereby allows extension growth. This growth in turn promotes access to other mineral elements and water, which favor plant growth and yield.

Generally, soils have large capacity to provide K to crop plants under normal conditions (Ranjha *et al.,* 1990), but increase in cropping intensity, extensive removal of straw from the field, excessive use of underground water and introduction of high yielding hybrid varieties have resulted in considerable exhaust of soil K (Malik *et al.,* 1989). Hence application of K is essential for optimum yield. Traditionally, potassium fertilizer directly are applied to soil gets fixed with clay minerals and becomes unavailable to crop plants (Ali *et al*., 2005b). Moreover, the price of K fertilizers is getting higher and becoming unaffordable by farmers (NFDC, 2005). Consequently, foliar application of potassium is more suitable, target oriented and economical technique for increasing the fertilizer use efficiency and grain yield over soil application (Farooqi *et al.,* 2012; Eichert and Burkhardt, 2001).

The assessment of alleviation of the detrimental effect of drought by modifying K fertilizer input in promising wheat genotypes has been relatively scarce in Bangladesh. Keeping these issues in mind, the present investigation was undertaken to develop a suitable K fertilizer application package as foliar application along with different irrigation schedule. So, the present investigation was carried out to expand wheat cultivation and to sustain wheat yield with following specific objectives-

- To study the effect of irrigation regimes on growth, yield and yield components of wheat.
- To evaluate the response on physiological variabilities, yield and yield components of wheat in relation to foliar spray of potassium.
- To assess the amount of water and water use efficiency of wheat under varying irrigation levels.
- To identify the suitable combination of irrigation level and foliar spray of potassium for maximizing grain yield of wheat.

CHAPTER 2

REVIEW OF LITERATURE

In Bangladesh, wheat is grown during *rabi* (winter) season and it is dry and as such, the inadequate soil moisture limits the use of fertilizers and consequently results in decreased grain yield. An attempt has been made in this chapter to present a brief review of research in relation to growth and yield of wheat as influenced by irrigations regimes and foliar application of potassium. It is an established fact that balanced fertilization especially potassium which is the most important plant nutrient and water management increases crop growth and gives higher yield. Some of the pertinent findings of the research with irrigation regimes and foliar application of potassium on the growth and yield of wheat are reviewed in this chapter.

2.1 Effect of irrigation

Many experiments have been conducted on the effect of irrigations on the growth, yield and yield contributing characters of wheat in different wheat growing countries of the world. Some of the results of those experiments were reviewed below:

Zareian *et al*. (2017) carried out an experiment in order to evaluate the effect of irrigation withholding and foliar potassium application on some physiological traits (photosynthesis, cell membrane stability and chlorophyll) and harvest index of wheat (*Triticum aestivum* L.) in 2011-2012 in two locations. The experimental factors were included drought stress (three levels of irrigation withholdings were irrigation withheld from ear emergence to physiological maturity, irrigation withheld from grain filling to physiological maturity and normal irrigation) and foliar potassium application (without potassium application, 1.5 and 3.0% K_2SO_4) on two wheat cultivars. Results showed that the studied characteristics were significantly reduced by increasing drought stress level. The highest harvest index was observed under normal irrigation (32.69%) and the lowest harvest index was obtained under severe stress (11.50%). Foliar application of 3.0% K_2SO_4 caused to significant differences in physiological characteristics, especially for leaf photosynthesis under severe drought stress condition.

Hasil *et al.* (2014) conducted a field experiment at physiology section of Agriculture Research Institute (ARI), Tandojam, Paksitan to investigate the effect of different irrigation scheduling on the growth and harvest index of wheat varieties in Rabi 2011-2012. The experiment was

laid out in a three replicated randomized complete block design (factorial) having net plot size of 6.0 m^2. Three wheat varieties i.e. SKD-1, TD-1 and Imdad were evaluated for their performance against three irrigation scheduling i.e. five irrigations (1^{st} 25 DAS and subsequent irrigations at 15 days interval), four irrigations (1^{st} 30 DAS and subsequent irrigations at 20 days interval) and three irrigations (1^{st} 35 DAS and subsequent irrigations at 25 days interval). The results showed that plant height, differed highly significant ($P<0.01$) for irrigation scheduling and non-significant ($P>0.05$) for varieties and interaction. Spikelets $spike^{-1}$ and seed index were highly significant ($P<0.01$) for irrigation and varieties whereas non-significant ($P>0.05$) for interaction. Tillers, spike length, grains $spike^{-1}$, biological yield and grain yield showed highly significant ($P<0.01$) effects for irrigation scheduling, varieties and their interaction whereas harvest index was influenced highly significant ($P<0.01$) between irrigation scheduling and varieties and significant ($P<0.05$) for their interaction. The wheat crop irrigated five times (1^{st} 25 DAS and subsequent irrigations at 15 days interval) resulted maximum plant height, tillers m^{-2}, spike length, spikelets $spike^{-1}$, grains $spike^{-1}$, seed index, biological yield, grain yield and harvest index as compared to four irrigations (1^{st} 30 DAS and subsequent irrigations at 20 days interval) and three irrigations (1^{st} 35 DAS and subsequent irrigations at 25 days interval). Among varieties SKD-1 ranked 1^{st} in all traits studied particularly grain yield followed by TD-1 and Imdad. However, it is concluded that interaction of five irrigations (1^{st} 25 DAS and subsequent irrigations at 15 days interval) and wheat variety SKD-1 proved optimum for obtaining maximum grain yield.

Sana Ullah Baloch *et al.* (2014) conducted a field experiment to investigate the effect of different irrigation schedules on growth and yield performance of wheat varieties and reported that the wheat crop irrigated five times resulted maximum plant height (86.206 cm), tillers m^{-2}, spike length, spikelet's $spike^{-1,}$ grains $spike^{-1}$, seed index, biological yield, grain yield and harvest index as compared to four irrigations and three irrigations.

Atikullah *et al*. (2014) conducted a field experiment to find out the consequence of irrigation levels on growth, yield attributes and yield of wheat (BARI Gom-26). Four different irrigation levels (viz. I_0: no irrigation i.e. control; I_1: Irrigation at 20 DAS at crown root initiation stage; I_2: Irrigation at 55 DAS at flowering stage and I_3: Irrigation at 75 DAS at grain filling stage were used. They reported that maximum dry matter content, crop growth rate (CGR) and relative growth rate (RGR) were found from I_1 which was statistically identical with I_2 whereas minimum from I_0. Plant height, number of tiller $hill^{-1}$, number of spike $hill^{-1}$, number of spikelets

spike^{-1}, spike length, filled grains spike^{-1}, total grains spike^{-1}, 1000-grains weight, grain yield , straw yield, biological and harvest index were correspondingly showed higher results as of growth characters.

Dong *et al*. (2013) was conducted a field experiment to study the effects of different irrigation and planting modes on the water consumption characteristics and dry matter accumulation and distribution of winter wheat. Three planting patterns (uniform row, wide-narrow row, and furrow) and four irrigation schedules (no irrigation, W_0; irrigation at jointing stage, W_1; irrigation at jointing and anthesis stages, W_2; and irrigation at jointing, anthesis, and milking stages, W_3; with 60 mm per irrigation) were installed. With increasing amount of irrigation, the total water consumption increased, while the soil water consumption and its ratio to total water consumption decreased significantly. As compared with W_0, the other three irrigation schedules had a higher dry matter accumulation after anthesis and a higher grain yield, but a lower water use efficiency (WUE).

Sarker *et al*. (2013) conducted an experiment to investigated the effects of number and timing of irrigation application on yields and reported that grain yield (GY), biomass, harvest index (HI), 1000-grain weight, grains/spike and spike length and water productivity (WP) were affected by deficit irrigations. During grain formation stage, water deficit did not affect the grain yield but saved water significantly. Such water deficit treatments also shortened the grain maturation period. The highest water productivity was observed in treatment which was irrigated only once at crown root initiation stage (T2) although the yield was comparatively low. The CRI (crown root initiation) stage was found the most sensitive to water stress. Water stress at vegetative stage also reduced the yield considerably.

Abderrazzak *et al.* (2013) conducted an experiment to determinate the optimal growth stage for applying supplemental irrigation to enhance bread wheat (*Triticum aestivum* L.) productivity and water use efficiency under rain-fed condition with three water treatments (I); rain-fed (I_0), irrigated (60 mm) at 21 according (I_1) and irrigated (60 mm) at 59 (I_2). They showed that I_2 improves water use efficiency, grain yield and its components by 91 and 60% respectively, compared to I_0 and I_1 treatments.

Yagoub *et al*. (2012) conducted a field experiment in the high terraces of Dongla area, Northern State, Sudan for two seasons (2008/09 and 2009/10). The objective of this study was to

determine the effect of watering regimes on growth of two cultivars of wheat. The irrigation treatments were skipping one irrigation at certain stages of growth of wheat as following: W1 = 1-20 days (germination + seedling development), W2 = 21-39 days (tillering + stem elongation or jointing), W3 = 40-59 days (booting +heading), W4 = 60-79 days (flowering of anthesis + milk stage), W5 = 80-99 days (dough + ripening), and W6 = control every 10 days. The two cultivars were WadiEliel and Npta. Parameters studied were plant height (cm), dry weight (gm) and number of tillers per square meter at every 24, 34, 44, 54, 64, 74, 84 and 94 days of growth. The results showed that Wadielneil cultivar had the highest weight compared with other cultivar (Npta) during all growth stages among the two seasons. Variation was significant (P=0.05) in 74, 84 and 94 days for growth in the first season; and 64, 74 and 94 days from growth of the second season. On the other hand, watering regimes obtained significant (P=0.05) effect in the second season at 54 and 74 days of growth at W4 and W6, respectively. The dry weight affected significantly (P=0.05) by watering regimes at 24, 34, 44 and 84 days of the first season and 24, 64 and 94 days of the second season. Wadielneil cultivar had the heaviest dry weight than Npta in all readings for both seasons, but showed significant difference (P=0.05) at 24 and 64 days at the second season. The watering regimes had significant difference (P=0.05) at tiller number/m^2 at 84 days of the first season and at 24, 44, 54 and 84 days at the second season. The cultivars had no significant effect on number of tillers except in 34, 74 and 94 days of the first season. The interaction of watering regimes X cultivars had no clear effect for all parameters of growth except the W_2V_1 in the number of tillers per meter squire in the second season only.

Sarwar *et al.* (2010) conducted a field study pertaining to the effect of different levels of irrigation on yield and yield components of wheat cultivars which was conducted during 2005-2006 growing season at Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan. Treatments were three cultivars (AS-2002, SH-2002, Aqab-2000), and five irrigation levels I_1 (irrigation at crown root stage), I_2 (irrigation at crown root + tillering), I_3 (irrigation at crown root + tillering + booting), I_4 (irrigation at crown root + tillering + booting + anthesis), and I_5 (irrigation at crown root + tillering + booting + anthesis + milking). Wheat cultivar AS-2002 recorded highest grain yield which was significantly higher than the other two cultivars. Wheat crop supplied with five irrigations at crown root + tillering + booting + earing + milking recorded the highest grain yield which was significantly higher than all the other irrigation levels. At highest irrigation level I_5, cultivars AS-2002 and SH-2002 produced grain yield at

par but significantly higher than Aqab-2000. At all the other irrigation levels, cultivar AS-2002 recorded significantly higher grain yield than the other two cultivars.

Ibrahim *et al.* (2010) conducted a field study in order to evaluate the effects of different water regimes during two years on growth and yield components of the cultivar Gemmeiza 9 cultivated under three and four irrigations at 30 days interval, and five and six irrigations at 25 days interval. Grain filling rate and effective grain filling period were also calculated for each treatment. Significant effects of the water regime were found on all measured traits. However, increasing the number of irrigations from five to six, keeping the same interval of time between irrigations, did not significantly increased grain yield, harvest index, number of tillers and spikes per m^2, spike length and fertility, 1000-grain weight and grain weight per spike. The grain production obtained by irrigation (or irrigation efficiency) was similar under three and four irrigations at 30 days interval but drastically decreased under five and six irrigations at 25 days interval. For the number of tillers and spikes per m^2 as well as for grain yield, gains decreased with each additional irrigation, up to three irrigations. Conversely, for the number of grain per spike and to a lesser extent for 1000-grain weight, the highest gains were noted when both the number and frequency of irrigation increased, i.e. when the crop was irrigated five times at 25 days interval, rather than four times at 30 days intervals. The study emphasizes the importance, for irrigated wheat, to define irrigation timing and frequency that allow maximal yield and optimal use of irrigation water.

Wang *et al*. (2012) conducted a field experiment to investigate the effects of different irrigations on grain yield and water use efficiency (WUE). Significant irrigation effect was observed on grain yield, kernel numbers and straw yield. The highest levels were achieved with a high irrigation supply, although WUE generally decreased linearly with increasing irrigation rates. The low irrigation treatment produced significantly lower grain yield, kernels number and straw yield than high irrigation treatment. The low irrigation treatment had a higher WUE than that of with high irrigation.

The effect of compensation irrigation on the yield and water use efficiency of winter wheat in Henan province was studied by Wu *et al*. (2011) and found that the effect of irrigation on plant height, the combinative treatment of irrigation in the former stage and medium irrigation compensation in the latter were better. The wheat yield was increased by 2.54%-13.61% compared to control and the treatments, irrigation of 900 m^3 ha^{-1} at the elongation stage and of

450 m^3 ha^{-1} at the booting stage or separate irrigation of 900 m3 ha^{-1} at the two stage were the highest.

Karim (2011) reported that crop growth rate (CGR) for the varieties was slower during early vegetative phase of the crop due to lower temperature; thereafter it increased sharply. Moisture stress at different crop growth stages affected CGR differently. Fully irrigated crops (T0) indicated significantly greater CGR than other crops throughout the season.

Islam *et al*. (2011) conducted an experiment to observe the effects of tillage and irrigation on the growth and yield of wheat (cv. Shatabdi). The irrigation treatments were I_0 = no irrigation, I_1= one irrigation, I_2 = two irrigation and I_3 = three irrigation. In case of irrigation practices, the tallest plant (86.57 cm) was found in I_3 and the shortest plant (74.53 cm) was found under the treatment I_0.

Mesbah (2009) conducted two field experiments at Al-Hussein society for reclaiming and cultivating land Cairo Alexandria desert road, Giza Governorate, Egypt, during 2007/2008 and 2008/2009 growing seasons to study the effect of irrigation regimes (1350, 1600 and1850 m^3/fed) and different treatments spraying with potassium 1, 2, 3% and control, 48 kg K_2O/fed as soil application on yield, yield component and water use efficiency of wheat (Giza 168 cultivar). Results indicated that differences between irrigation regimes for leaf area index, plant height, number of tillers $plant^{-1}$, number of spikelets/spike, spike length , 100-grain weight, harvest index in first season only, water use efficiency and grain yield per fed were significant in the two seasons. Irrigating wheat plant with 1850 m^3/fed gave the highest value for all studied traits except harvest index and water use efficiency. On the other hand, irrigation with 1350 m^3 /fed gave the highest values for water use efficiency only, in the two seasons. The differences between 1600 m^3/fed and 1850 m^3 /fed were insignificant for all studied traits except water use efficiency. Number of tillers, spike length, in the first season only, leaf area index, plant height, number of spikelets/spike, 100-grain weight, grain yield/fed, harvest index and water use efficiency were significantly increased with increasing potassium concentration from 1 to 2 or 3% in the two growing seasons. The interaction between irrigation regimes and spraying with potassium were significant for all studied traits except leaf area index and harvest index in the second season, plant height, number of tillers/plant, number of spikelets/spike, spike length in the first and second seasons. Irrigation wheat plants with 1600 m^3 /fed and foliar application of 2 to 3% potassium gave the highest value of most studied attributes. The

differences between foliar spraying of 1% potassium and the control treatment were significant, while the differences between control treatment and 2 to 3% potassium spray were insignificant of most studied attributes. Also, results show that, irrigation wheat plants until 1600 m^3/fed in critical stages of wheat and sprayed with 2% potassium increased the grain yield/fed and yield components and water use efficiency under new reclaimed soil conditions.

Kabir *et al*. (2009) conducted a field study in order to evaluate the effect of seed rate and irrigation level on the performance of wheat cv. Gourab. The experiment comprises of two factors namely (1) four seed rate viz. 100, 120, 140 and 160 kg ha^{-1} and (2) four levels of irrigation namely (i) no irrigation i.e. control, (ii) one irrigation given at crown root initiation (CRI) stage, (iii) two irrigations given at CRI and spikeinitiation stages and (iv) three irrigation given at CRI, spike initiation and grain filling stages. All of the yields contributing characters were significantly affected by seed rate except 1000-grain weight. The highest plant height (82.36 cm), total tillers $plant^{-1}$ (8.99), effective tillers $plant^{-1}$ (3.49), spike length (8.05 cm), spikelets $spike^{-1}$ (15.50), filled grain $spike^{-1}$ (31.05), grain yield (2.82 t^{-1}), straw yield (3.73 t^{-1}), biological yield (6.55 t^{-1}) and harvest index (42.43%) were recorded from the seed rate of 140 kg ha^{-1}. Most of the yields contributing characters were significant due to effect of irrigation level. The highest plant height (82.33 cm), spike length (8.37 cm), filled grain $spike^{-1}$ (31.90), effective tillers $plant^{-1}$ (3.31), grain yield (3.30 t ha^{-1}), straw yield (4.09 t ha^{-1}), biological yield (7.39 t ha^{-1}) and harvest index (44.47%) were recorded when one irrigation given at CRI stage. The interaction between seed rate and irrigation level influenced significantly all the plant characters except plant height, spikelets $spike^{-1}$ and 1000-grains weight. The highest spike length (8.63 cm), grain yield (3.7 t ha^{-1}), biological yield (8.06 tha^{-1}) and harvest index (45.91%) were found from the seed rate of 140 kg ha^{-1} combined with one irrigation applied at CRI stage.

A field experiment was carried out by Magdy *et al*. (2009) at Tag AL-Ezz, Agricultural Research Station Farm, Dakahlia Governorate, Agricultural Research Center, Egypt during 2006-2007 and 2007-2008 seasons to study the effect of irrigation withholding i.e. without (control treatment), withholding last irrigation and last two irrigations and potassium foliar application i.e. without irrigation (control treatment), 1.5 and 3.0 % K_2O, as well as, their interaction on growth, yield and its components and grain quality of wheat cultivar Sakha 93. Also, a laboratory experiment was conducted at Seed Technology Research Unit in Mansoura, Dakahlia Governorate, Field Crop Research Institute, Agricultural Research Center, Egypt, to

determine the germination percentage and seedling vigor tests (seed quality) of seed produced from the field experiment. The results indicated that water stress during grain filling through withholding last or last two irrigations markedly reduced growth, straw and grain yields and its components as well as seed quality characters in both seasons. In contrary, slight increases in grain protein content were resulted from withholding treatments in both seasons. Foliar application of potassium at the rate of 3.0 % K_2O gave the highest values of all studied wheat characters followed by 1.5 % K_2O as compared with control treatment in both seasons. It can be concluded from this study that maximum values of grain and straw yields as well as quality of grains and seed could be achieved from wheat cultivar Sakha 93 giving five irrigations and sprayed with 3.0 % K_2O. In case of shortage irrigation at the end of plant life cycle, it can be withholding the last irrigation and compensate happened reduction by spraying plants with 3.0 % K_2O solution.

Haider *et al.* (2007) carried out a field experiment to study the influence of different irrigation regimes on the spike formation and grain growth, relative growth rate of grain, grain abortion, yield and some yield components of four wheat varieties in two growing seasons. Irrigation regimes had significant effects on the aforesaid parameters and the varieties were found to be more efficient under well irrigated conditions. A drastic reduction in spike and grain growth and yield and increase in grain abortion was noticed when the varieties were grown under rain fed condition. Wheat varieties were found to be the most efficient to have higher values of spike and grain growth, relative grain growth rate and yield under all the irrigation regimes in both the growing seasons.

A field trials were conducted by Onyibe (2005) at irrigation research stations of the Institute for Agricultural Research, Kadawa, Sudan. The objective was to study the effect of irrigation regime (60, 75 and 90% Available Soil Moisture (ASM) on the growth and yield of two recently introduced wheat cultivars (Siete cerros and Pavon 76). The result revealed that increase of irrigation regime from 60 to 90% ASM did not significantly affect most of the growth, yield and yield parameters evaluated in the study. Each increase in irrigation regime however increased days to maturity, water use and thermal time but decreased water use efficiency. Pavon 76 produced superior grain yield than Siete ceros only in one season. Pavon 76 had a higher LAI, more tillers and spikes/m^2 and larger grain size, but had shorter plants, lower grain weight and grain number/spike and matured earlier than Siete cerros. Irrigation level of 60% ASM is recommended for both varieties in the Sudan savanna ecology. At this

ASM the highest water use efficiency of 4.0-4.8kg/mm/ha was obtained and grain yield was not significantly compromised. Grain yield was more strongly correlated with grain weight per spike than with grain number per spike.

Al-Kaisi (1997) conducted a field study to investigate the effective irrigation scheduling to manage water for spring wheat (*Triticum aestivum*L.) in southwestern Colorado under variable water applications. This study was conducted (1) to determine the effects of varying rates of water replacement (0.0ET, 0.33ET, 0.67ET, 1.0ET, and 1.33ET) on spring wheat grain yield, dry matter yield, root water uptake and water use efficiency, (2) to develop local crop coefficients and (3) to evaluate the irrigation scheduling program called 'SCHED' that had been used in the area. Daily weather data was used to calculate reference ET using the Penman equation. Crop ET was predicted by using the irrigation scheduling program, 'SCHED'. Both grain yield and dry matter increased significantly with the increase in water application rates, up to l.0ET application rate. Crop coefficients estimated at various water application rates were greater than the values used in the irrigation scheduling program. Total water use efficiency (TWUE) and irrigation water use efficiency (IWUE) for grain yield were considerably greater at 0.33ET than for other rates, whereas TWUE and IWUE for dry matter yield followed the order 0.33ET > l.0ET > 0.67ET > 1.33ET > 0.0ET.

2.2 Effect of foliar application of potassium

Potassium is an essential nutrient for plants. Muriate of potash (MOP) is used as a common source of potassium fertilizer. The rate and foliar application of potassium have remarkable influence on the growth, yield and yield contributing characters of wheat. Different researcher reported the effect of potassium on yield contributing component and grain yield. Some available information and literature related to the effect of source of potassium on the growth and yield of wheat are discussed below:

Desoky *et al*. (2017) carried out two pot experiments at greenhouse of Agriculture Botany Department, Faculty of Agriculture, Zagazig University, Sharkya Governorate, Egypt, during two successive winter seasons (2014/2015 and 2015/2016), to study the role of potassium in mitigation the harmful impact of drought stress conditions on wheat plants c.v Misr 2 grown in Egypt. Growth parameters, yield and biochemical constituents were evaluated. Results show that all plant growth characters studied (shoot dry weight, leaf area and plant height) as well as yield and its components (dry weight of grains /plant, number of spikes/plant, number of

grains/plant, number of grains/spike, and1000-grains weight) were decreased with increasing irrigation intervals (irrigation every 10, 20 and 30 days) during the two successive growing seasons. The most effective treatment was irrigation every 30 days in decreasing yield and its components. Integrated application of potassium at the rate of 0.1 and 0.2 % alleviated these negative effects by enhancing the growth and productivity. However, these increases were less than the control treatment. Moreover, it was found that drought stress decreased RWC, ELWR, RWL, photosynthetic pigments contents, whilst increasing, total phenol, proline as well as peroxidase and catalase activities in the leaves of wheat plants during the two growing seasons. However, application of proline or potassium increased all these parameters and decreasing total phenols. Treatment of proline at rate of 0.2 % was the most effective in this respect. It is recommended from the study that application of proline or potassium can fully or partially counteract the adverse effect of drought stress on growth, and productivity of wheat plants through their effects on biochemical constituents.

Shah *et al*. (2017) carried out an experiment to know the yield and nutrient uptake performance of two wheat (*Triticum aestivum* L.) varieties to foliar feeding of 2% potassium (K) at three various growth phases was explored under water restricted environment in a wire house trial at the Agriculture Research Station, Harichand, Charsadda, Pakistan. The target was to find out the preeminent K application stage for enhancement in the drought tolerance potential. Drought stress was generated by suppression of irrigation at the three growth phases and then K was sprayed with the carboxymethyl cellulose as a sticking agent, however Tween-20 was used as a surfactant for foliar spray. Data about several agronomic characters (plant height, spike length, number of spikelets per spike, number of grains per spike, 1000- grain weight and grain yield per plant) of crop were documented via standard techniques. Moreover, at maturity, aboveground nitrogen, phosphorus, K, sodium and calcium uptakes by the crop were determined. The results pointed out that drought stress at all three acute growth phases unfavorably affected plant height, spike length, number of spikelets per spike, number of grains per spike, 1000-grain weight, grain yield and nutrient uptake of the wheat plant. The exogenous K application under drought stress at all three acute growth phases boosted tolerance of wheat by decreasing noxious nutrient's uptake and augmenting the yield and yield characters. Extreme enhancement in all the documented yield parameters and nutrients uptake was attained when K was practiced at grain filling stage of both the varieties.

Zareian *et al.* (2014) conducted a field experiment in order to evaluate the effects of drought stress and potassium foliar application on grain yield, its components and some physiological traits of three wheat (*Triticum aestivum*L.) cultivars, field experiment was conducted during growing season of 2011-2012 at Seed and Plant Certification and Registration Research Institute (SPCRI), Karaj, Iran. The experiment was carried out using a split plot factorial based on a randomized complete blocks design with three replications. The experimental treatments included three irrigation regimes; normal, mild stress (water withhold at the grain filling phase) and severe stress (water withhold at the ear emergence phase); potassium foliar treatments included 0, 1.5% and 3.0% K_2O applications and three wheat cultivars. Relative water content (RWC) and net photosynthesis were measured after grain filling stage. Also the number of spikes per area, number of grains per spike, 1000-grain weight and grain yield were measured. Results showed relative water content and net photosynthesis were significantly decreased by drought stress. These traits showed significant increase by increasing potassium foliar application. Also results indicated that water stress through withholding at the ear emergence and grain filling phases reduced grain yield and its components. Foliar application of potassium at the rate of 3.0% K_2O gave the highest values of all studied characters followed by 1.5% K_2O as compared with control treatment. It is concluded that maximum values of grain yield could be achieved from wheat cultivar WS-82-9 giving normal irrigation and sprayed with 3.0% K_2O.

Rahman, *et al.* (2014) carried out a field experiment at Bangladesh Agricultural Research Institute (BARI) farm, Gazipur to evaluate the effect of foliar application of potassium orthophosphate on grain yield and kernel quality of wheat under the terminal heat stress imposed by late sowing for two consecutive years (2008-09 and 2009-10). Five combinations of foliar applications of potassium orthophosphate and Tilt were tested on three wheat varieties, namely Kanchan, Shatabdi, and Prodip. The result indicated that foliar application of potassium orthophosphate was effective in increasing SPAD value (measure of leaf chlorophyll content) and leaf area of all the wheat varieties, whereas Tilt application was effective only in Kanchan. The grain size of wheat in terms of 1000-grain weight was improved and thereby contributed to grain yield. Also the foliar application of potassium orthophosphate decreased the number of immature, smaller and deformed kernel, and thus improved the kernel quality. Two foliar sprays of 0.1% potassium orthophosphate solution at 70 DAS (days after sowing) and 80 DAS performed better results than other applications. There were varietal differences in response to foliar treatments and the variety Prodip and Shatabdi were more responsive to potassium

orthophosphate compared to Kanchan. Potassium orthophosphate was suggested to improve grain yield and kernel quality of wheat under terminal heat stress condition.

Raza *et al*. (2013) carried out an experiment to find out the physiological and nutrient uptake performance of two wheat (*Triticum aestivum*L.) cultivars (Lasani-2008 and Auqab-2000) to foliar application of 1% potassium (K) at three different growth stages (tillering, flower initiation and grain filling) was investigated under water limited environment in a wire house experiment at the Nuclear Institute for Agriculture and Biology, Faisalabad, Pakistan. The aim was to find out the best K application stage for improvement in drought tolerance potential. Drought stress was created by withholding irrigation at the three growth stages and then K was sprayed with carboxymethy cellulose as a sticking agent, whereas Tween-20 was used as a surfactant for foliar spray. At maturity, aboveground nitrogen, phosphorus, K, sodium and calcium uptakes by the crop were measured. Besides, water potential, osmotic potential and turgor potential of crop were also estimated. The results indicated that the drought stress at all three critical growth stages of wheat adversely affected plant's nutrient uptake, water potential, osmotic potential and turgor potential of wheat plants. The exogenous application of K under drought stress at all three critical growth stages enhanced tolerance of wheat by reducing toxic nutrient's uptake and improving the physiological efficiency. In this regards, both varieties showed uniform behavior. Maximum improvement in all the recorded nutrients uptake and physiological parameters was achieved when K was applied at grain filling stage of both cultivars.

Khan *et al*. (2013) conducted a pot experiment in the Department of Biological Sciences, University of Sargodha, Pakistan to determine the effect of potassium (K) on wheat under saline and non-saline conditions. Foliar spray of K (0, 300, 600 mgL^{-1}) was applied on wheat under different salinity levels (0, 150 m mol). Salinity levels were created according to the saturation percentage of the soil. Each pot was filled with 7kg well-mixed soil. This experiment was laid out in a randomized complete block design with two factors factorial arrangement and with three replications. Different growth and physiological attributes were collected from the conducted experiment. Application of K increased the shoot and root fresh and dry weight. Salinity also affected the chlorophyll contents but the application of K enhanced the chlorophyll contents under saline and non-saline conditions. Foliar application of K also minimized the toxicity of sodium. Similarly, grains yield was also decreased under saline conditions but the foliar application of K reduced the salinity stress and enhanced the grains

yield. These results indicated that foliar-applied K ameliorated the effect of salinity on wheat plants.

Hassanein *et al*. (2012) carried out an experiment to observe effect of foliar spray of potassium on wheat under drought stress. The goal of the study was analysis of drought stress defense triggers in wheat plants grown in dry sandy lands using methods of grain-priming and/or foliar pretreatments on the preanthesis stages. Grain-priming was induced using a low dose of salicylic acid (SA) while foliar pretreatments were performed using Thiourea (Th). Morphological, biochemical and yield components data revealed that wheat originated from grain-priming combined with foliar applications had exhibited stronger anti-drought effects. A raised tolerance level was ascertained from the up-regulation of crop production and quality in drought cultivation compared to normally irrigated wheat.

Aown *et al*. (2012) carried out a field study to find out the response of wheat (*Triticum aestivum* L.) cultivars Lasani-2008, Auqab-2000) to foliar application of 1% potassium at different growth stages (tillering, flower initiation and milking) under water limited environment. They found that drought stress at all three critical growth stages adversely affected plant height, spike length, number of spikelet per spike, number of grain per spike, 1000-grain weight and grain yield of wheat plant. Foliar application of K at all three critical growth stages improved the drought tolerance of plants and improved the growth and yield components, however, grain filling stage was found more responsive.

Hasina *et al.* (2011) conducted a field study to find out the effect of foliar application of Nitrogen (N), Potassium (K) and Zinc (Zn) solutions on the growth of wheat cultivar Ghazanive-98. Data was recorded on emergence of plants m^{-2}, number of tiller m^{-2}, plant height (cm), number of days to anthesis and number of spikes m^{-2}. The statistical analysis showed that number of plants emerged m^{-2}, number of tillers m^{-2}, plant height (cm) and number of spikes m^{-2} were significantly affected while number of days to anthesis was not affected significantly by foliar treatments. Maximum emergence m^{-2} (309), number of tillers (527) m^{-2}, plant height (100.50cm) and number of spikes (238) m^{-2} were recorded in those plots which were sprayed with 0.5% N, 0.5% K and 0.5% Zn solutions two times while minimum emergence m^{-2} (130), number of tillers (263 m^{-2}, plant height (75.25cm) were recorded in control plots and minimum number of spikes (123) m^{-2} was recorded in plots sprayed with 0.5% K solution two times. It

was concluded that growth performance of wheat was highly influenced by the application of two times spray of 0.5 % N, 0.5% K and 0.5% Zn solutions.

Barraclough *et al*. (1996) conducted two experiments on winter wheat crops in 1990 and 1991 with the aim of testing if late foliar supplements of K and N, applied at key development stages, could improve grain yield and grain N content. Foliar sprays of KNO_3 solution, supplying up to 40 kg K ha^{-1} in total, at flag leaf unfolded inflorescence completed and the watery-ripe stage of grain filling, had no effect on yield, yield components or grain N. Urea, supplying 40 kg N ha^{-1} at flag leaf unfolded, had no effects on grain yield and grain N in 1990, but in 1991 grain N was increased by 0.14% whilst yield was reduced by up to 0.6 t ha^{-1}. Urea scorched flag leaf tips in both years. In 1990, the spring was very dry and foliar supplements might have been expected to have had an effect, but on this highly fertile soil all crop K and N requirements were met from the soil.

Jiguang *et al*. (2013) conducted a hydroponics experiment in a non-controlled greenhouse. Seedlings of drought-tolerant SN16 and intolerant JM22 were simultaneously treated by five levels of K_2CO_3 (0, 2.5, 5, 7.5, 10 mM) and two levels of PEG6000 (0, 20%) for 7 days. External K_2CO_3 significantly increased shoot K^+ content, water potential, chlorophyll content as well as gas exchange, but decreased electrolyte leakage (EL) and Management Allowable Depletion (MAD) content in both cultivars under PEG6000 stress. Antioxidant enzymes activities were up-regulated by PEG6000 while external K_2CO_3 reduced those changes. Molecular basis was explained by measuring the expression levels of antioxidant enzymes related genes. Shoot and root biomass were also increased by K_2CO_3 supply under drought stress. Although adequate K_2CO_3 application enhanced plant growth for both cultivars under drought stress, SN16 was better than JM22 due to its high drought tolerance. Adequate external K may effectively protect winter wheat from drought injuries. Drought-tolerant wheat combined with adequate external K supply be a promising strategy for better growth in arid and semi-arid regions.

Amal *et al.* (2011) conducted a study to develop management recommendations that maximize growth and yield of wheat plants grown in sandy soil to meet the growing demands for wheat under the constrains of depleting natural resources, environmental fluctuation and increased population and also to study the efficiency of foliar feeding of urea and potassium. To achieve the aforementioned objectives, two field experiments were carried out at the Agricultural

Production and Research Station, National Research Centre EL- Nubaria province, EL- Behira Governorate, Egypt, during the two successive winter seasons 2007/2008 and 2008/2009 to study the response of two wheat cultivars to foliar fertilizers of urea and potassium on growth and productivity the results could be summarized as follows. Gemmiza-10 cultivar significantly surpassed Sakha-93 in growth characters at 65, 90 and 115 days after sowing and also, yield and its components. Foliar fertilizer of urea and potassium caused significant stimulatory effect on growth parameters, however, foliar feeding with urea 2% + K_2O 2% gave the highest significant values for all growth characters at 65, 90 and 115 days after sowing and also for yield and its components i.e. plant height, number of spikes/m^2, weight of spikes/m^2 as well as grain, straw and biological yields/feddan. The interaction between Gemmiza-10 cultivar 2 and foliar fertilizer of urea and potassium (urea 2%+K_2O 2%) showed a significant increase in growth characters at 65, 90 and 115 days after sowing and also yield and its components i.e. plant height, number of spikes/m^2, weight of spikes/m^2, grain, straw and biological yields/m^2, grain, straw and biological yields/feddan.

CHAPTER 3

MATERIALS AND METHODS

Materials required and methods followed in the experiments during the study period are presented in this chapter. The experiments were carried out for the two consecutive Rabi seasons during the period from November 2015 to April 2017.

3.1 Description of the experimental site

3.1.1 Location

All the experiments were conducted in the research farm and laboratory of Crop Physiology and Ecology Department, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200. Geographically the experimental field was located at 25°38' N latitude and 88°41' E longitude, with a height of 37.85 m above the sea level belonging to Agro-ecological Zone-1 (AEZ-1) named old Himalayan piedmont plain (UNDP and FAO 1988).

3.1.2 Soil and Climate

The experimental field was a medium high land with sandy loam textured soil. The pH value of the soil is 6.8. General characteristics and description of soil of the experimental site has been presented in Appendix- I. Daily weather data for the both the growing seasons were obtained at the meteorological station, Bangladesh Wheat and Maize Research Institute, Nasipur, Dinajpur, Bangladesh. A chart of the monthly air temperature (°C), rainfall (mm), relative humidity (%) and sunshine (hour's day) during the experimental period of the years (2015-2016 and 2016-2017) has been presented in Appendix- II. During the growing period average temperature was 21.64 °C in 2015-2016 and 21.23 °C in 2016-2017, which were suitable for wheat production. Total rainfall was 82 mm in 2015-2016 and 215 mm in 2016-2017 which were not sufficient for wheat production.

3.2 Experimental treatments

The treatments included in the experiment ware as follows-

A. Irrigation regimes: 4

i) No irrigation-I_0

ii) Irrigation with 3200 m^3 ha^{-1} water –I_1

iii) Irrigation with 3800 m^3 ha^{-1} water –I_2

vi) Irrigation with 4400 m^3 ha^{-1} water –I_3

Irrigation water was applied at 21, 45 and 70 DAS i.e. one at tillering stage, one at booting stage and final one after heading.

B. Application of potassium fertilizer: 4

i) Control: The recommended dose of potassium i.e. 50 kg K ha^1 in the form of KCl– K_0

ii) 50% of the recommended dose of potassium i.e. 25 kg K ha^1 in the form KCl + Foliar spray with 1% K_2O using K_2SO_4—K_1

iii) 50% of the recommended dose of potassium i.e. 25 kg K ha^1 in the form of KCl + Foliar spray with 2% K_2O using K_2SO_4—K_2

iv) 50% of the recommended dose of potassium i.e. 25 kg K ha^1 in the form of KCl + Foliar spray with 3% K_2O using K_2SO_4—K_3

Potassium was applied through spraying of 1%, 2% and 3% of K_2O at 19, 43 and 68 DAS using K_2SO_4. The control plot received no potassium spray except basal dose of potassium i.e. 50 Kg K ha^{-1} through muriate of potash. Foliar spray was done in the morning prior two days of irrigation usining 0.1% Twen-20 as surfactant.

B. Wheat variety

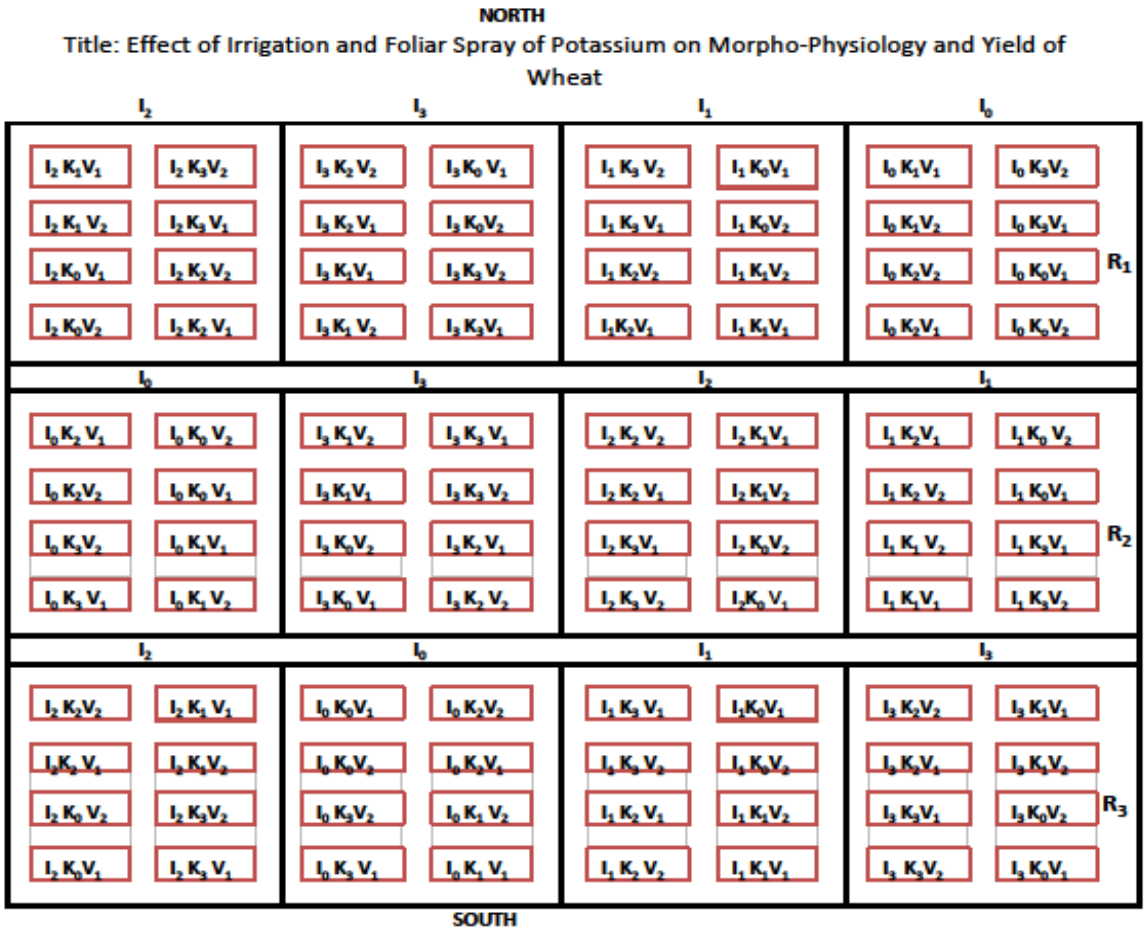
i) BARI Gom 27—V_1

ii) BARI Gom 28—V_2

3.3 Experimental design and layout

The experiment was laid out in a split-split plot design with three replications. The irrigations were assigned in the main plots, potassium in the sub plots and wheat variety were in the sub-sub plots. The unit plot size was 2.5 m X 2.0 m having a plot to plot distance 0.5m. Block to block distance was 1 m. Total number of plots were 96.

Expermental Layout:



Legent:

I_0 = No irrigation

I_1 = Irrigation with 3200 m^3 ha^1

I_2 = Irrigation with 3800 m^3ha^1

I_3 = Irrigation with 4400 m^3ha^1

K_0 = The recommended dose of potassium i.e. 50 kg K ha^1 in the form of KCl– K_0

K_1 = 50% of the recommended dose of potassium i.e. 25 kg K ha^1 in the form KCl + Foliar spray with 1% K_2O using K_2SO_4—K_1

K_2 = 50% of the recommended dose of potassium i.e. 25 kg K ha^1 in the form of KCl + Foliar spray with 2% K_2O using K_2SO_4—K_2

K_3 = 50% of the recommended dose of potassium i.e. 25 kg K ha^1 in the form of KCl + Foliar spray with 3% K_2O using K_2SO_4—K_3

V_1 = BARI Gom-27

V_2 = BARI Gom-28

3.4 Plant materials

Two wheat varieties (*Triticum aestivum*L.) i.e. BARI Gom 27 and BARI Gom 28 were collected from Bangladesh Wheat and Maize Research Institute, Nasipur, Dinajpur, Bangladesh. These varieties released in 2012 by Bangladesh Agricultual Research Institute (BARI), Jodebpur, Gazipur.

Varietal information

Specifications	BARI Gom-27	BARI Gom-28
Development year	2012	2012
Developed by	Bangladesh Wheat and Maize Research Institute, Nasipur, Dinajpur, Bangladesh.	Bangladesh Wheat and Maize Research Institute, Nasipur, Dinajpur, Bangladesh.
Identifying character	The variety is high yielding, short stature and 2-3 days earlier in heading than Shatabdi. It is resistant to stem rust (race Ug99) disease and moderately tolerant to terminal heat stress. It is resistant to leaf rust and tolerant to BpLB disease. Grains are white amber in colour and medium in size (35-40g). Leaf narrow, erect. Glaucosity in spike, culm and flag leaf sheath is weak. Brown necrosis in spike is present. Stem is flexible. Upper culm node hair few. Lower glume beak (LGB) length short (<5.1mm). LGB spicules-numerous, shoulder medium and deeply elevated.	The variety is high yielding, short stature and 7-10 days earlier in heading than Shatabdi. It is highly tolerant to terminal heat stress due to its earliness. Grains are white amber in colour and medium in size (43.0-48.0g). Leaf broad, flag leaf attitude erect. Flag leaves are moderately spiral. Glaucosity in spike and culm is medium and strong in flag leaf sheath. Upper culm node hair few/medium. Lower glume beak (LGB) length is long (>12.1 mm). LGB spicules-numerous, LGB shape sloppy. Lower glume shoulder shape pointed and shoulder width medium and deeply indented.
Crop duration	104 -110 days	102-108 days
Yield	3.50 - 5.00 t/ha	4.0-5.5 t/ha

3.5 Land preparation

The land of the experimental plots were opened on 16 November with power tiller and it was made ready for sowing seeds on 30 November by ploughing and cross ploughing with a country plow followed by laddering. All weeds and stubbles were removed from the land. The bunds around the individual plots were made firm enough to control water movement between the

plots. The unit plot was spaded one day before planting and basal dose of fertilizer were incorporated thoroughly.

3.6 Fertilizer application

The land was fertilized with 180 Kg ha^{-1} TSP, 180 Kg ha^{-1} Urea, 120 Kg ha^{-1} Gypsum, 6 Kg ha^{-1} Boric Acid and 12 Kg ha^{-1} Zinc Sulphate. Potassium was applied through spraying at 1%, 2% and 3% of K_2O as per experimental specifications using K_2SO_4. The control plot received no potassium spray except basal dose of potassium i.e. 50 Kg K ha^{-1}. Potassium was applied through spraying of 1%, 2% and 3% of K_2O at 25, 45 and 70 DAS using K_2SO_4.

3.7 Collection and sowing of seeds

Seeds of designated wheat varieties were collected from Bangladesh Wheat and Maize Research Institute, Nashipur, Dinajpur. Seeds were sown continuously by hand in 20 cm apart rows @ 120 kg ha^{-1} on 30 November, 2015 and 30 November, 2016.

3.8 Intercultural operation

3.8.1 Weeding and thinning

Weeding was done twice during the whole growing period, the one after 19 DAS and the other after 44 DAS. Thinning, weeding and gap-filling operations were done before the 1^{st} irrigation to keep plant to plant distance approximately 4 cm.

3.8.2 Irrigation

The plots were irrigated as per aforesaid experimental treatments. Proper care was taken to stop leaching of irrigated water between the adjacent plots.

3.9 Soil sample collection

Soil sample from each plot were collected for chemical analysis before sowing. The samples were then composite to make a bulk sample. Bulk samples were sieved to remove unwanted materials. Initial soil moisture content was calculated for calculation of consumptive use of water and to calculate water use efficiency of the crops. Remaining samples were preserved in polythene bags for future laboratory analysis.

3.10 Plant sample collection

Five rows of each plot were selected for collecting data on growth and phenological parameters. Growth study was started from 20 DAS and continued up to 80 DAS at 15 days interval. Three plants per plot were uprooted randomly at each time. Each plant sample were separated into leaf, stem and spike (when appear). Number of tillers per plant were counted. The samples were packed separately in labeled brown paper bags and were oven dried for 72 hrs at 70-80^{0}C. Dry weight was then measured separately with an electrical balance. The leaf area of the collected leaves were taken and were weighted after oven-drying and leaf area was calculated by using the following formula: Area of leaf = Leaf length X Leaf width X 0.75 (Mossad *et al*., 1995).

3.11 Growth analysis technique

From the dry weights of different plant parts and leaf area data, the following growth attributes such as LAI, CGR, RGR, RLGR, NAR, LAR, SLA and LWR were calculated between two successive harvests by following the classical technique of growth analysis (Radford, 1967 and Hunt, 1978).

1. Leaf area index (LAI) = $\frac{\text{Leaf area}}{\text{Ground area}}$

2. Crop growth rate (CGR) = $\frac{W_2 - W_1}{t_2 - t_1}$

3. Relative growth rate (RGR) = $\frac{\log_t W_2 - \log_t W_1}{t_2 - t_1}$

4. Relative leaf growth rate (RLGR) = $\frac{\log_t LA_2 - \log_t LA_1}{t_2 - t_1}$

5. Net assimilation rate (NAR) = $\frac{(W_2 - W_1)(\log_t W_2 - \log_t W_1)}{(LA_2 - LA_1)(t_2 - t_1)}$

6. Leaf area ratio (LAR) = $\frac{\text{Leaf area}}{\text{Ground area}}$

7. Specific leaf area (SLA) = $\frac{\text{Leaf area}}{\text{Leaf dry weight}}$

8. Leaf weight ratio (LWR) = $\frac{\text{Leaf dry weight}}{\text{Total plant dry weight}}$

Where, W_2 and W_1 are the total dry weights, LA_2 and LA_1 are the leaf area per plant at t_2 and t_1, the latter and the former harvest, respectively.

3.12 Experimental data collection

3.12.1 Morphological characters

i) Plant height at 20, 35, 50, 65 and 80 DAS.

ii) Number of leaf plant^{-1} at 20, 35, 50, 65 and 80 DAS.

iii) Number of tillers plant^{-1} at 20, 35, 50, 65 and 80 DAS.

3.12.2 Growth parameters

Following parameters were calculated using the formula proposed by Radford (1967) and Hunt (1978).

i) Total dry matter plant^{-1} at 20, 35, 50, 65 and 80 DAS.

ii) Leaf Area Index (LAI) at 20, 35, 50, 65 and 80 DAS.

iii) Crop Growth Rate (CGR) at 20-35, 35-50, 50-65 and 65-80 DAS.

iv) Relative Growth Rate (RGR) at 20-35, 35-50, 50-65 and 65-80 DAS.

v) Net Assimilation Rate (NAR) at 20-35, 35-50, 50-65 and 65-80 DAS.

vi) Leaf Area Ratio (LAR at 20-35, 35-50, 50-65 and 65-80 DAS.

vii) Relative Leaf Growth Rate (RLGR) at 20-35, 35-50, 50-65 and 65-80 DAS.

viii) Specific Leaf Area (SLA) at 20-35, 35-50, 50-65 and 65-80 DAS.

ix) Leaf weight ratio (LWR) at 20-35, 35-50, 50-65 and 65-80 DAS.

3.12.3 Phenological parameters

The following stages were recorded in days when 50% plants of each replication reach a definite stage in both the growing seasons.

i. Crown Root iniiation stage

ii. Tillering stage

iii. Booting stage

iv) Heading stage

v) Anthesis stage

vi) Physiological maturity

3.12.4 Plant characteristics and dry matter at different phenological stages

The following plant characteristics were recorded at the crown root initiation, tillering, booting, heading, anthesis and physiological maturity stages.

i) Plant height

ii) Leaf dry matter plant^{-1}

iii) Stem dry matter plant^{-1}

iv) Spike dry weight plant^{-1} (when present)

v) Total dry matter plant^{-1}

vi) Leaf area plant^{-1}

3.12.5 Water relations

3.12.5.1. Moisture retention capacity

Moisture retention capacity of the flag leaves was measured during the anthesis stage of the crop. For this purpose, the leaves were collected in tightly fastened polythene bags. Two leaves/replication/cultivar/treatment were collected at 8:30 am and their fresh weight (FW) was taken immediately. Then the leaves were arranged systematically in a tray. After arrangement of the leaves, their fresh weight (FW) was taken at 30 minutes intervals for 8 times and there after 3 times at 90 minutes intervals. Finally, the leaves were dried in an oven at 85°C for 24 hours and their dry weight (DW) was taken by an electronic balance. The moisture retention capacity of leaves was calculated from the following formula.

$$\text{Moisture retention capacity (\%)} = \frac{\text{FW - DW}}{\text{FW}} \times 100$$

Here,

FW=Fresh weight of leaf

DW= Dry weight of leaf

3.12.5.2 Relative leaf water content

Relative leaf water content (RLWC) was determined from the fully expanded flag leaves. The leaves were collected at 8:00 am, 12:00 noon and 4:30 pm. Three leaves were taken from each replication of each cultivar. Their fresh weight (FW) was taken immediately and was sinked into water in petri dish and kept for 3 hours. After 3 hours, they were taken off from water and was drying with blotting paper. When the cells of the leaves were fully turgid, their turgid weight (TW) determined. Then the leaves were dried in an oven and their dry weight (DW) was taken. The relative leaf water content was calculated following formula (Barrs and Weatherly, 1962).

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

3.12.6 Biochemical characters

3.12.6.1 Estimation of chlorophyll

Chlorophyll content of the flag leaves during the anthesis stage was estimated. One mg of leaf sample was taken from different portions of the flag leaf. Sample was taken in 100 ml of 80% aqueous acetone in brown colored bottle and was kept in dark for 48h. The optical density (OD) of this solution was determined against 80% acetone as blank using a spectrophotometer (Model: SPECTRO UV-VIS RS, Labomed Inc, USA) at 645 and 663 nm. The chlorophyll a, b and total chlorophyll were determined according to the formulae used by Witham *et al.* (1986) as follows:

mg chlorophyll a /g leaf tissue = [12.7 (D 663)-2.69 (D 645)] × [v/(100 × W)]

mg chlorophyll b /g leaf tissue = [22.9 (D 645)-4.68 (D 663)] × [v/(100 × W)]

mg total chlorophyll (a+b) /g leaf tissue = [20.2 (D 645)-8.02 (D 663)] × [v/(100 × W)]

Where, W = Fresh weight of leaf sample (1 mg)

V = Volume of the solution (10 ml)

D = Optical density

663 and 645 are wave lengths in nm.

3.12.6.2. Estimation of proline

Proline content of the flag leaves during the anthesis stage in two wheat varieties was estimated. Flag leaves from each replication of each variety 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 flag 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).

3.12.7 Grain growth parameters

Grain growth study was started from the start of anthesis. After anthesis, 10 spikes from each plot were tagged with identifying marks to collect them on 7, 14, 21, 28 and 35 days after anthesis (DAA). Three spikes from each plot were collected and packed separately in labeled paper bags and were dried for 72 hours at 70-80 °C

i) Number of spikelets spike^{-1} at 7, 14, 21, 28, 35 DAA
ii) Number of grains spike^{-1} at 14, 21, 28, 35 DAA
iii) Dry weight of spike at 7, 14, 21, 28, 35 DAA
iv) Dry weight grain^{-1} at 7, 14, 21, 28, 35 DAA
v) Grain growth rate at 7-14, 14-21, 21-28, 28-35 DAA

3.12.8 Yield and yield components

The experimental crop of each plot was harvested separately at full maturity. Out of 15 rows of the crop, the central 5 rows were harvested for collecting data on yield and yield contributing characters. The harvested crop of each plot was bundled separately, tagged properly and brought to the clean threshing floor. The bundles were dried on open sunshine, threshed and then seeds were cleansed. The seed and straw weights for each plot were recorded after proper drying in the sun. Prior to harvesting, 5 plants were selected randomly from each plot and uprooted carefully for collecting data on yield contributing characters.

i) Plant height
ii) Effective tillers plant^{-1}
iii) Spike length
iv) Extrusion length
v) Fertile spikelets spike^{-1}
vi) Infertile spikelets spike^{-1}
vii) 1000-grain weight
viii) Grain yield
ix) Straw yield
x) Biological yield
xi) Harvest index

Harvest index (HI) was calculated by dividing economic yield by biological yield of the plant in each plot and by multiplying with 100 and express in percentage.

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.12.9 Association between yield and yield components

Association between yield and yield components were determined after final harvest with the help of computer package SPSS. Association was determined in respect to irrigation and potassium application in both the years.

3.12.10 Consumptive use of water and water use efficiency

3.12.10.1 Consumptive use of water

Soil samples were collected from each plot with an auger up to 1 meter depth of soil for determining soil moisture content before sowing and after harvest of the crop. Soil moisture was determined gravimetrically up to l m depth of soil profile from 5 soil layers (0-20 cm, 20-

40 cm, 40-60 cm, 60-80 cm and 80-100 cm) before sowing of seeds and at the final harvest with the help of an auger. The moisture content values were used to compute consumptive water use (CWU) according to the following formula proposed by Dastane (1972).

Consumptive use of water (mm) = $IR + ER + \sum_{i=1}^{n} \frac{Mb_i - Me_i}{100} \times A_i \times D_i$

Here,

IR= Irrigation water

ER= Rainfall

Mb_i= Moisture percentage at the beginning of the season of the ith layer of the soil profile.

Me_i= Moisture percentage at the end of the season of the ith layer of the soil profile.

D_i= Depth of ith layer of the soil profile within the root zones and

n= Number of soil layers in the root zone D.

A_i=Specific density of soil.

3.12.10.2. Water use efficiency

Water use efficiency was calculated by using the following formula

$$\text{WUE} = \frac{\text{Grain yield (kg/ha)}}{\text{Consumptive use of water (mm)}} \times 100$$

3.13 Estimation of potassium in grain and straw of wheat

Straw and grain samples from each plot were taken. Approximately 10 g of samples of each plot were preserved separately in polythene bags for chemical analysis to determine K content in straw and grain. K content of wheat straw and grain was determined by the Flame Photometr in central laboratory, Soil Resource Development Institute, Khamerbari, Dhaka

3.14 Meteorological data

Meteorological data was collected from the Agro-meteorological center, Bangladesh Wheat and Maize Research Institute, Nashipur, Dinajpur, Bangladesh which is about 4 km from the experimental field. The information like maximum and minimum temperature, sunshine hour and precipitation were collected from November, 2015 to April, 2016 and November, 2016 to April, 2017.

3.15 Statistical analysis and graphical presentation

All recorded parameters were analyzed statistically. A program called Microsoft Excel 2007 was used for the spreadsheet analysis and numerical calculations. All recorded data were statistically analyzed following the ANOVA technique and the significance of mean differences were adjusted by Tukey's test with the help of computer using STATA program. Simple correlation coefficients between pairs of characters were determined with the help of computer package SPSS. All the figures in the thesis were presented in the form of line graphs and bar diagrams which were composed with the help of spreadsheet package Microsoft Excel 2007.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter comprised with presentation and discussion of the results obtained from the Water physiological attribute and yield of wheat and their interaction on growth contributing characters have been presented in Tables and Figures. The results have been presented and discussed with the help of tables and graphs and possible interpretations were given under the following headings.

4.1 Morphological Characteristics

4.1.1 Plant height

The analyzed data in regards to plant height was significantly influenced by different levels of irrigation during the experimentation period are presented in Table 1A and Fig. 1A for first year (2015-2016) and Table 1B and Fig. 1B for second year (2016-2017) respectively. Irrigation amounts showed a non-significant effect on plant height at the early stage of growth (20 DAS) in both the years. Then plant height was slowly increased up to 35 DAS and then it was rapidly increased up to 65 DAS and there was a steady increase till 80 DAS for both the years. Superior plant height was consistently recorded when the plots treated with I_2 (Irrigation with 3800 m^3 ha^{-1}) treatment of irrigation where the inferior ones was observed when no supplementary irrigation was applied. Plant height for all treatments was almost similar up to the crown root initiation stage (20 DAS), as no supplemental irrigation was applied before that stage to any treatment. However, a marked decline was observed in case of I_0 (no irrigation) when irrigation was imposed at 20 DAS. At 35 DAS, the highest plant height was recorded from I_2 treatment which was statistically similar to I_3 and I_1 treatments in both the years. Plant height for irrigated crops was almost similar up to tillering stage, because first irrigation was applied before that stage. At 50 DAS, the tallest plant was found in I_2 treatment which were statistically similar to I_3 and I_1 treatments in both the years. At 65 and 80 DAS, the maximum plant height was recorded in I_2 treatment which was statistically similar with I_3 in the second year (2016-2017) of experiment. The shortest plant was observed from I_0 treatment at all growing stages in both the years. Supplemental irrigation increased plant height by applying at all critical growth stages which might be due to sufficient availability of nutrients. These results were in line with those of Sarwar *et al.* (2010), Khan *et al.* (2001) and Thompson and Chase (1992) who reported that irrigation treatments significantly influenced plant height of wheat.

Atikullah *et al.* (2014) stated that significant variation for plant height of wheat at different days after sowing due to different irrigation levels. This result is in good agreement with the result of Islam (1997) who reported that plant height increased with increasing number of irrigations.

Effects of variety on plant height of wheat at different stages of growth are shown in Table 2A for first year (2015-2016) and Table 2B for second year (2016-2017) respectively. Plant height was not statistically significant for varieties in both the years. The highest plant height was found in BARI Gom 28 (V_2) in both the growing seasons.

Influence of foliar applications of potassium on plant height at different plant growth stages are presented in Table 3A and Fig. 2A for first year (2015-2016) and Table 3B and Fig. 2B for second year (2016-2017) respectively. Significant variation was observed in plant height with foliar applications of potassium at 20, 35, 50, 65 and 80 DAS under the presented study in both the years. At 20 DAS, the tallest plant was obtained in K_0 (no irrigation) treatment of potassium which was statistically significantly similar with K_1 and K_3 during the two successive growing seasons and the shortest plant was reveled in K_2. Significant variation was observed in plant height after applying potassium treatments at 35, 50, 65 and 80 DAS in both the growing seasons. At 35, 50, 65 and 80 DAS, the highest plant was recorded in K_2 treatment which was statistically similar with K_3 and K_1 during the two successive growing seasons. At early growth stages, amount and availability of potassium was high in K_1 treatment resulting in higher plant height. But at later stages, potassium availability increased in other treatments and enhanced crop growth. From the presented study, it was observed that foliar application of K to wheat plant under water deficit condition plays a mitigating role and for consequence enhanced crop growth and development. Mengel and Kirkby (2001) reported that, for many physiological processes such as activation of enzymes, photosynthesis, maintenance of turgescence, translocation of photosynthates, K is essential element. It has been concluded by Desoky *et al.* (2017) that potassium can counteract the adverse effect of drought stress on plant height and productivity of wheat plants through their effects on biochemical constituents. Hasanuzzaman *et al.*, 2018, Wang *et al*., 201, Yadov, 2006 and Yadav *et al*., 2004 proposed that plants mineral nutrient especially K plays a key role in enhancing the resistance of plant to stress situations and foliar application of K ameliorated this negative effect to a significant level. The presented result is in agreement with the findings of Brhane *et al.* (2017), Abbas *et al.* (2013), Zareian *et al. (*2013), Aown *et al.* (2012), Tahir *et al.* (2008) and Ahmad *et al*. (2007) in wheat.

The interaction effects of irrigation regimes and foliar applications of potassium on plant height are presented in Table 4A for first year (2015-2016) and Table 4B for second year (2016-2017) respectively. The interaction effect between amount of irrigation and foliar applications of potassium was significant for the plant height at 20, 35, 50, 65 and 80 DAS in both the years. At 20 DAS, the maximum plant height was found in I_2K_2 treatment which was statistically similar with I_3K_1 and I_1K_1 treatments in both the growing seasons. At 35 DAS, the maximum plant height was recorded in I_2K_2 treatment which was statistically similar with I_3K_1 and I_1K_1 in case of first year (2015-2016) but in the second year (2016-2017) the highest plant height was found in I_3K_1 which was at par with I_2K_2. In case of 50 DAS, the maximum plant height was found in I_2K_2 treatment which was statistically similar with I_3K_2, I_3K_1 and I_2K_1 treatments during the two successive growing seasons. At 65 and 80 DAS, the maximum plant height was recorded in I_2K_2 which was statistically similar with I_3K_2 in both the growing seasons. The minimum plant height was recorded in I_0K_0 treatment at all growth stages during the two successive growing seasons.

Table 1: Effect of irrigation on plant height of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Irrigation	A. Plant height (cm) (2015-2016)					B. Plant height (cm) (2016-2017)				
	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS
I_0	21.845 a	30.736 b	57.632 b	63.348 c	76.753 c	21.288 a	30.762 b	54.408 b	61.384 c	75.523 c
I_1	22.248 a	41.766 a	71.701 a	77.111 b	88.634 b	21.282 a	37.753 a	67.661 a	74.292 b	84.264 b
I_2	21.699 a	40.874 a	70.671 a	81.348 a	92.872 a	20.527 a	40.893 a	68.446 a	78.872 a	91.452 a
I_3	21.844 a	40.127 a	68.459 a	76.418 b	90.673 ab	21.312 a	40.170 a	65.761 a	75.652 b	89.432 ab
CV (%)	14.345	5.619	5.892	3.572	4.234	14.012	5.453	5.448	3.712	4.803

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 2: Effect of variety on plant height of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Variety	A. Plant height (cm) (2015-2016)					B. Plant height (cm) (2016-2017)				
	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS
V_1	21.734 a	38.308 a	67.086 a	74.089 a	86.984 a	21.024 a	37.336 a	64.055 a	72.446 a	84.499 a
V_2	22.083 a	38.444 a	67.145 a	75.017 a	87.481 a	21.184 a	37.454 a	64.083 a	72.653 a	85.837 a
CV (%)	14.345	5.619	5.892	3.572	4.234	14.012	5.453	5.448	3.712	4.803

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 3: Effect of potassium on plant height of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Potassium	A. Plant height (cm) (2015-2016)					B. Plant height (cm) (2016-2017)				
	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS
K_0	21.849 a	33.332 b	63.442 b	69.871 b	81.584 b	21.513 a	34.338 b	59.742 b	64.866 b	78.724 b
K_1	21.949 a	39.446 a	66.644 ab	72.401 b	85.554 b	20.534 b	37.282 a	62.904 ab	70.688 b	81.347 b
K_2	21.848 b	40.392 a	69.652 a	77.513 a	89.113 a	21.469 a	39.505 a	67.786 a	76.983 a	91.725 a
K_3	21.991 ab	40.334 a	68.725 a	78.427 a	92.681 a	20.901 ab	38.454 a	65.845 a	77.662 a	88.876 a
CV (%)	14.345	5.619	5.892	3.572	4.234	14.012	5.453	5.448	3.712	4.803

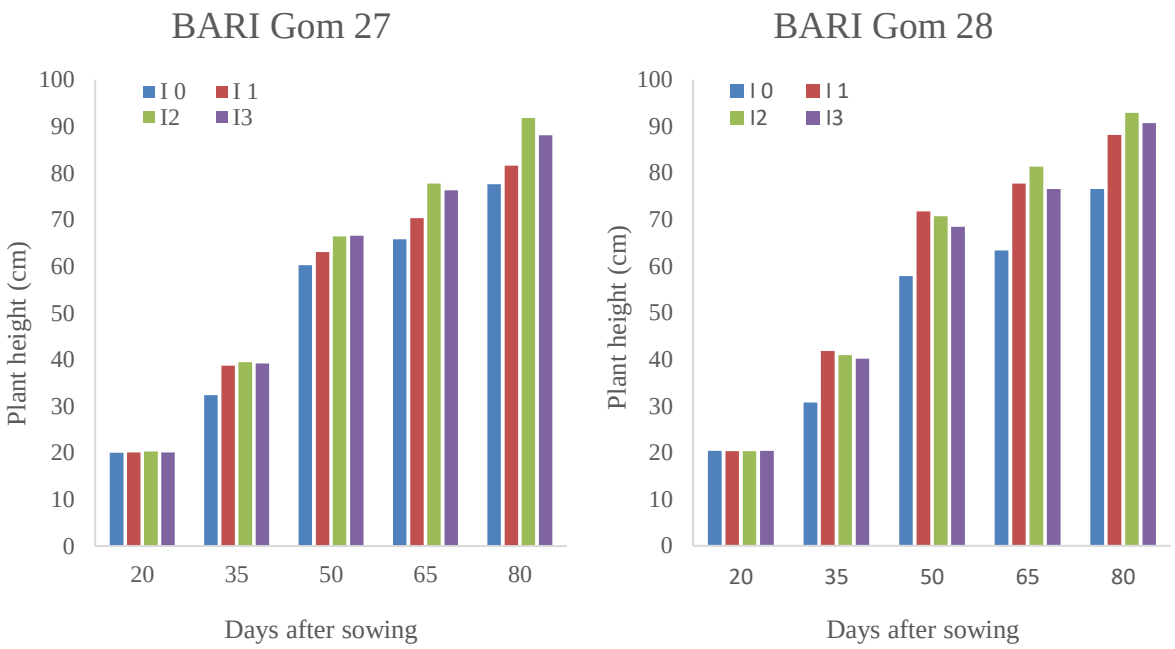
At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 4: Interaction effect of irrigation and potassium on plant height of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Interaction (irrigation x potassium)	A. Plant height (cm) (2015-2016)					B. Plant height (cm) (2016-2017)				
	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS
$I_0 K_0$	20.740 de	29.346 g	54.239 h	59.583 k	71.452 k	19.820 f	27.251 k	51.456 h	57.042 k	68.806 m
$I_0 K_1$	23.155 d	37.233 d	67.857 d	71.556 g	81.797 h	22.127 a-c	34.829 g	64.362 d	68.733 g	78.671 j
$I_0 K_2$	22.265 c	36.238 e	66.980 d	73.075 f	85.550 f	21.280 de	33.906 h	63.518 d	70.179 f	82.325 h
$I_0 K_3$	21.757 c	35.795 e	65.547 e	70.087 h	83.878 g	20.793 e	33.446 h	61.744 e	67.227 h	80.698 i
$I_1 K_0$	20.443 e	30.878 f	56.885 g	62.767 j	74.466 j	19.738 f	29.930 j	54.096 g	60.609 j	72.073 l
$I_1 K_1$	23.117 ab	43.333 a	70.156 bc	74.95 e	85.300 f	22.313 ab	42.447 bc	67.029 c	72.563 e	82.719 h
$I_1 K_2$	22.193 c	42.476 b	69.385 c	79.700 d	89.734 d	21.427 c-e	41.581 de	66.633 c	77.224 d	87.055 f
$I_1 K_3$	21.633 cd	41.523 c	67.545 d	73.363 f	87.203 e	20.885 de	40.687 f	64.508 d	71.007 f	84.587 g
$I_2 K_0$	20.513 e	31.193 f	60.1234 f	65.69 i	78.983 i	19.813 f	30.615 i	57.400 f	63.642 i	77.290 k
$I_2 K_1$	22.000 c	42.349 b	73.183 a	81.343 c	90.656 d	21.250 de	41.888 cd	70.107 a	79.556 c	88.866 e
$I_2 K_2$	23.187 a	43.367 a	73.600 a	86.123 a	99.987 a	22.392 a	42.959 ab	70.511 a	84.942 a	100.340 c
$I_2 K_3$	21.557 cd	41.548 c	71.217 b	79.457 d	93.687 c	20.822 de	41.076 ef	68.197 b	77.606 d	91.863 d
$I_3 K_0$	20.557 e	31.383 f	59.617 f	65.335 i	81.334 h	19.863 f	30.986 h	56.984 f	64.508 i	79.846 ij
$I_3 K_1$	23.335 a	43.372 a	73.345 a	80.976 c	94.560 c	22.540 a	43.140 a	70.311 a	79.867 c	92.969 d
$I_3 K_2$	22.332 bc	42.545 b	72.925 a	86.024 a	99.845 a	21.580 b-d	42.375 bc	69.922 a	84.352 a	98.888 a
$I_3 K_3$	21.758 c	41.433 c	71.245 b	82.823 b	97.302 b	21.023 de	41.204 ef	68.326 b	81.738 b	95.693 b
CV (%)	14.345	5.619	5.892	3.572	4.234	14.012	5.453	5.448	3.712	4.803

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

A



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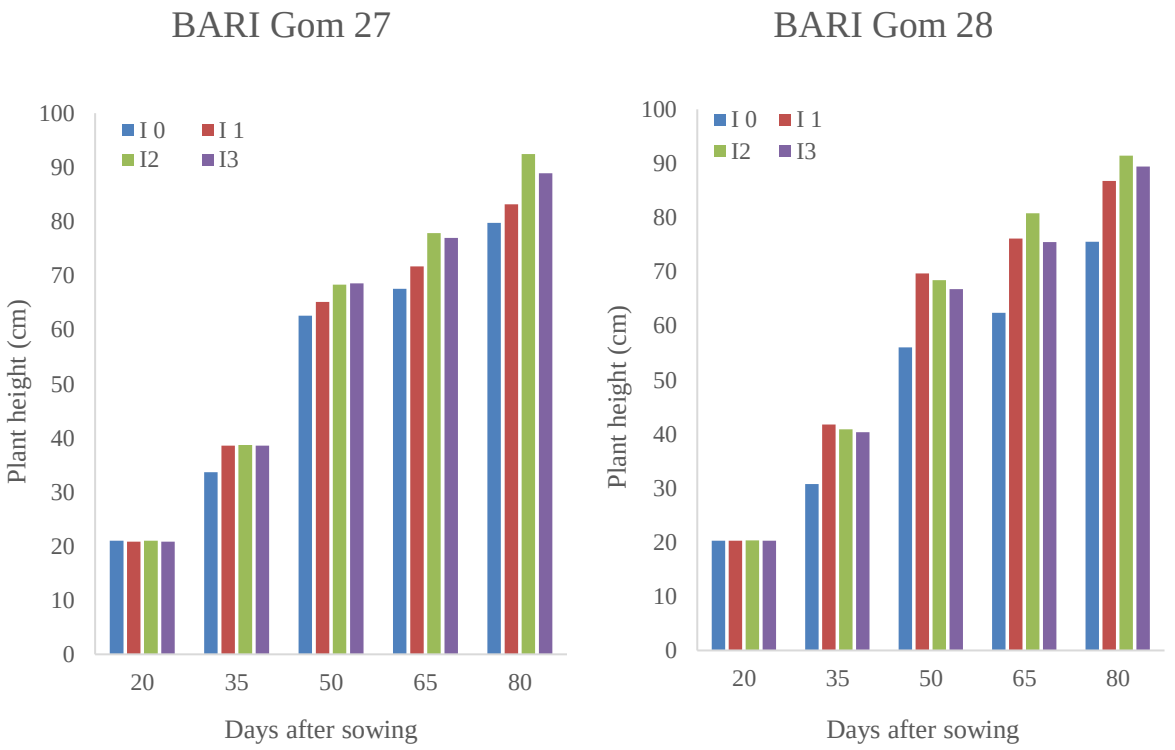
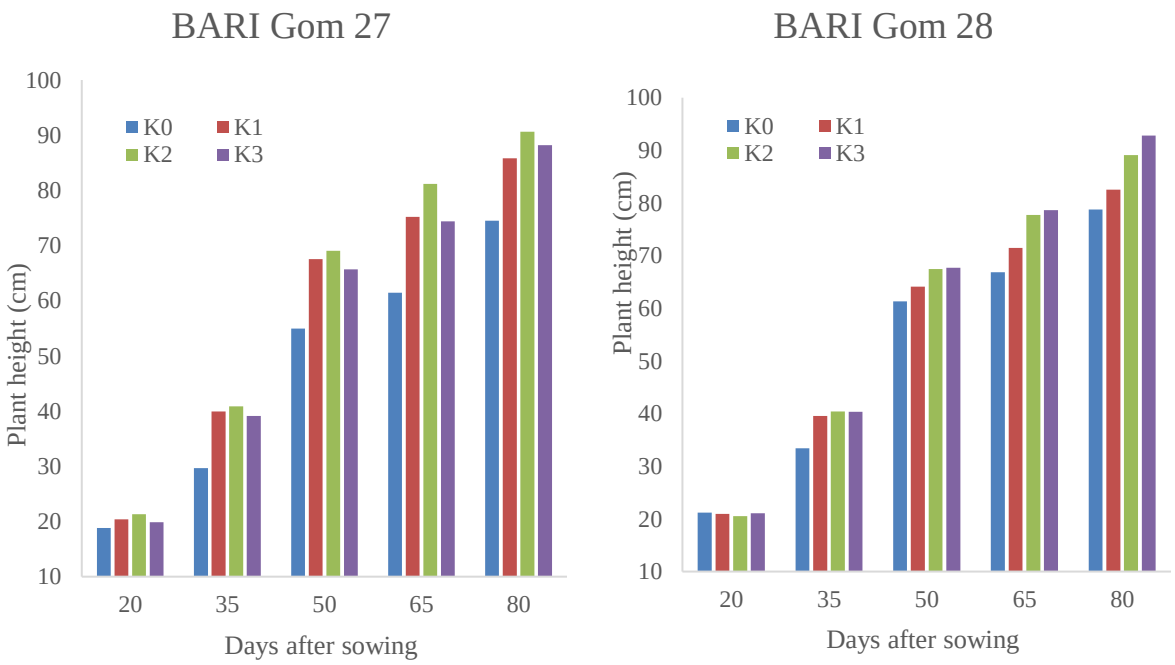


Fig. 1: Effect of irrigation on plant height at different days after sowing in 2015-2016 (A) and 2016-2017 (B)

A



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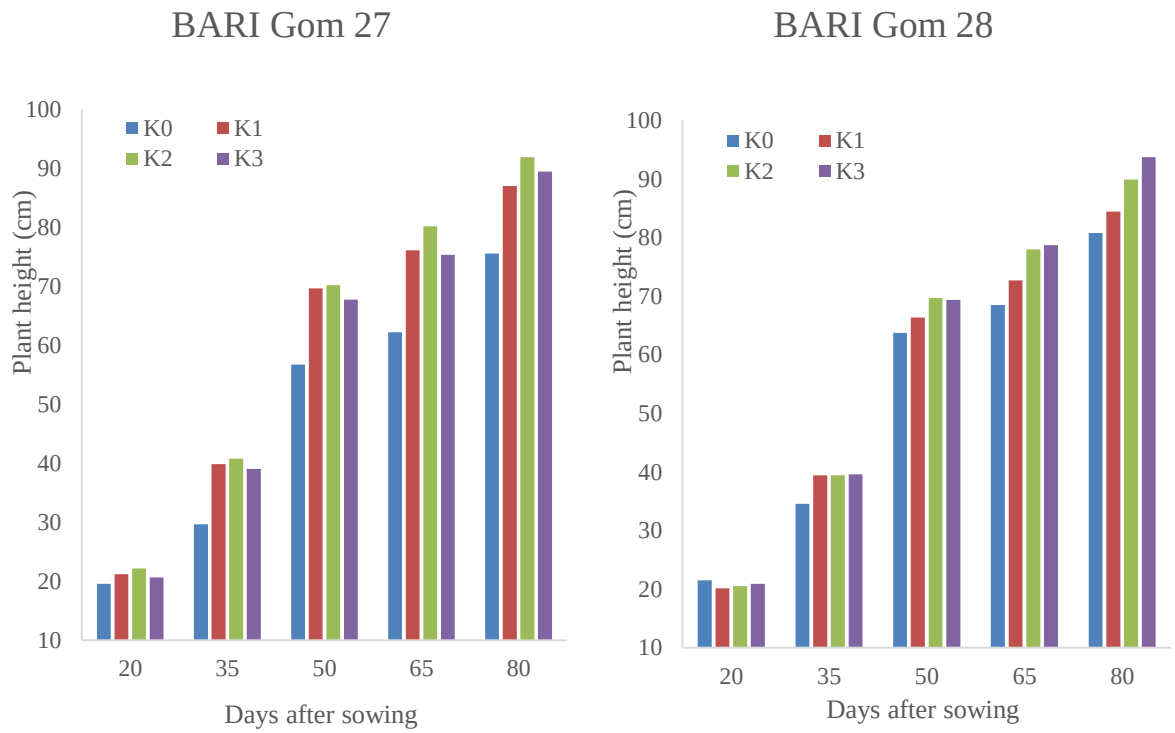


Fig. 2: Effect of potassium on plant height at different days after sowing in 2015-2016 (A) and 2016-2017 (B)

4.1.2 Number of leaf plant^{-1}

The number of leaf plant^{-1} was significantly affected by different irrigation regimes at all growth stages of wheat are presented in Table 5A and Fig. 3A for first year (2015-2016) and in Table 5B and Fig. 3B for second year (2016-2017) respectively. The result suggested significant effect of irrigation regimes on the number of leaf plant^{-1}. Irrigation treatment showed a non-significant effect on number of leaf plant^{-1} at the early stage of growth (at 20 DAS) in both the years. The number of leaf plant^{-1} was increased up to 65 DAS and then decreased till 80 DAS for both the years. Higher number of leaf plant^{-1} was recorded in I_2 treatment whereas the lower number was observed when no supplementary irrigation (I_0) was applied. Number of leaf plant^{-1} for all treatments was almost similar up to the crown root initiation stage (20 DAS), as no supplemental irrigation was applied before that stage to any treatment. However, a marked variation was observed when irrigation was imposed at different days after sowing up to 65 DAS in all treatments. At 35 DAS, the highest number of leaf plant^{-1} was recorded from I_2 treatment followed by I_3 and I_1 treatments in both the years. At 50 DAS, the maximum number of leaf plant^{-1} was found in I_2 treatment which were statistically similar to I_3 and I_1 treatments in first year and I_3 in the second year of experiment. At 65 and 80 DAS, the maximum number of leaf plant^{-1} was recorded in I_2 treatment which was statistically similar with I_3 followed by I_1 in both the growing seasons. The minimum number of leaf plant^{-1} was observed from I_0 treatment at all growing stages in both the years. Supplemental irrigation significantly increased number of leaf plant^{-1} in the presented study. This result is agreement with the findings of Hasil *et al.* (2014). In the presented study it was strongly evident that, supplemental irrigation at three growth stages reduced the effect of drought stress and thus leaf number boost up in irrigated plot over the control. These results were in line with those of Sarwar *et al.* (2010), Khan *et al.* (2001) and Thompson and Chase (1992) in wheat. Atikullah *et al.* (2014) stated that significant variation for number of leaves of wheat at different days after sowing due to different irrigation levels. This result is also similar with the findings of Islam (1997) who reported that leaf number increased with increasing number of irrigations in wheat.

Effects of variety on number of leaf plant^{-1} of wheat at different growth stages are shown in Table 6A for first year (2015-2016) and Table 6B for second year (2016-2017) respectively. Significant variation was found in regards to number of leaf plant^{-1} at all plant growth stages except 50 and 65 DAS. In case of 50 and 65 DAS, the maximum number of leaf plant^{-1} was recorded in BARI Gom 28 (V_2) in both the growing seasons.

Influence of foliar applications of potassium on number of leaf plant^{-1} at different plant growth stages are presented in Table 7A and Fig. 4A for first year (2015-2016) and Table 7B and Fig. 4B for second year (2016-2017) respectively. Significant variation was observed in number of leaf plant^{-1} with foliar applications of potassium at all growth stages except 20 DAS in both the years. At 20 DAS, the tallest plant was obtained in K_0 followed by K_3 and K_1 treatments of potassium during the two successive growing seasons. Significant variation was observed in number of leaf plant^{-1} after applying potassium treatments at 35, 50, 65 and 80 DAS in both the growing seasons. At 35, 50, 65 and 80 DAS, the maximum number of leaf plant^{-1} was recorded in K_2 (50% of the recommended rate for the variety i.e. 25 kg K ha^1 in the form of muriate of potash + Foliar spray with 1% K_2O using K_2SO_4) treatment followed by K_3 and K_1 in both the growing seasons and the lowest leaf plant^{-1} was found in K_0 treatment. This result is in agreement with the findings of Brhane *et al.* (2017), Abbas *et al.* (2013), Zareian *et al.* (2013), Aown *et al.* (2012), Tahir *et al.* (2008) and Ahmad *et al*. (2007).

The interaction effects of irrigation regimes and foliar applications of potassium on number of leaf plant^{-1} are presented in Table 8A for first year (2015-2016) and Table 8B for second year (2016-2017) respectively. The interaction effect between amount of irrigation and foliar applications of potassium was significant for the number of leaf plant^{-1} at 20, 35, 50, 65 and 80 DAS in both the years. At 20 DAS, the maximum number of leaf plant^{-1} was recoded in I_2K_2 treatment which was at par with all other treatments except I_0K_0, I_0K_1, I_2K_3 and I_3K_2 treatments during the two successive growing seasons. At 35 DAS, the highest number of leaf plant^{-1} was recorded in I_2K_2 treatment which was statistically similar with I_2K_3 and the lowest was recorded in I_0K_0 in both the years. In case of 50 and 65 DAS, the maximum number of leaf plant^{-1} was found in I_2K_2 treatment in both the years which was statistically similar with I_3K_2 and I_3K_3 treatments in the first year experiment only and the lowest leaf plant^{-1} was found in I_0K_0 treatment in both the growing seasons. At 80 DAS, the maximum number of leaf plant^{-1} was reveled in I_2K_2 treatment in both the years which was statistically similar with I_2K_3, I_3K_1, I_3K_2 and I_3K_2 treatments in the first year (2015-2016) experiment only. The minimum number of leaf plant^{-1} was recorded in I_0K_0 treatment at all growth phages in both the growing seasons.

Table 5: Effect of irrigation on number of leaf of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Irrigation	A. Number of leaf plant^{-1} (2015-2016)					B. Number of leaf plant^{-1} (2016-2017)				
	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS
I_0	3.873 a	5.654 d	7.634 b	10.67 b	10.469 b	3.661 a	5.149 d	6.444 d	9.942 b	9.369 b
I_1	3.756 a	6.808 c	8.611 ab	11.41 b	10.938 b	3.82 a	6.197 c	7.975 c	11.646 b	10.23 b
I_2	3.667 a	8.268 a	9.512 a	14.02 a	13.532 a	3.778 a	9.612 a	11.11 a	14.79 a	14.06 a
I_3	3.853 a	7.699 b	9.491 a	13.37 a	12.480 a	3.889 a	8.438 a	9.927 a	13.394 a	13.72 a
CV (%)	6.15	8.14	19.35	12.41	11.96	10.46	6.15	11.22	9.88	14.71

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 6: Effect of variety on number of leaf of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Variety	A. Number of leaf plant^{-1} (2015-2016)					B. Number of leaf plant^{-1} (2016-2017)				
	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS
V_1	3.802 a	6.956 a	8.777 b	11.956 b	11.632 a	3.84 a	7.165 a	8.572 b	12.111 b	11.56 a
V_2	3.772 a	7.258 a	8.847 a	12.780 a	12.078 a	3.734 a	7.532 a	9.156 a	12.775 a	12.13 a
CV (%)	6.15	8.14	19.35	12.41	11.96	10.46	6.15	11.22	9.88	14.71

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 7: Effect of potassium on number of leaf of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Potassium	A. Number of leaf plant^{-1} (2015-2016)					B. Number of leaf plant^{-1} (2016-2017)				
	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS
K_0	3.812 a	6.010 d	6.734 d	10.05 d	9.734 d	3.792 a	5.928 d	7.127 d	10.45 d	9.935 d
K_1	3.805 a	6.759 c	8.226 c	11.66 c	11.263 c	3.805 a	6.954 c	8.385 c	11.71 c	11.122 c
K_2	3.724 a	8.147 a	10.68 a	14.73 a	13.854 a	3.746 a	8.645 a	10.71 a	14.56 a	13.89 a
K_3	3.805 a	7.512 b	9.609 b	13.03 b	12.569 b	3.805 a	7.869 b	9.233 b	13.05 b	12.433 b
CV (%)	6.15	8.14	19.35	12.41	11.96	10.46	6.15	11.22	9.88	14.71

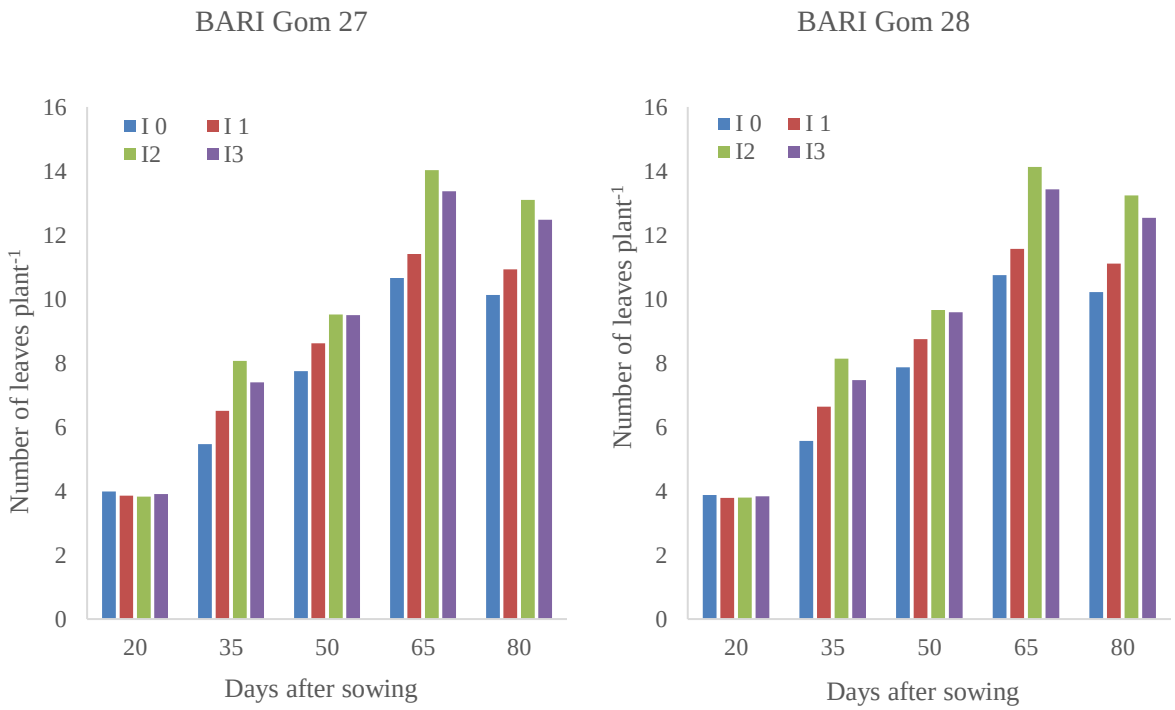
At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 8: Interaction effect of irrigation and potassium on number of leaf of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Interaction (irrigation x potassium)	A. Number of leaf plant^{-1} (2015-2016)					B. Number of leaf plant^{-1} (2016-2017)				
	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS
$I_0 K_0$	3.165 d	4.398 i	5.983 j	7.688 j	7.372 i	3.165 d	4.762 g	5.452 k	7.997 j	7.570 j
$I_0 K_1$	3.610 bcd	4.827 hi	7.647 gh	10.17 hi	9.755 gh	3.610 bcd	5.177 fg	5.860 jk	9.232 ij	8.830 i
$I_0 K_2$	3.983 abc	6.507 efg	9.113 de	13.46 cde	12.65 bcd	3.983 abc	6.162 ef	7.792 fgh	11.89 efg	11.17 fgh
$I_0 K_3$	3.885 abc	6.137 fg	8.247 efg	11.32 fgh	10.73 efg	3.885 abc	5.695 efg	6.672 hij	10.66 ghi	9.990 hi
$I_1 K_0$	3.835 abc	5.733 gh	6.513 ij	9.153 ij	8.805 hi	3.835 abc	5.337 fg	6.425 ijk	9.592 hij	9.252 i
$I_1 K_1$	4.110 ab	6.465 efg	7.825 fgh	10.44 ghi	9.922 fgh	4.110 ab	6.118 ef	7.387 ghi	11.27 fgh	10.76 gh
$I_1 K_2$	3.555 cd	7.227 de	10.21 b	14.17 bcd	13.54 abc	3.555 cd	7.857 bcd	9.988 d	14.20 bcd	13.60 bcd
$I_1 K_3$	3.778 abc	6.580 efg	9.413 cd	11.89 efg	11.45 def	3.778 abc	6.678 de	8.098 fg	11.92 efg	11.22 fgh
$I_2 K_0$	3.943 abc	7.665 cd	8.097 fgh	12.26 ef	11.60 de	3.943 abc	7.650 cd	8.760 ef	13.12 cde	12.40 def
$I_2 K_1$	3.777 abc	8.780 b	8.663 def	13.33 cde	12.44 bcd	3.777 abc	8.923 b	10.70 cd	13.80 bcd	13.03 cde
$I_2 K_2$	3.835 abc	10.17 a	11.15 a	15.89 a	14.92 a	3.835 abc	11.50 a	13.20 a	17.10 a	16.14 a
$I_2 K_3$	3.557 bcd	9.635 ab	10.14 bc	14.63 abc	13.44 abc	3.557 bcd	10.77 a	11.78 bc	15.15 b	14.67 b
$I_3 K_0$	4.223 a	6.245 efg	7.197 hi	11.11 fgh	11.99 cde	4.223 a	5.953 efg	7.870 fg	11.11 fgh	10.52 h
$I_3 K_1$	3.723 abc	6.960 def	8.770 def	12.71 def	14.11 ab	3.723 abc	7.598 cd	9.587 de	12.54 def	11.87 efg
$I_3 K_2$	3.610 bcd	8.682 bc	11.36 a	15.40 ab	13.48 abc	3.610 bcd	9.063 b	11.87 b	15.04 b	14.68 b
$I_3 K_3$	4.000 abc	7.708 cd	10.67 ab	14.27 abcd	13.48 abc	4.000 abc	8.338 bc	10.38 d	14.46 bc	13.82 bc
CV (%)	6.15	8.14	19.35	12.41	11.96	10.46	6.15	11.22	9.88	14.71

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

A



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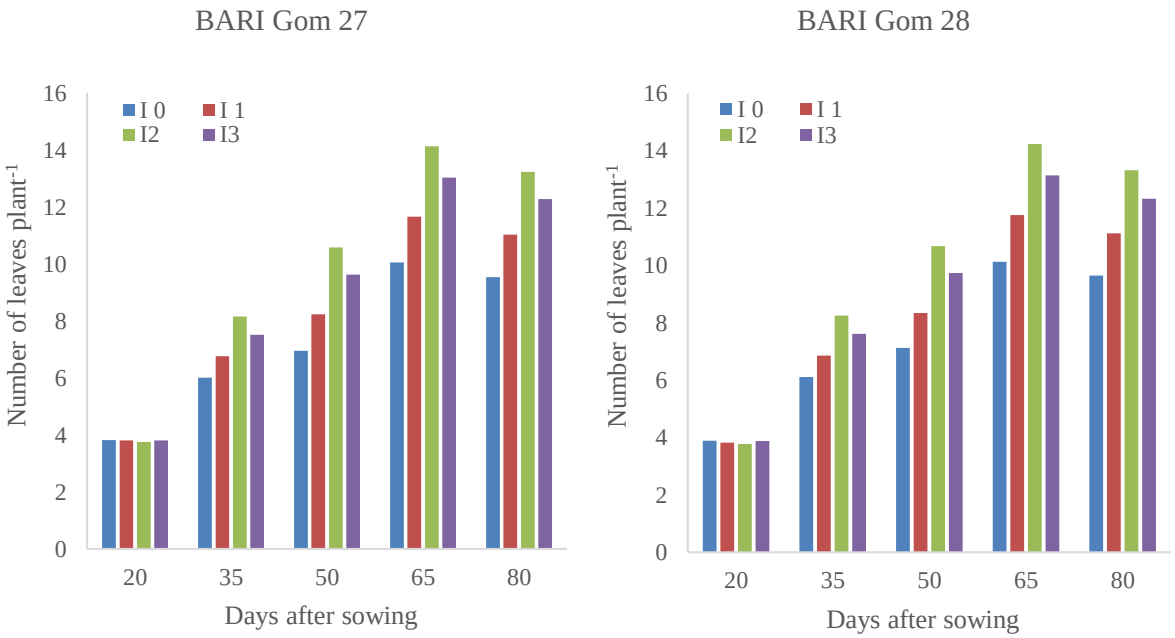
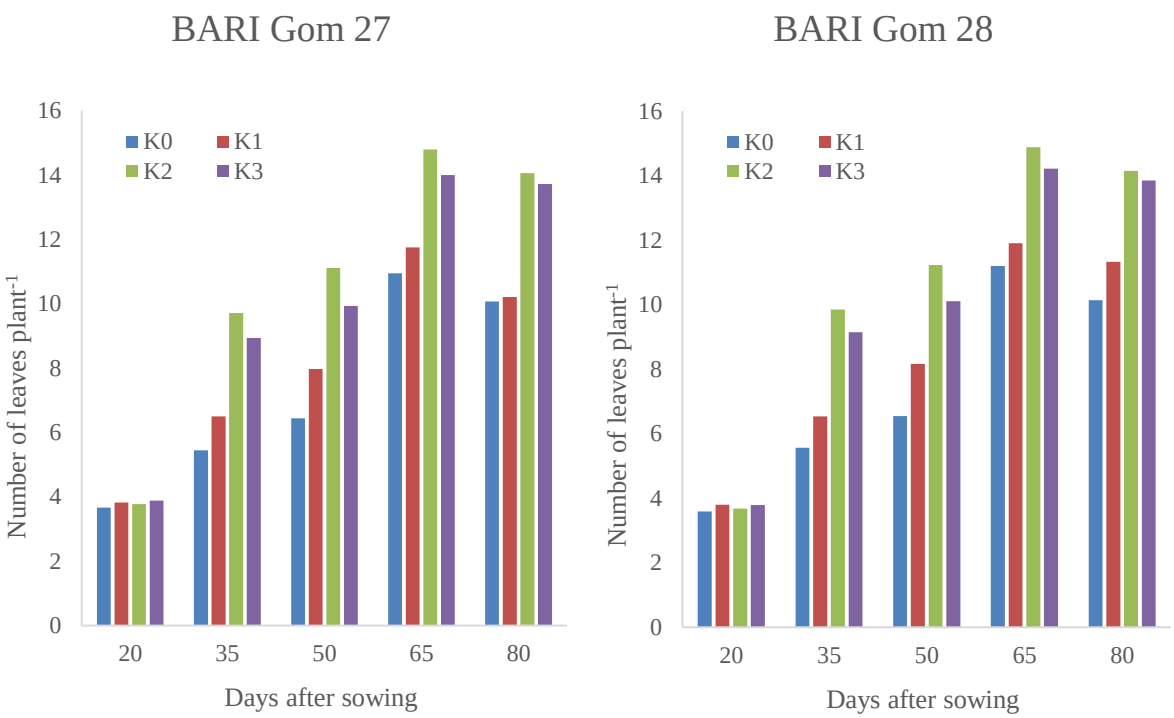


Fig. 3: Effect of irrigation on number of leaf plant^{-1} at different days after sowing in 2015-2016 (A) and 2016-2017 (B)

A



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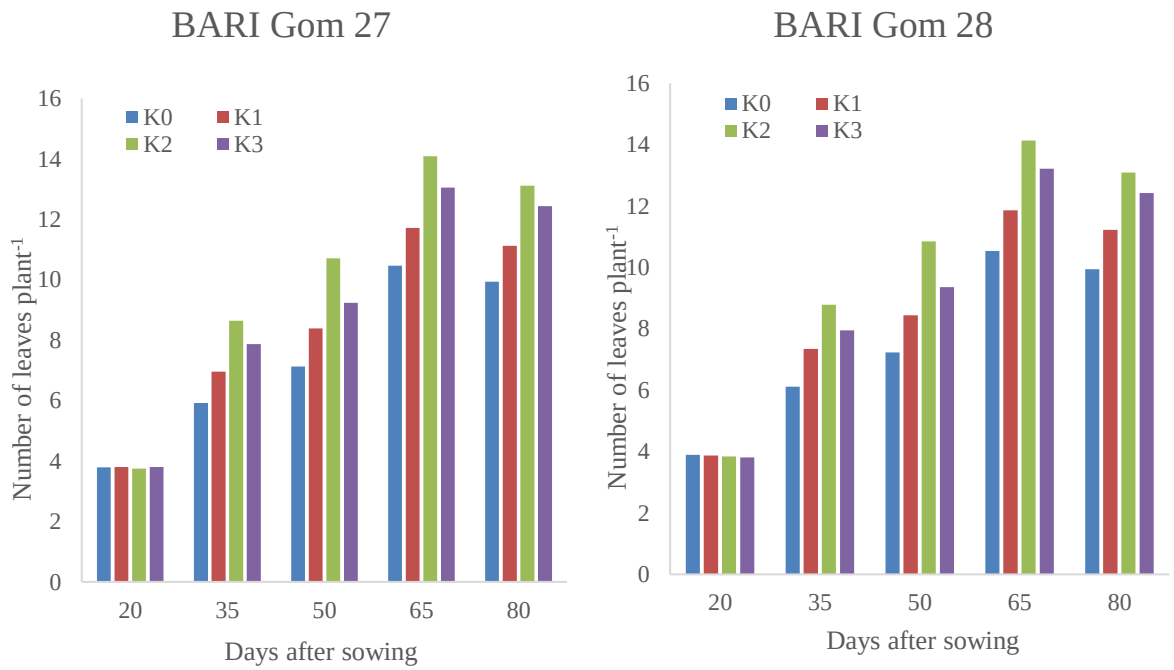


Fig. 4: Effect of potassium on number of leaf plant^{-1} at different days after sowing in 2015-2016 (A) and 2016-2017 (B)

4.1.3 Number of tillers plant^{-1}

The number of tillers plant^{-1} of wheat varieties was significantly influenced by different amount of irrigations are shown in Table 9A and Fig. 5A for first year (2015-2016) and Table 9B and Fig. 5B for second year (2016-2017) respectively. The results indicated that the number of tillers plant^{-1} of wheat were significant due to different irrigation treatments at all the growth stages except at 20 DAS in both the growing seasons. At 35 DAS, the highest tillers plant^{-1} was observed in I_3 and I_2 treatments which was statistically similar with I_1 and the lowest tillers plant^{-1} was found in I_1 treatment in both the growing seasons. At 50 DAS, the highest tillers plant^{-1} was observed in I_2 treatment which was statistically similar with I_3 and I_1 treatments during the two successive growing seasons and the lowest tillers plant^{-1} was found was observed in I_0 treatment in the two successive growing seasons. At 65 and 80 DAS, the highest tillers plant^{-1} was recorded in I_3 treatment which was statistically similar with I_2 treatment followed by I_1 in both the years. The lowest tillers plant^{-1} was found in I_0 condition except at 20 DAS in both the growing seasons in every stages of plant growth. This results is in agreement with other researchers. Sana Ullah Baloch *et al.* (2014) reported that there was straight effect of irrigation schedules on the number of tillers plant^{-1}. Shirazi *et al.* (2014) stated that number of tillers plant^{-1} was significantly increased due to application of irrigation water. Atikullah *et al.* (2014) stated that number of tillers of wheat showed major variation at different DAS due to different irrigation levels. Maximum number of tillers was found in I_1 (irrigation at CRI stage) while the minimum number of tillers observed in I_0 (no irrigation). Naeem *at al.* (2010) reported that plants irrigated with five times resulted in maximum no. of tillers m^{-2} as compared to all other treatments might be due to the sufficient availability of water at tillering stage with more uptakes of nutrients.

Influence of varieties on tillers plant^{-1} at different growth stages are shown in Table 10A for first year (2015-2016) and Table 10B for second year (2016-2017) respectively. The effect of variety on number of tillers plant^{-1} was not statistically significant at 20, 35 and 50 DAS in both the years. Significant variation for tillers plant^{-1}of wheat at 65 and 80 DAS was observed due to variety. Between the two varieties, the higher tillers plant^{-1} was recorded in BARI Gom 28 and the lower number of tillers plant^{-1} was recorded in BARI Gom 27 in both the years. Tillers plant^{-1} increased up to 65 DAS and thereafter declined.

The summery data of tillers plant^{-1} at different growth stages as significantly affected by foliar application of potassium have been presented in Table 11A and Fig. 6A for first year (2015-2016) and Table 11B and Fig. 6B for second year (2016-2017) respectively. In general, the tiller production plant^{-1} increased up to 65 days after sowing and thereafter it decline due to mortality of younger tillers irrespective of the treatment. Significant variation was observed in case of tillers plant^{-1} with foliar spraying of potassium in both the growing seasons. At the early stage of wheat plant (at 20 and 35 DAS), the data reveled that there was no significant variation on number of tillers plant^{-1} in both the growing seasons except K_0 at 35 DAS in both the growing seasons. This is due to availability of potassium in all treatments resulting similar tiller plant^{-1} in both the growing period. At 50, 65 and 80 DAS, the maximum tillers plant^{-1} were observed in K_2 treatments of potassium which was statistically similar with K_3 followed by K_1 treatment of potassium in both the growing seasons. The lowest tillers plant^{-1} was recorded in K_0 at all growing phases of wheat plant in both the years. Similar results were reported by Aown *et al*. (2012) in wheat. This results also supported the findings of Hasina *et al.* (2011) and Amal *et al.* (2011).

The interaction effect between amount of irrigation and foliar application of potassium was significant for the tillers plant^{-1} at 20, 35, 50, 65 and 80 DAS in both the years are presented in Table 12A for first year (2015-2016) and Table 12B for second year (2016-2017) respectively. At 20 and 35 DAS, the maximum tillers plant^{-1} were observed in I_2K_2 treatment of irrigation and potassium which was statistically similar with I_3K_1 and I_1K_1 treatments in both the growing seasons. At 50 DAS, the highest number of tillers plant^{-1} were observed in I_3K_2 treatment which was at par with I_2K_2 in both the growing years. At 65 and 80 DAS, the superior tillers plant^{-1} was produced in treatment of I_2K_2 which was statistically similar with I_3K_1, I_3K_2, I_3K_3 and I_2K_1 treatments in both the growing seasons. The minimum number of tillers plant^{-1} were found in treatment of I_0K_0 at 35, 50, 65 and 80 DAS during the two successive growing seasons.
In all cases, lower tiller number was recored at 80 DAS than 65 DAS. Lowering of tiller number at 80 DAS compare to 65 DAS was due to senescence of later tiller (Asaf *et al*. 2014 and Anonymous. 2018).

Table 9: Effect of irrigation on number of tillers of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Irrigation	A. Number of total tillers plant^{-1} (2015-2016)					B. Number of total tillers plant^{-1} (2016-2017)				
	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS
I_0	1.049 a	1.512 b	1.731	2.392 c	2.10 c	1.044 a	0.986 b	2.163 b	2.317 c	2.033 c
I_1	0.916 a	1.825 a	2.502	2.983 bc	2.675 bc	0.897 a	1.842 a	2.609 ab	2.917 bc	2.608 bc
I_2	1.034 a	1.842 a	3.021	3.698 ab	3.233 ab	1.031 a	1.958 a	3.118 a	3.508 ab	3.167 ab
I_3	1.009 a	1.842 a	3.621	3.932 a	3.733 a	1.048 a	1.858 a	2.711 a	3.74 a	3.667 a
CV (%)	14.784	9.239	4.541	6.390	7.567	17.737	8.643	5.123	6.456	7.428

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 10: Effect of variety on number of tillers of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Variety	A. Number of total tillers plant^{-1} (2015-2016)					B. Number of total tillers plant^{-1} (2016-2017)				
	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS
V_1	0.922 a	1.811 a	2.763 a	3.703 a	2.752 a	1.02 a	1.775 a	2.674 a	3.578 a	2.924 a
V_2	1.081 a	1.699 a	2.6746 a	2.799 b	3.118 b	0.99 a	1.546 a	2.625 a	2.664 b	2.813 b
CV (%)	14.784	9.239	4.541	6.390	7.567	17.737	8.643	5.123	6.456	7.428

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 11: Effect of potassium on number of tillers of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Potassium	A. Number of total tillers plant^{-1} (2015-2016)					B. Number of total tillers plant^{-1} (2016-2017)				
	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS
K_0	1.012 a	1.498 b	1.547 c	1.738 c	1.475 c	1.011 a	1.554 b	1.442 c	1.667 c	1.408 c
K_1	1.019 a	1.862 a	2.673 b	3.462 b	3.153 b	0.904 a	1.674 a	2.767 b	3.258 b	3.083 b
K_2	0.967 a	1.809 a	3.436 a	4.128 a	3.751 a	1.082 a	1.801 a	3.342 a	4.042 a	3.683 a
K_3	1.011 a	1.852 a	3.22 ab	3.675 ab	3.362 ab	1.022 a	1.616 a	3.05 ab	3.517 ab	3.3 ab
CV (%)	14.784	9.239	4.541	6.390	7.567	17.737	8.643	5.123	6.456	7.428

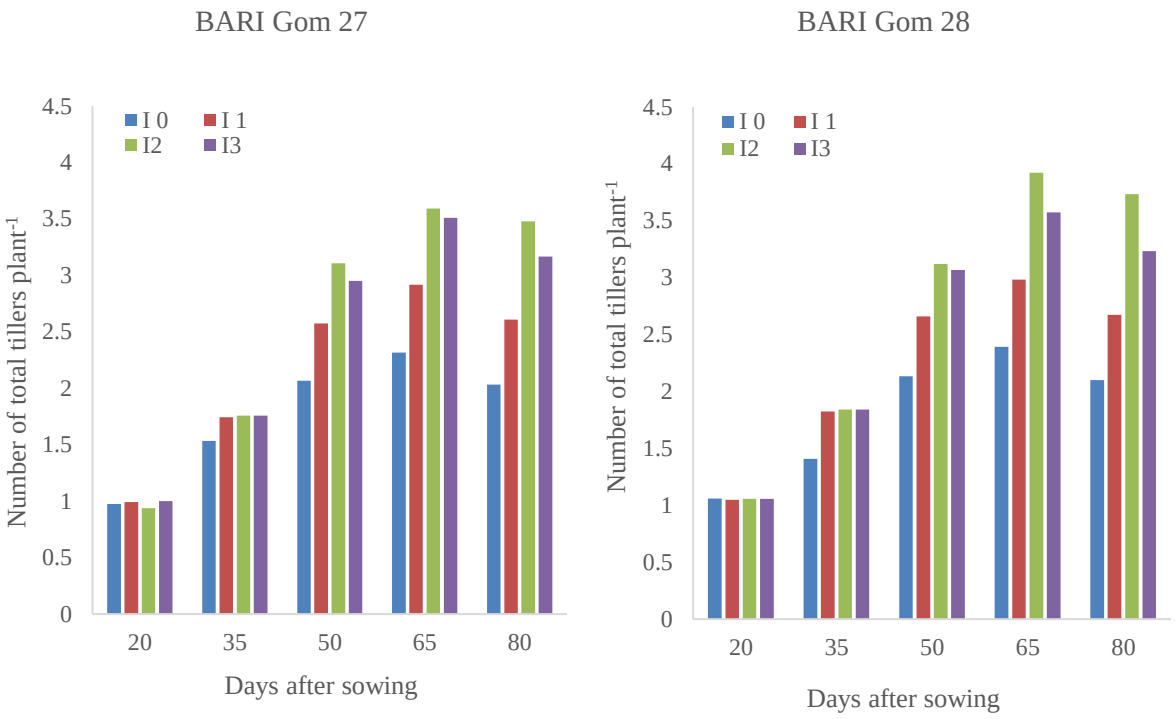
At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 12: Interaction effect of irrigation and potassium on number of tillers of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Interaction (Irrigation × Potassium)	A. Number of total tillers plant^{-1} (2015-2016)					B. Number of total tillers plant^{-1} (2016-2017)				
	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS
$I_0 K_0$	0.233 d	0.333 f	1.167 h	1.433 h	1.200 i	0.267 d	0.267 d	1.100 f	1.333 h	1.133 i
$I_0 K_1$	1.165 b	2.251 b	2.433 de	2.667 d-h	2.433 d-i	1.163 b	1.941 b	2.367 de	2.600 d-h	2.367 d-i
$I_0 K_2$	1.167 b	2.000 cd	2.700 d	2.967 c-g	2.600 d-h	1.167 b	1.933 b	2.633 d	2.900 c-g	2.533 d-h
$I_0 K_3$	0.767 c	1.467 e	2.233 e	2.500 e-h	2.167 e-i	0.767 c	1.400 c	2.167 e	2.433 e-h	2.100 e-i
$I_1 K_0$	0.300 d	0.533 f	1.367 gh	1.733 gh	1.433 hi	0.267 d	0.467 d	1.267 f	1.667 gh	1.367 hi
$I_1 K_1$	1.767 a	2.900 a	3.167 c	3.400 b-e	3.067 b-f	1.700 a	2.833 a	3.100 c	3.333 b-e	3.000 b-f
$I_1 K_2$	1.333 b	2.200 c	3.333 c	3.700 b-e	3.400 b-e	1.233 b	2.133 b	3.267 c	3.633 b-e	3.333 b-e
$I_1 K_3$	0.833 c	1.667 de	2.733 d	3.100 c-f	2.800 c-g	0.767 c	1.533 c	2.667 d	3.033 c-f	2.733 c-g
$I_2 K_0$	0.267 d	0.533 f	1.733 fg	1.767 gh	1.533 g-i	0.267 d	0.467 d	1.667 e	1.700 gh	1.467 g-i
$I_2 K_1$	1.300 b	2.267 bc	3.433 bc	4.100 a-c	3.700 a-d	1.200 b	2.167 b	3.367 bc	4.033 a-c	3.633 a-d
$I_2 K_2$	1.867 a	2.934 a	3.733 ab	5.200 a	4.800 a	1.733 a	2.833 a	3.667 ab	4.133 a	4.733 a
$I_2 K_3$	0.833 c	1.667 de	3.167 c	3.867 b-d	3.500 a-e	0.767 c	1.567 c	3.100 c	3.800 b-d	3.433 a-e
$I_3 K_0$	0.233 d	0.533 f	1.800 f	2.033 f-h	1.733 f-i	0.233 d	0.467 d	1.733 e	1.967f-h	1.667 f-i
$I_3 K_1$	1.833 a	2.901 a	3.433 bc	4.567 ab	4.267 ab	1.767 a	2.833 a	3.367 bc	4.500 ab	4.200 ab
$I_3 K_2$	1.300 b	2.233 c	3.867 a	4.555 ab	4.200 ab	1.200 b	2.167 b	3.800 a	4.500 ab	4.133 ab
$I_3 K_3$	0.833 c	1.667 de	3.200 c	4.433 ab	4.133 a-c	1.583 cd	1.567 c	3.133 c	4.367 ab	4.067 a-c
CV (%)	14.784	9.239	4.541	6.390	7.567	17.737	8.643	5.123	6.456	7.428

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

A



B

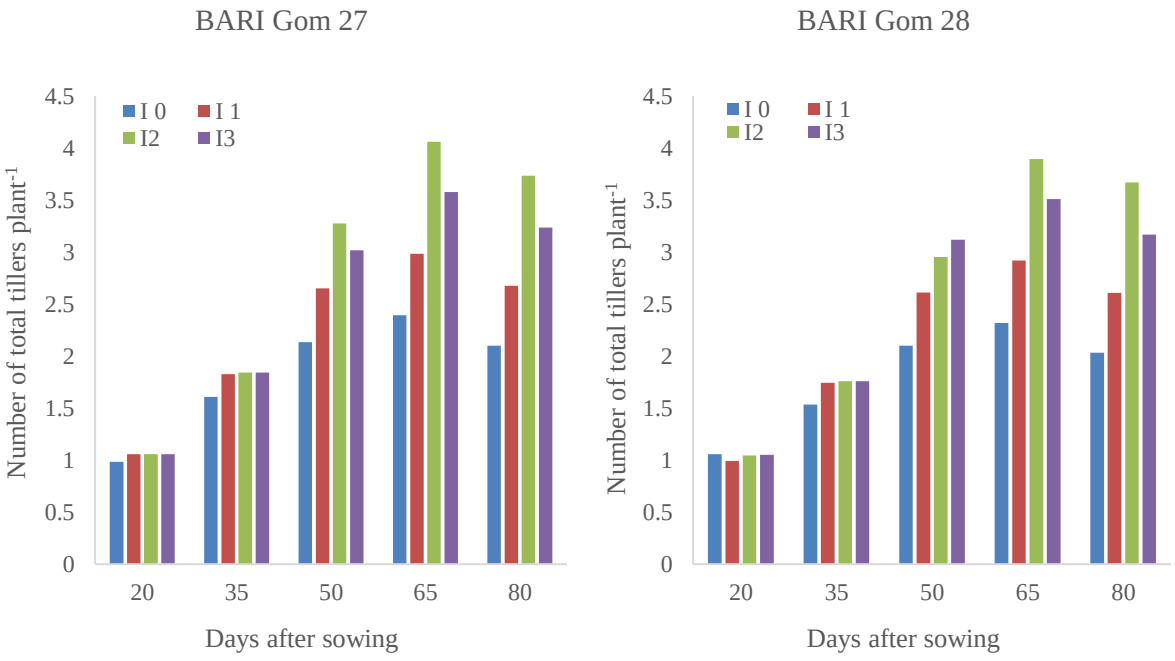
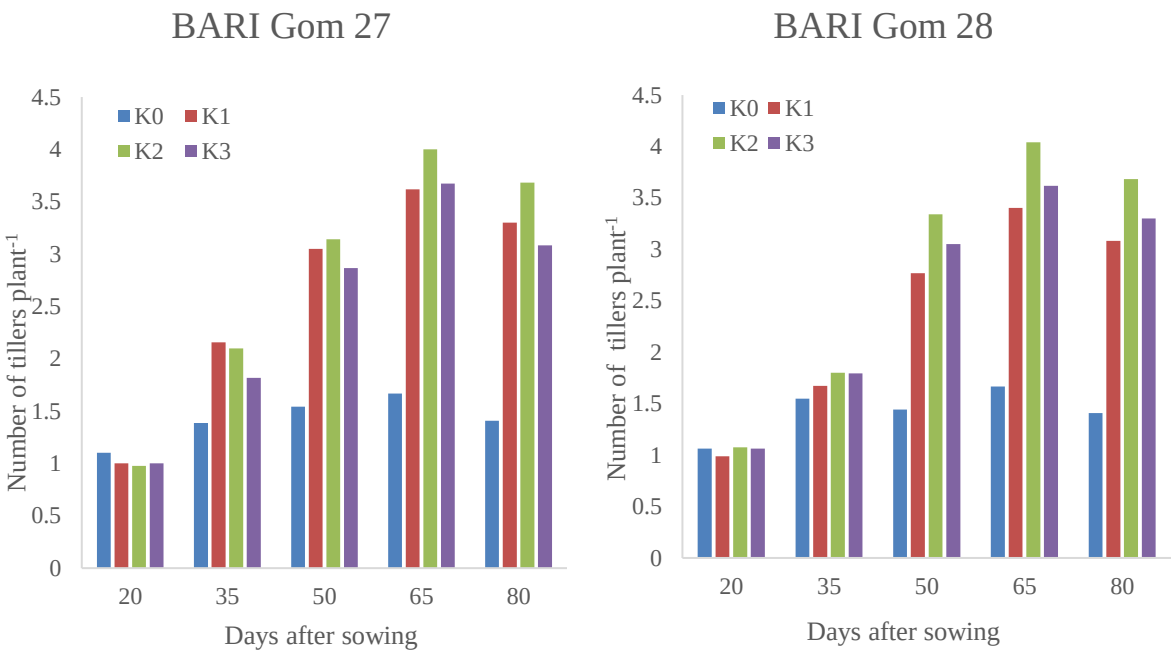


Fig. 5: Effect of irrigation on number of tillers at different days after sowing in 2015-2016 (A) and 2016-2017 (B)

A



B

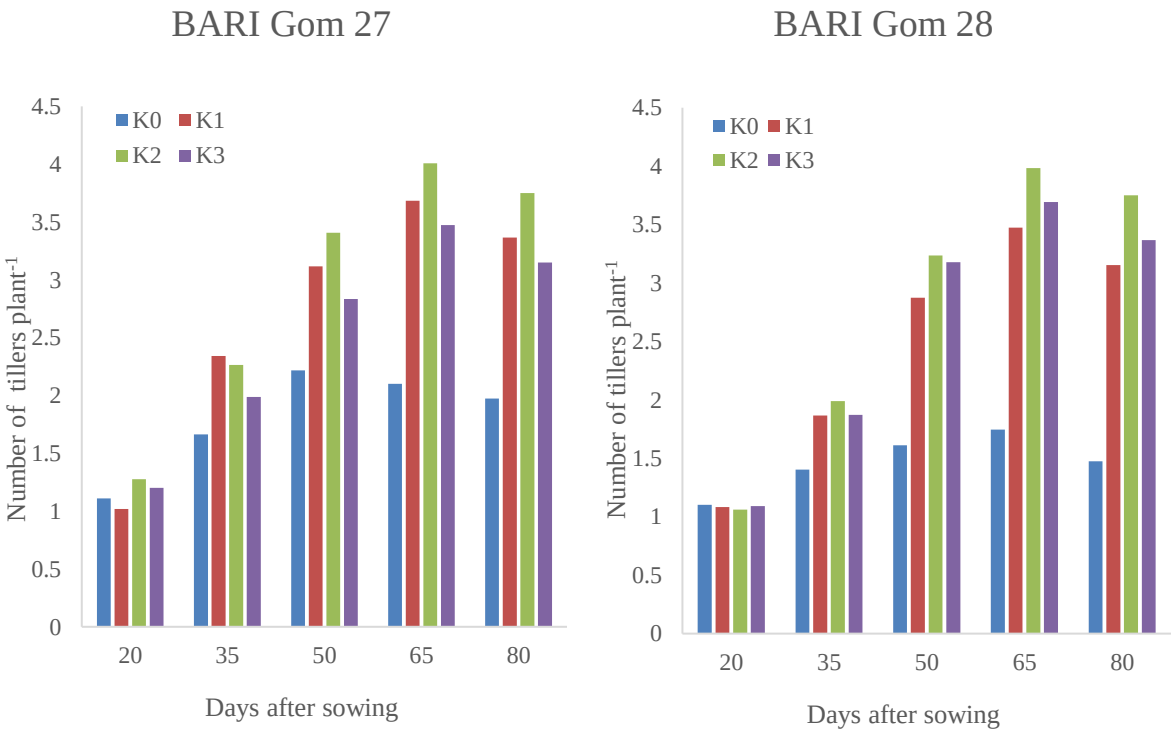


Fig. 6: Effect of potassium on number of tillers at different days after sowing in 2015-2016 (A) and 2016-2017 (B)

4.2 Growth Parameters

4.2.1 Total dry matter

Significant variation was observed on total dry matter m^{-2} of wheat due to different irrigation regimes at all the growth durations in both growing seasons are presented in Table 13A and Fig. 7A for first year (2015-2016) and Table 13B and Fig. 7B for second year (2016-2017) respectively. It is evident from data that dry matter production increased as the growth progressed, values being maximum at harvest, nevertheless, remained slower in first 30 days stages but they increased markedly thereafter. Total dry matter m^{-2} was increased with the increasing number of irrigations. Total dry matter m^{-2} increased steadily until 35 DAS and then increased sharply with the advancement of growth period in both the years. At 20 DAS, the highest total dry matter m^{-2} was recorded in I_2 treatment which was at par with I_1 and I_3 treatments in both the years. At 35 DAS, the highest total dry matter m^{-2} was found in I_1 treatment which was statistically identical with I_2 and I_3 treatments in both the growing seasons. At 50 DAS, the highest total dry matter m^{-2} was found in I_2 treatment which was statistically similar with I_1 followed by I_3 treatment in first (2015-2016) and second (2016-2017) year experiments. At 65 and 80 DAS, the highest total dry matter m^{-2} was found in I_2 treatment which was statistically similar with I_3 followed by I_1 treatment in both the growing seasons. The lowest total dry matter m^{-2} was observed in I_0 condition of all the growing periods in both the years. The cause of rapid increased in TDM at the later stages of growth was possibly due to the development of considerable number of late tillers (Talukder, 1987). Pal and Upasani (2007) observed that four irrigations produced highest TDM than other irrigation treatments. Abdorrahmani *et al.* (2005) reported that two irrigations produced highest TDM and moisture stress reduced TDM production. Ashok and Sharma (2004) observed that the irrigation treatments increased TDM. Similar result was reported in wheat by many workers (Nahar and Paul 1998, Rahman *et al.*, 2001, Shen *et al.,* 2001 and Mollah and Paul 2011.

Influence of varieties on total dry matter at different growth stages are shown in Table 14A for first year (2015-2016) and Table 14B for second year (2016-2017) respectively. The effect of variety significantly influenced the total dry matter m^{-2} at 20 and 35 DAS in both the growing seasons. At 50, 65 and 80 DAS, the effect of variety on total dry matter m^{-2} was not statistically significant. Between the two varieties, BARI Gom 28 produced higher total dry matter m^{-2} than BARI Gom 27 (V_1) of all growing periods in both the years.

There was statistically significant effect for potassium packages on total dry matter m^{-2} at 20, 35, 50, 65 and 80 DAS in both the years are presented in Table 15A and Fig. 8A for first year

(2015-2016) and Table 15B and Fig. 8B for second year (2016-2017) respectively. At 20 and 35 DAS, the highest total dry matter m^{-2} was recorded in K_2 (50% of the recommended rate of K for the variety i.e. 25 kg K ha^{-1} in the form of muriate of potash + Foliar spray with 1% K_2O using K_2SO_4 treatment which was statistically identical to K_3 and K_1 treatments in both the growing seasons. At 50, 65 and 80 DAS, the highest total dry matter m^{-2} was produced in K_2 treatment which was statistically similar with K_3 followed by K_1 in both the years. The lowest values were observed in K_0 of all growing periods in both the growing seasons. Increase in TDM may be due to role of potassium which stimulates biological process in the plant such as enzyme activity, respiration, photosynthesis, chlorophyll and production of carbohydrates. Similar results were obtained by Desoky *et al*. (2017) who reported that potassium can counteract the adverse effect of drought stress on growth characters (shoot dry weight, leaf area and plant height) as well as yield and its components (dry weight of grains/plant, number of spikes/plant, number of grains/plant, number of grains/spike, and 1000-grains weight) of wheat plants (Hussain *et al.*, 2008). Adequate amounts of K can enhance the total dry mass accumulation of crop plants under drought stress in comparison to lower K concentrations (Egilla *et al*. 2001). These findings is also corroborated with Hasina *et al.* (2011) and Mesbah (2009). Amal *et al.* (2011) showed a significant increase in growth characters at 65, 90 and 115 DAS and also yield components due to increasing potassium levels. Lindhauer (1989) reported that fine K nutrition not only increased plant total dry mass and leaf area, but also improved the water retention in plant tissues under drought stress.

The interaction effect between number of irrigation and foliar applications of potassium were significant for total dry matter m^{-2} at all the growing periods in both the years are showed in Table 16A for first year (2015-2016) and Table 16B for second year (2016-2017) respectively. At 20 DAS, the highest TDM was recorded in the treatment I_2K_1 which was statistically identical with I_2K_2, I_3K_1, I_3K_2, I_3K_3, I_1K_1, I_1K_2 and I_1K_3 in the first year (2015-2016) and with I_1K_1, I_2K_2, I_3K_2, I_1K_2, I_2K_3, I_0, I_3K_3 and I_1K_3 in the second year of experiment (2016-2017). At 35 DAS, the highest TDM was recorded in treatment I_3K_1 which was statistically identical with I_3K_2, I_2K_1, I_2K_2, I_2K_3, I_3K_3, I_1K_2 and I_1K_3 in both the growing seasons. At 50 DAS, the highest TDM was recorded in treatment I_3K_2 which was statistically identical with I_3K_1 in the first year (2015-2016) but I_3K_1 and I_2K_2 in the second year of experiment (2016-2017). At 65 and 80 DAS he highest TDM was recorded in treatment I_3K_2. At 20, 35, 50, 65 and 80 DAS the lowest TDM were recorded in I_0K_0 in both the crop growing seasons.

Table 13: Effect of irrigation on total dry matter m^{-2} of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Irrigation	A. Total dry matter m^{-2} ($g\ m^{-2}$) (2015-2016)					B. Total dry matter m^{-2} ($g\ m^{-2}$) (2016-2017)				
	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS
I_0	31.175 b	115.508 b	336.340 c	718.871 c	887.547 c	32.542 b	118.825 b	368.894 c	721.7885 c	890.274 c
I_1	40.238 a	168.234 a	468.208 ab	947.982 b	1234.307 b	41.921 a	170.654 a	497.253 ab	1025.652 b	1281.162 b
I_2	41.329 a	163.548 a	483.124 a	1083.352 a	1359.761 a	40.542 a	166.884 a	511.691 a	1082.223 a	1372.639 a
I_3	37.893 a	157.341 a	441.483 b	994.432 ab	1307.897 ab	39.778 a	159.712 a	476.361 b	1041.007 ab	1316.401 ab
CV (%)	6.736	16.476	7.3370	3.457	2.972	6.458	16.348	6.127	3.479	2.908

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 14: Effect of variety on total dry matter m^{-2} of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Variety	A. Total dry matter m^{-2} ($g\ m^{-2}$) (2015-2016)					B. Total dry matter m^{-2} ($g\ m^{-2}$) (2016-2017)				
	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS
V_1	34.742 b	142.468 b	416.209 a	926.806 a	1180.222 a	35.791 b	144.572 b	454.22 a	958.203 a	1209.867 a
V_2	40.576 a	159.848 a	448.369 a	945.511 a	1214.534 a	41.601 a	163.465 a	472.88 a	977.133 a	1220.371 a
CV (%)	6.736	16.476	7.3370	3.457	2.972	6.458	16.348	6.127	3.479	2.908

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 15: Effect of potassium on total dry matter m^{-2} of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Potassium	A. Total dry matter m^{-2} ($g\ m^{-2}$) (2015-2016)					B. Total dry matter m^{-2} ($g\ m^{-2}$) (2016-2017)				
	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS
K_0	33.459 b	127.151 b	375.609 c	884.331 c	1036.359 c	34.762 b	128.443 c	402.241 c	840.754 c	1045.023 c
K_1	38.389 a	153.135 a	414.772 bc	941.443 bc	1149.878 bc	38.788 a	153.458 b	447.254 b	933.988 bc	1162.876 bc
K_2	40.28 a	166.255 a	483.674 a	981.129 a	1347.604 a	41.548 a	172.562 a	522.753 a	1082.734 a	1373.442 a
K_3	38.507 a	158.092 a	455.101 ab	937.733 ab	1255.672 ab	39.687 a	161.611 ab	481.951 ab	1013.194 ab	1279.134 ab
CV (%)	6.736	16.476	7.3370	3.457	2.972	6.458	16.348	6.127	3.479	2.908

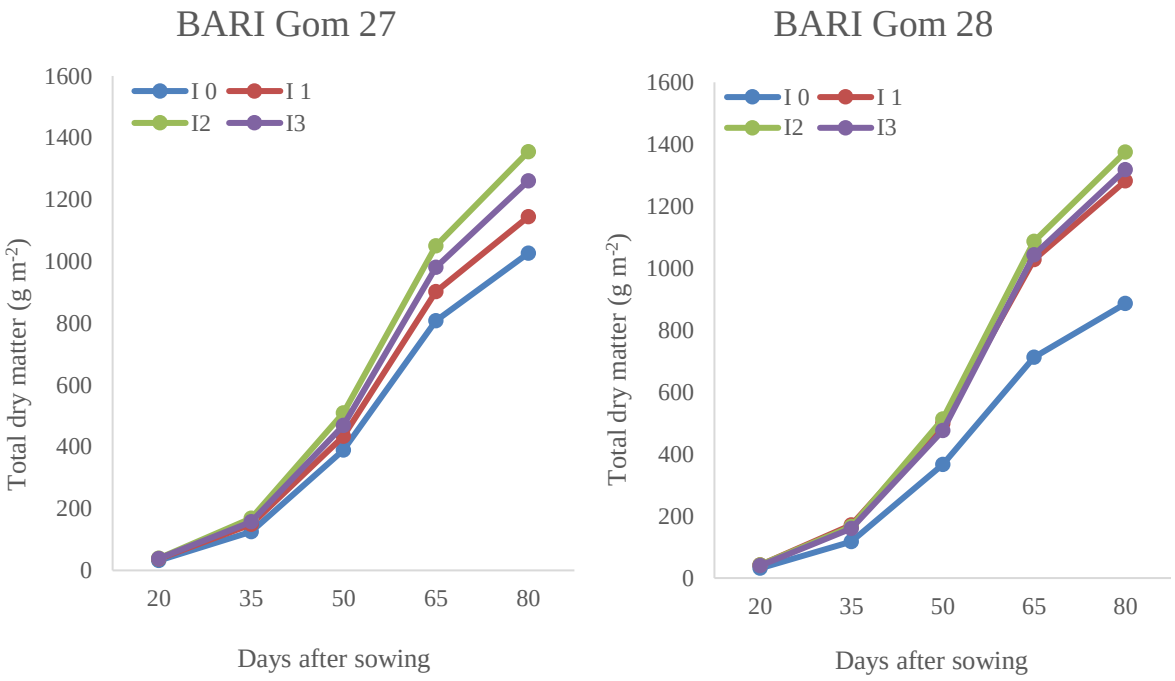
At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 16: Interaction effect of irrigation and potassium on total dry matter m^{-2} of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Interaction (Irrigation× Potassium)	A. Total dry matter m^{-2} (g m^{-2}) (2015-2016)					B. Total dry matter m^{-2} (g m^{-2}) (2016-2017)				
	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS
$I_0 K_0$	28.667 e	90.567 g	307.805 l	590.673 l	753.218 n	30.345 e	94.771 e	320.890 k	622.345 k	771.661 m
$I_0 K_1$	35.062 b-e	140.877 c-e	424.344 gh	866.298 h	1085.878 j	36.876 b-e	146.553 bc	441.642 g	912.919 g	1112.707 i
$I_0 K_2$	34.489 c-e	138.234 de	429.785 gh	908.145 g	1160.472 i	36.222 c-e	143.578 bc	446.846 g	957.234 f	1188.456 h
$I_0 K_3$	33.145 de	132.656 e	399.810 i	871.455 h	1109.367 j	34.670 de	137.762 c	416.349 h	918.215 g	1135.562 i
$I_1 K_0$	30.051 e	109.762 fg	343.212 k	663.192 k	834.655 m	31.462 e	113.545 de	354.889 j	687.567 j	851.099 l
$I_1 K_1$	41.958 a	168.538 ab	464.745 ef	957.372 f	1202.270 h	43.678 a	175.256 a	480.543 ef	992.509 e	1225.0734 g
$I_1 K_2$	40.982 a-c	163.567 a-c	487.756 de	1018.608 e	1302.735 f	42.992 a-c	170.342 ab	504.356 de	1056.541 d	1327.492 e
$I_1 K_3$	39.342 a-d	162.743 a-c	444.585 fg	971.349 f	1240.756 g	41.104 a-d	162.670 ab	459.663 fg	1006.707 e	1264.267 f
$I_2 K_0$	31.288 e	121.565 ef	366.744 j	718.241 j	906.500 l	31.092 c	123.843 cd	380.120 i	739.555 i	917.9543 k
$I_2 K_1$	43.245 a	175.556 ab	504.523 cd	1040.574 de	1329.548 e	44.983 a	177.992 a	523.056 cd	1071.454 cd	1345.670 e
$I_2 K_2$	42.145 a	170.609 ab	520.869 c	1102.690 c	1432.519 c	43.6890 ab	172.948 ab	539.892 a-c	1135.407 b	1449.750 c
$I_2 K_3$	40.432 a-c	164.293 ab	487.245 de	1065.445 d	1376.858 d	42.603 a-c	166.734 ab	505.067 d	1097.347 c	1393.567 d
$I_3 K_0$	32.451 e	138.656 de	409.412 hi	787.331 i	995.431 k	41.955 a-d	138.678 c	409.640 h	802.763 h	1001.875 j
$I_3 K_1$	43.902 a	186.129 a	547.377 ab	1113.833 bc	1435.378 c	32.342 c	185.730 a	547.523 ab	1135.563 b	1444.756 c
$I_3 K_2$	43.133 a	180.554 a	561.345 a	1173.989 a	1524.923 a	43.3901 ab	180.266 a	561.670 a	1196.209 a	1534.342 a
$I_3 K_3$	42.252 ab	174.222 ab	524.866 bc	1129.345 b	1467.545 b	41.734 a-d	173.634 ab	524.653 b-d	1150.348 b	1477.674 b
CV (%)	6.736	16.476	7.3370	3.457	2.972	6.458	16.348	6.127	3.479	2.908

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

A



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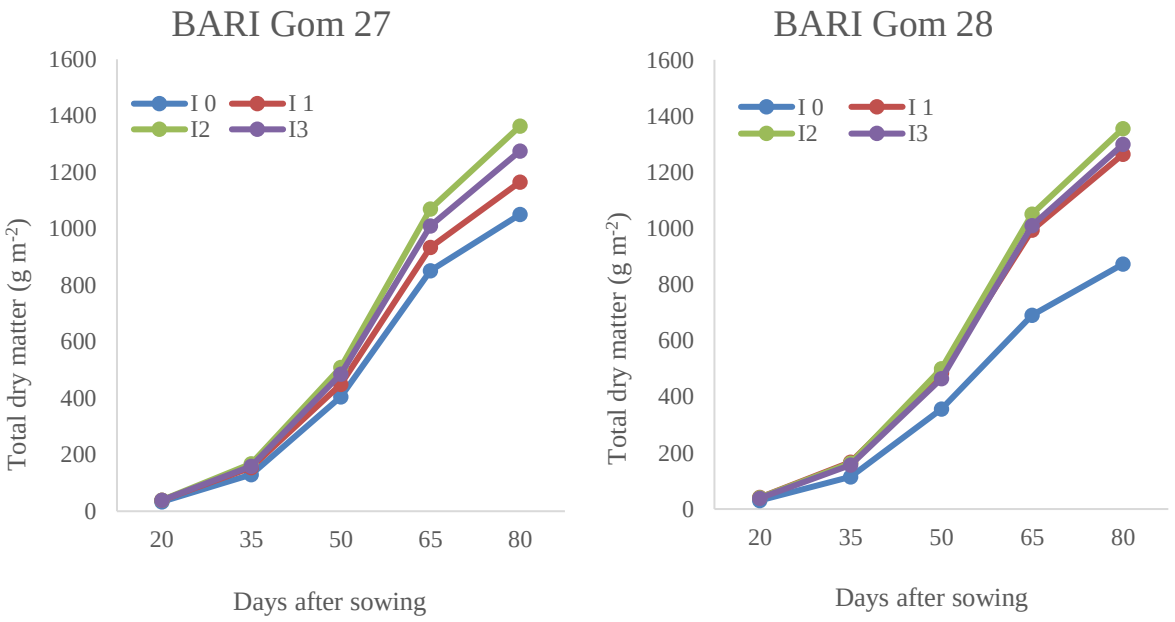
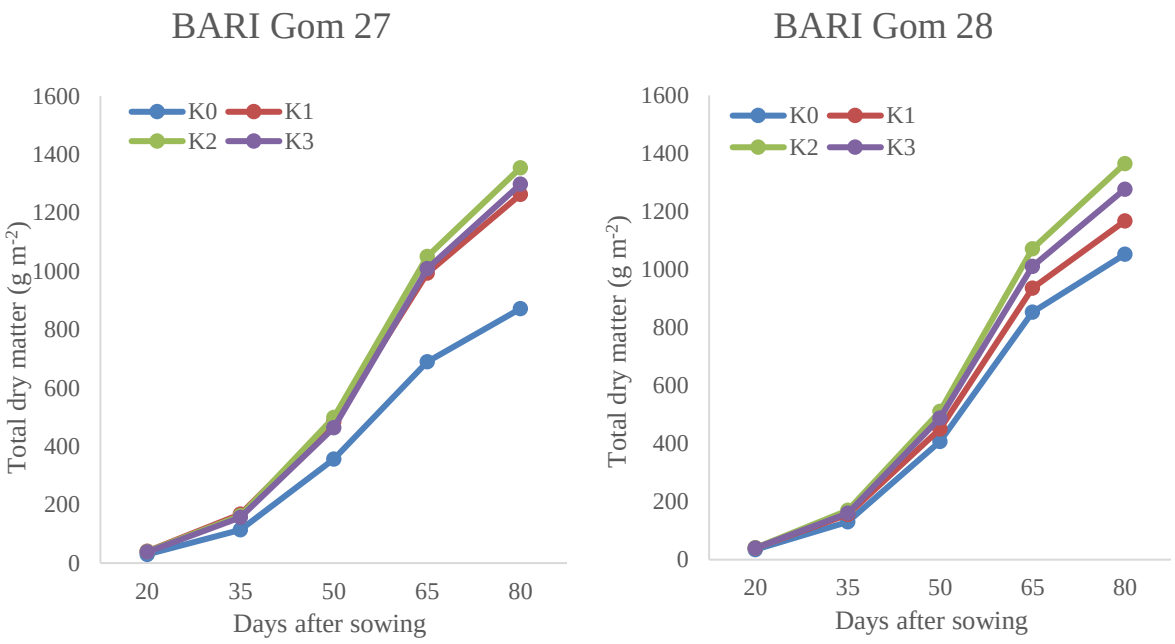


Fig. 7: Effect of irrigation on total dry matter m^{-2} at different days after sowing in 2015-2016 (A) and 2016-2017 (B)

A



B

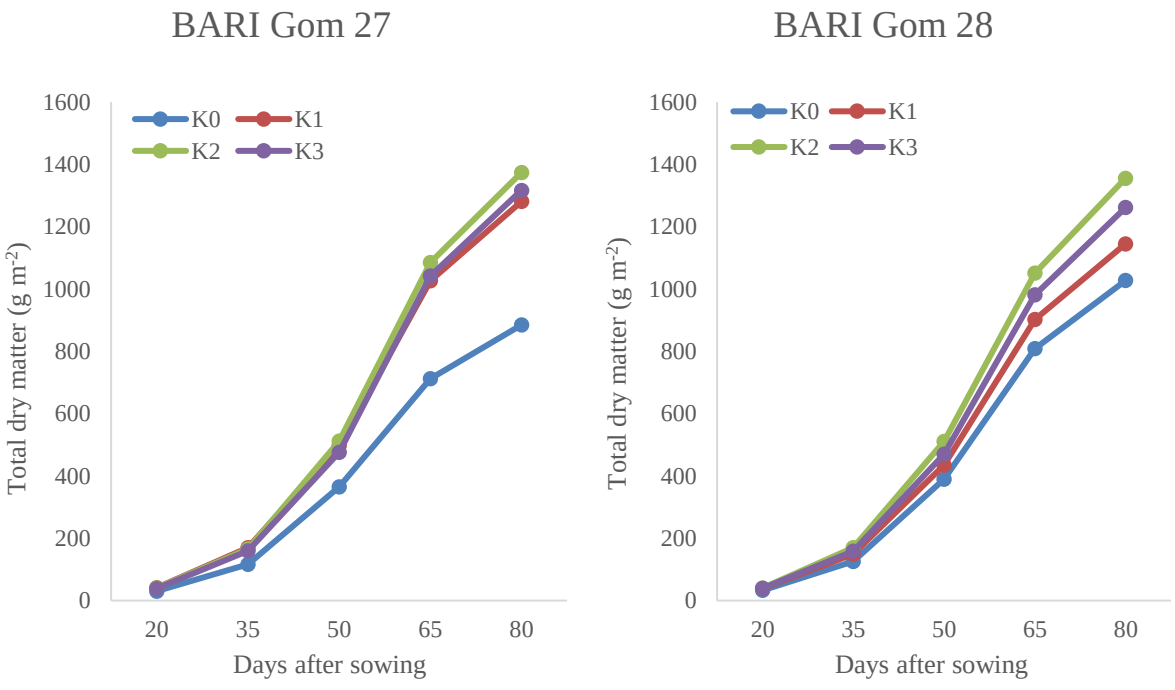


Fig. 8: Effect of potassium on total dry matter m^{-2} at different days after sowing in 2015-2016 (A) and 2016-2017 (B)

4.2.2 Leaf area index

The leaf area index at different growth phases as affected by irrigation have been presented in Table 17A and Fig. 9A for first year (2015-2016) and Table 17B and Fig. 9B for second year (2016-2017) respectively. Irrigation level had significant effects on leaf area index (LAI) at all the growing stages except at 20 DAS in both the years. At 35 DAS, the highest leaf area index (LAI) was observed in I_2 which was at par with I_3 and I_1 treatments in both the years. During 50, 65 and 80 DAS, the highest leaf area index (LAI) was observed in I_2 followed by I_3 and I_1 in both the growing seasons. The lowest values at 20, 35, 50, 65 and 80 DAS were found in I_0 treatment in both the years. Leaf area index for all treatments were almost similar up to 20 DAS, as no supplementary irrigation was applied before that stage to any treatment. The value of LAI in the irrigated treatments was greater than the control at almost all the phases of growth. The result was in agreement with several crop plants like wheat by Leverton 1990, Nahar and Paul 1998 and Rahman 2004, in barley by Bahadur, 2008 and Kirby 1969, in Sorghum by Constable and Hearn 1978, in mustard by Mondal and Paul 1995 and in rape by Kundu 1992. The increase of LAI occurred due to increase of leaf expansion in the irrigated plants. Increase in soil moisture resulted in increased turgor pressure in the cells and turgor forces played a part in the process of leaf expansion. With an increase in the level of irrigation, uptake of nutrients was more; hence more expansion of leaves took place (Mondal *et al.*, 1986). Soil moisture increased the relative leaf water content which increased cell expansion and ultimately leaf area was increased. Mandal *et al.* (2002) reported that LAI increased significantly with increasing levels of irrigation. Similar findings was also reported by Akram, 2011.

The effects of variety on leaf area index (LAI) was not statistically significant are presented in Table 18A for first year (2015-2016) and Table 18B for second year (2016-2017) respectively. Between the two varieties, BARI Gom 28 (V_2) produced higher leaf area index (LAI) than BARI Gom 27 (V_1) in both the years.

Foliar applications of potassium had significant effect on leaf area index (LAI) at different phases of crop growth in both the years are presented in Table 19A and Fig. 10A for first year (2015-2016) and Table 19B and Fig. 10B for second year (2016-2017) respectively. At 20, 35 and 50 DAS, the highest leaf area index (LAI) values were recorded in K_2 treatment followed by K_3 and K_1 treatments in both the growing period. At 65 and 80 DAS, the highest leaf area index (LAI) was obtained in K_2 treatment which was statistically similar with K_3 treatment followed by K_1 in both the growing seasons. The lowest leaf area index (LAI) values at

different growing stages were recorded in K_0 in both the years. In presented study, highest LAI was found in K_2 foliar applications of potassium. This findings was similar with the findings of Imanparast *et al*. (2013) who reported that growth traits like seedling length, leaf sum lengths, leaf width, leaf area index, and seedling dry weight, root dry weight significantly reduced under water stress condition. Application potassium remarkably increased the values of those mentioned traits.Similar results were reported by Desoky *et al*. (2017) and Rahman, *et al*. (2014) where foliar spray of potassium orthophosphate was applied during terminal drought of wheat plants. The increase in LAI was due to increase in number of leaf per plant and leaf size in wheat for increasing level of K applicaion. Lindhauer (1989) reported that fine K nutrition not only increased plant total dry mass and leaf area, but also improved the water retention in plant tissues under drought stress.

Interaction effect of irrigation and potassium had showed significant variation in leaf area index (LAI) of wheat at different days after sowing in both the growing seasons are presented in Table 20A and for first year (2015-2016) and Table 20B for second year (2016-2017) respectively. At 20 and 35 DAS, the highest leaf area index (LAI) was observed in I_2K_2 and I_3K_1 treatment in first growing season and in the second year, the highest LAI was found in I_2K_2 treatment. At 50 DAS, the highest leaf area index (LAI) was observed in I_2K_2 treatment which was at par with I_3K_2 and I_2K_1 treatment in both the growing seasons. At 65 DAS, the highest leaf area index (LAI) was observed in I_2K_2 treatment which was statistically significant with I_2K_3 treatment in both the growing seasons. At 80 DAS, the maximum leaf area index (LAI) was observed in I_2K_2 treatment in both the growing periods. The lowest leaf area index (LAI) was obtained in I_0K_0 treatment at all the growing phases in both the growing seasons.

Table 17: Effect of irrigation on leaf area index of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Irrigation	A. Leaf area index (2015-2016)					B. Leaf area index (2016-2017)				
	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS
I_0	0.122 a	0.936 b	1.597 c	2.682 c	3.257 c	0.128 a	0.967 b	1.66 c	2.713 c	3.429 c
I_0	0.123 a	1.021 a	1.907 b	3.016 b	3.509 b	0.132 a	1.046 a	2.0 b	3.148 b	3.663 b
I_2	0.127 a	1.029 a	2.108 a	3.238 a	4.045 a	0.138 a	1.078 a	2.075 a	3.196 a	3.851 a
I_3	0.125 a	1.022 a	2.012 b	3.033 b	3.521 b	0.129 a	1.057 a	2.007 b	3.139 b	3.679 b
CV (%)	2.274	2.061	6.308	6.456	8.508	2.276	2.061	6.983	6.041	8.173

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 18: Effect of variety on leaf area index of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Variety	A. Leaf area index (2015-2016)					B. Leaf area index (2016-2017)				
	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS
V_1	0.122 a	0.985 a	1.856 a	2.986 a	3.581 a	0.128 a	1.03 a	1.928 a	3.033 a	3.645 a
V_2	0.126 a	1.019 a	1.956 a	2.997 a	3.586 a	0.136 a	1.044 a	1.944 a	3.065 a	3.667 a
CV (%)	2.274	2.061	6.308	6.456	8.508	2.276	2.061	6.983	6.041	8.173

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 19: Effect of potassium on leaf area index of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Potassium	A. Leaf area index (2015-2016)					B. Leaf area index (2016-2017)				
	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS
K_0	0.104 c	0.746 c	1.592 c	2.149 c	2.689 c	0.11 c	0.764 c	1.371 c	2.182 c	2.755 c
K_1	0.123 b	1.075 b	1.883 b	3.199 b	3.767 b	0.133 b	1.11 b	2.095 b	3.263 b	3.827 b
K_2	0.138 a	1.136 a	2.171 a	3.368 a	4.063 a	0.151 b	1.182 a	2.175 a	3.436 a	4.145 a
K_3	0.132 b	1.052 b	1.977 b	3.253 ab	3.815 ab	0.134 b	1.092 b	2.104 b	3.316 ab	3.895 ab
CV (%)	2.274	2.061	6.308	6.456	8.508	2.276	2.061	6.983	6.041	8.173

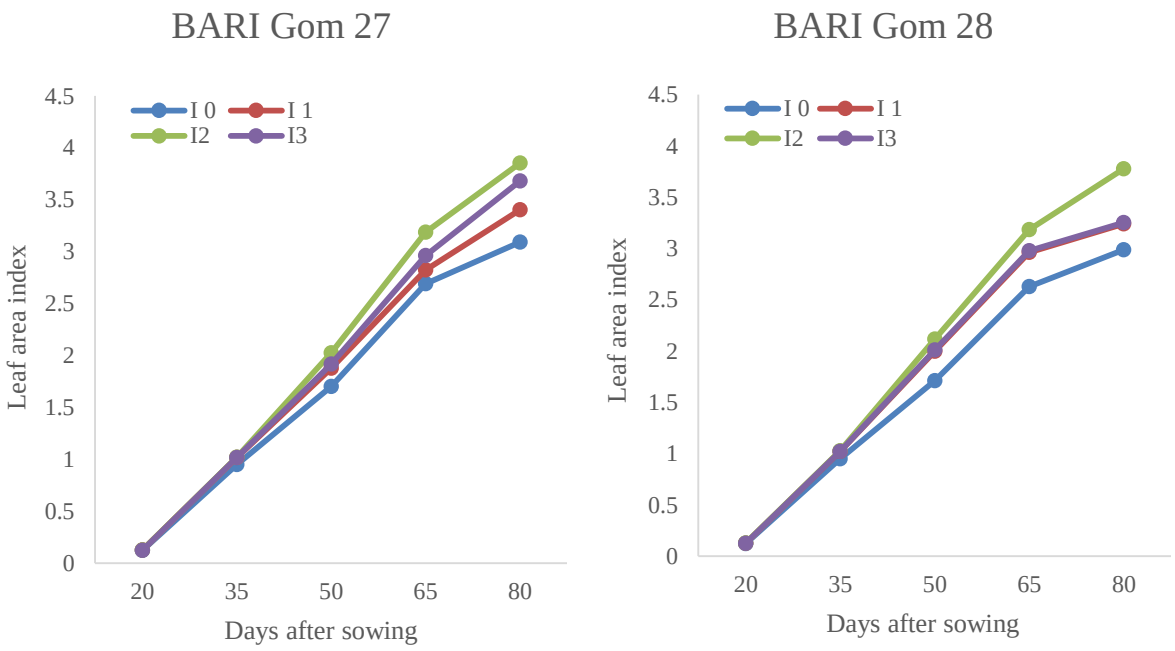
At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 20: Interaction effect of irrigation and potassium on leaf area index of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Interaction (Irrigation × Potassium)	A. Leaf area index (2015-2016)					B. Leaf area index (2016-2017)				
	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS
$I_0 K_0$	0.111 i	0.667 g	1.364 l	1.966 m	2.460 o	0.111 e	0.690 h	1.386 l	2.010 m	2.511 p
$I_0 K_1$	0.142 b	1.108 b	1.869 g	2.886 j	3.245 k	0.143 ab	1.149 b	1.901 g	2.941 j	3.310 l
$I_0 K_2$	0.132 e	1.029 e	1.824 h	2.993 h	3.359 i	0.134 bc	1.066 f	1.851 h	3.049 h	3.432 j
$I_0 K_3$	0.129 g	1.003 e	1.747 i	2.921 i	3.295 j	0.130 d	1.047 f	1.776 i	2.974 i	3.355 k
$I_1 K_0$	0.112 h	0.755 f	1.556 k	2.108 l	2.656 n	0.117 e	0.790 g	1.582 k	2.151 l	2.705 o
$I_1 K_1$	0.113 h	1.153 a	2.021 d	3.144 g	3.551 h	0.144 a	1.198 a	2.053 d	3.207 g	3.621 i
$I_1 K_2$	0.129 cd	1.091 bc	1.988 e	3.270 e	3.795 f	0.134 b	1.135 b-d	2.022 e	3.329 e	3.863 g
$I_1 K_3$	0.126 ef	1.064 d	1.947 f	3.177 f	3.616 g	0.134 d	1.110 e	1.973 f	3.241 f	3.863 h
$I_2 K_0$	0.105 i	0.762 f	1.702 j	2.237 k	2.791 m	0.117 e	0.792 g	1.726 j	2.280 k	2.834 n
$I_2 K_1$	0.127 e	1.092 bc	2.153 ab	3.380 d	3.930 e	0.139 b	1.139 b	2.187 ab	3.443 d	4.005 f
$I_2 K_2$	0.137 a	1.150 a	2.167 a	3.615 a	4.714 a	0.149 a	1.197 a	2.197 a	3.689 a	4.783 a
$I_2 K_3$	0.127 g	1.072 cd	2.135 b	3.606 ab	4.385 b	0.136 b	1.134 b-d	2.168 b	3.678 ab	4.466 b
$I_3 K_0$	0.106 h	0.764 f	2.084c	3.421 c	4.022 d	0.133 d	1.112 c-e	2.112 c	3.488 c	4.090 e
$I_3 K_1$	0.136 a	1.153 a	1.709 j	2.251 k	2.884 l	0.112 e	0.793 g	1.736 j	2.289 k	2.921 m
$I_3 K_2$	0.130 c	1.094 b	2.138 ab	3.404 cd	4.272 c	0.138 b	1.134 bc	2.178 ab	3.467 cd	4.323 d
$I_3 K_3$	0.126 e	1.073 cd	2.095 c	3.492 b	4.357 b	0.135 cd	1.111 de	2.125 c	3.554 b	4.413 c
CV (%)	2.274	2.061	6.308	6.456	8.508	2.276	2.061	6.983	6.041	8.173

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

A



B

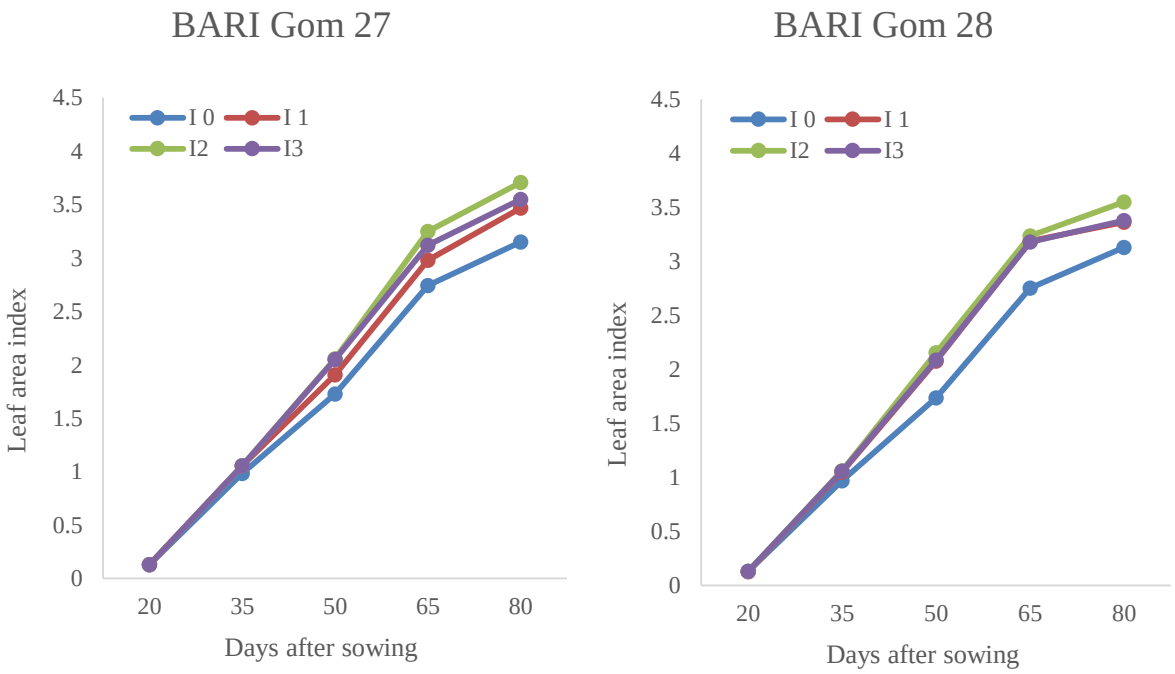
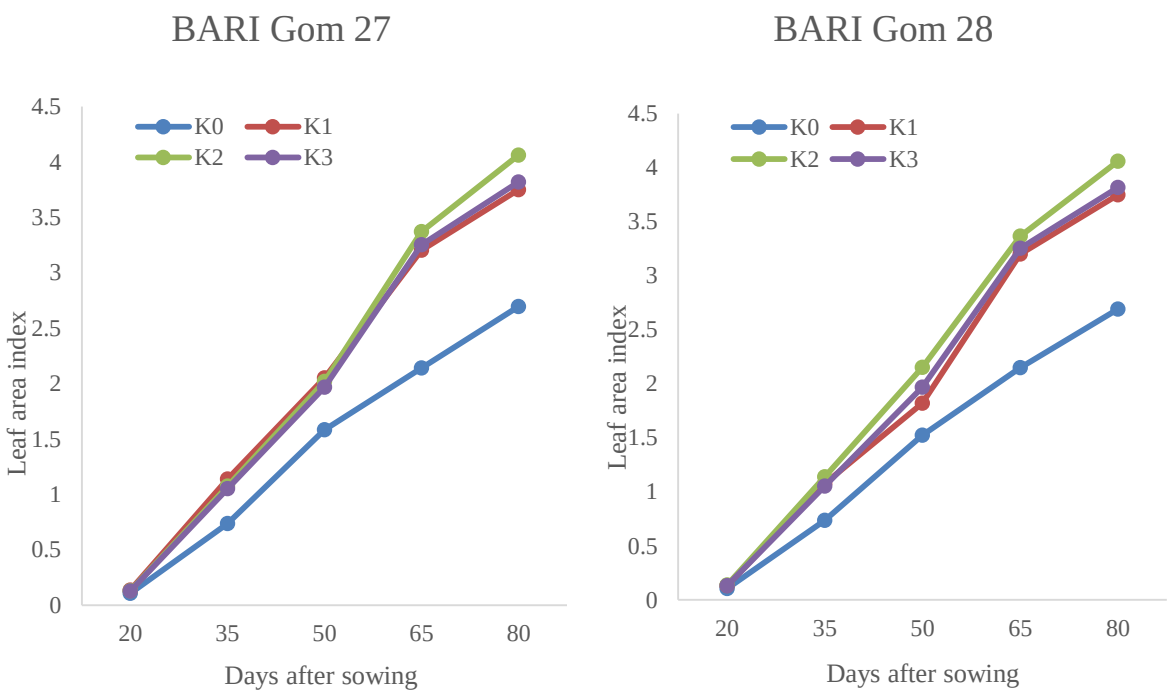


Fig. 9: Effect of irrigation on leaf area index at different days after sowing in 2015-2016 (A) and 2016-2017 (B)

A



B

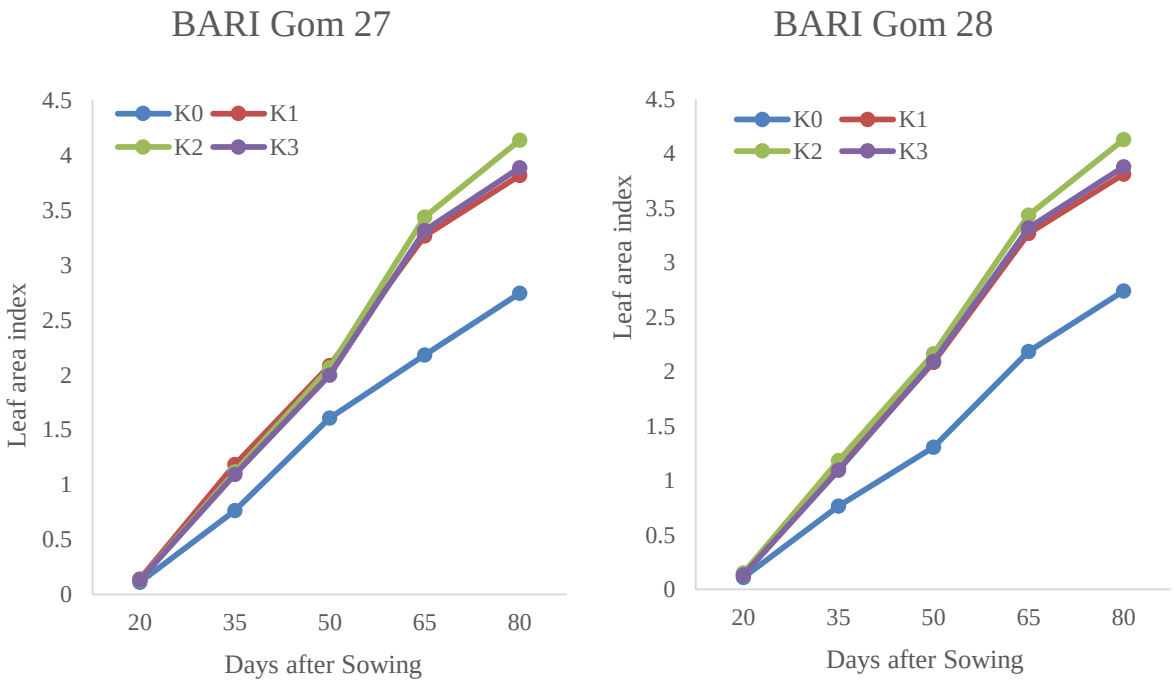


Fig.10: Effect of potassium on leaf area index at different days after sowing in 2015-2016 (A) and 2016-2017 (B)

4.2.3 Crop growth rate

Effects of irrigation on crop growth rate (CGR) are presented in Table 21A and Fig. 11A for first year (2015-2016) and Table 21B and Fig. 11B for second year (2016-2017) respectively. CGR represents the net result of photosynthesis, respiration and canopy area interaction. So, it is consider more meaningful function of crop growth. In different irrigation regimes, starting from a lower value, crop growth rate (CGR) reached a certain peak and thereafter declined with lower positive values. Number of irrigation showed significant effect on crop growth rate (CGR) at all the growing periods in both the years. The highest CGR was found in I_2 at all the growing periods in both the growing years which was statically significant with I_3 at 20-35, 50-65 and 65-80 DAS in both the growing seasons. The lowest value of CGR was observed in I_0 treatment at all the growing periods in both the growing periods. CGR increased slowly at early stages of growth and reached the peak at 50-65 DAS and thereafter it declined. Similar results were reported in wheat (Nahar and Paul, 1998 and Sarker *et al.*, 1996), in sorghum (Rabindranath and Shiv Raj, 1983), in rape (Clarke and Simpson, 1978 and Kundu, 1992) and in mustard (Mondal and Paul, 1992). Higher CGR for normal growing condition was due to higher production of dry matter owing to higher LAI (Haider, 2007). Sarker and Paul (1998) reported that CGR of wheat was higher in irrigated condition than that of rain-fed condition. Akram (2011) reported that moisture stress at different crop growth phases affected CGR differently. Pal *et al.* (2002) observed that application of four irrigations gave higher CGR than two or three irrigations in wheat.

Influence of varieties on crop growth rate (CGR) of wheat at different stages of growth are presented in Table 22A for first year (2015-2016) and Table 22B for second year (2016-2017) respectively. The effect of variety on crop growth rate (CGR) was not statistically significant at most of the growth periods except 20-35 DAS. Between the two varieties, BARI Gom 28 (V_2) produced higher CGR than BARI Gom 27 (V_1) in both the years.

The effects of foliar applications of potassium on crop growth rate (CGR) at different phases of growth are shown in Table 23A and Fig. 12A for first year (2015-2016) and Table 23B and Fig. 12B for second year (2016-2017) respectively. Foliar spray of potassium fertilizer had significant effect on crop growth rate (CGR) during 20-35, 35-50, 50-65 and 65-80 DAS during the two successive growing seasons. At 20-35 DAS, the highest CGR was found in K_1 treatment which was statically identical to K_2 and K_3 treatments in both the growing seasons. During 35-50, K_2 treatment produced the highest CGR which was at par with K_1 treatment in

both the growing periods. At 50-65 and 65-80 DAS, the highest CGR was found in K_2 treatment which was statically similar with K_3 treatment in both the growing seasons. The lowest CGR during 20-35, 35-50, 50-65 and 65-80 DAS were found in K_0 at all growing period in both the growing seasons. Foliar application of potassium with 2% solution produced the highest CGR at all growing periods. Similar results were found in wheat by El-Shaer *et al.,* 1979 and Kumar *et al.,* 1995. Singh and Agarwal (2001) stated that the higher Leaf Area Index (LAI) and Leaf Area Duration (LAD) attained through fertilization led to high photosynthetic efficiency, which contributed to higher CGR.

Crop growth rate (CGR) varied significantly within the period of 20-35, 35-50, 50-65 and 65-80 DAS due to the interaction effect of irrigation and foliar applications of potassium in both the growing seasons are presented in Table 24A for first year (2015-2016) and Table 24B for second year (2016-2017) respectively. The highest crop growth rate (CGR) was observed in the treatment I_2K_2 which was significantly differed from the remaining treatments in both the growing seasons. The lowest values of CGR were found in I_0K_0 treatment in all the growing periods in both the growing seasons.

Table 21: Effect of irrigation on crop growth rate of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Irrigation	A. Crop growth rate (g $m^{-2}day^{-1}$) (2015-2016)				B. Crop growth rate (g $m^{-2}day^{-1}$) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
I_0	7.587 c	18.702 c	28.188 c	15.753 c	7.34 b	18.802 b	29.766 c	14.43 c
I_1	8.523 b	20.263 bc	32.269 bc	17.176 bc	8.70 a	20.065 a	32.61 bc	16.257 bc
I_2	9.795 a	23.858 a	37.087 a	21.264 a	9.906 a	22.128 a	37.699 a	20.373 a
I_3	8.656 ab	21.707 b	35.369 ab	19.542 ab	9.111 a	23.439 a	35.109 ab	18.459 ab
CV (%)	2.574	3.132	4.213	6.169	2.631	2.973	4.231	6.672

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 22: Effect of variety on crop growth rate of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Variety	A. Crop growth rate (g $m^{-2}day^{-1}$) (2015-2016)				B. Crop growth rate (g $m^{-2}day^{-1}$) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
V_1	7.728 b	21.086 a	33.197 a	18.319 a	8.353 b	21.056 a	33.262 a	17.575 a
V_2	9.552 a	21.179 a	33.259 a	18.549 a	9.175 a	21.161 a	34.329 a	17.184 a
CV (%)	2.574	3.132	4.213	6.169	2.631	2.973	4.231	6.672

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 23: Effect of potassium on crop growth rate of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Potassium	A. Crop growth rate (g $m^{-2}day^{-1}$) (2015-2016)				B. Crop growth rate (g $m^{-2}day^{-1}$) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
K_0	6.747 b	17.214 c	23.204 c	13.165 c	7.261 b	16.929 c	23.207 c	12.424 c
K_1	9.512 a	22.247 ab	34.761 b	18.873 a	9.496 a	22.225 ab	35.667 b	17.865 b
K_2	9.324 a	23.504 a	37.606 a	21.364 a	9.242 a	23.695 a	38.414 a	20.138 a
K_3	8.978 a	21.565 b	37.341 ab	20.335 ab	9.058 a	21.584 b	37.895 ab	19.089 ab
CV (%)	2.574	3.132	4.213	6.169	2.631	2.973	4.231	6.672

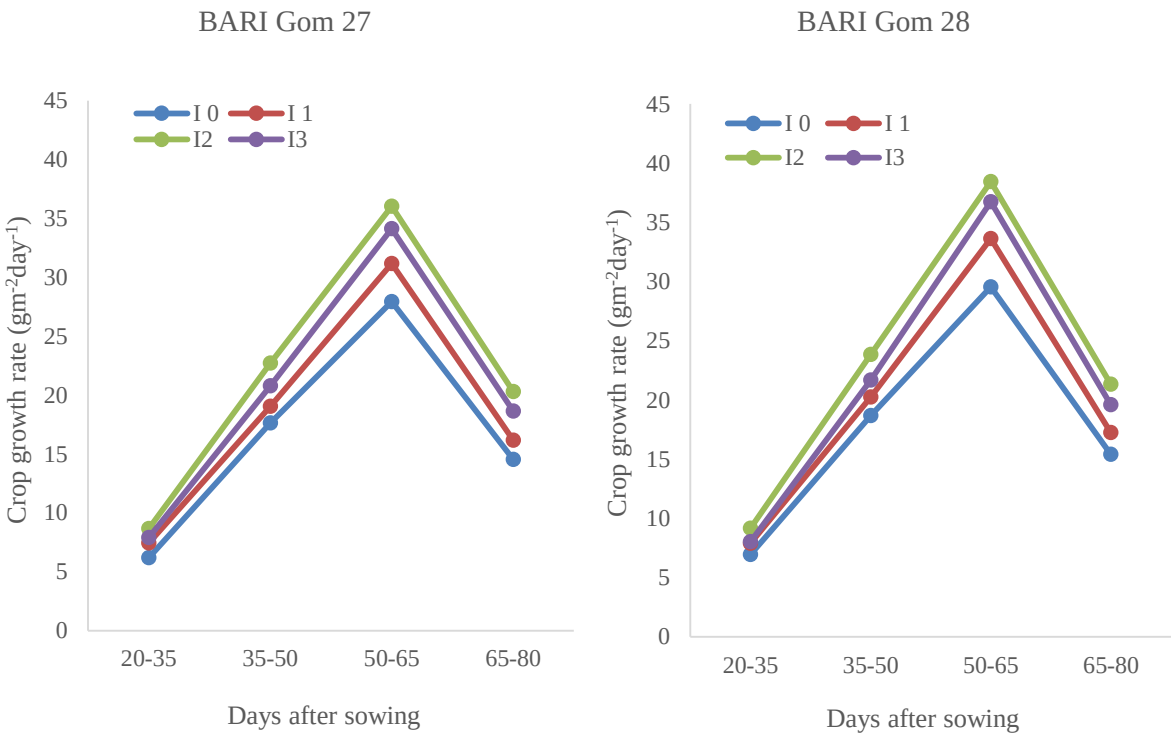
At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 24: Interaction effect of irrigation and potassium on crop growth rate of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Interaction (Irrigation × Potassium)	A. Crop growth rate (g m^{-2}day-1) (2015-2016)				B. Crop growth rate (g m^{-2}day-1) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
$I_0 K_0$	5.231 h	15.572 l	19.792 l	11.863 l	5.765 h	15.567 m	20.334 k	10.945 l
$I_0 K_1$	8.176 ef	19.945 h	30.373 h	15.683 i	8.674 c-e	19.989 h	31.654 g	12.245 i
$I_0 K_2$	7.909 ef	20.562 g	32.834 g	17.845 g	8.456 d-f	20.783 g	34.267 ef	16.472 g
$I_0 K_3$	7.723 f	18.902 i	32.453 g	16.882 h	7.898 ef	19.197 i	33.671 f	15.533 h
$I_1 K_0$	6.367 g	16.721 k	22.374 k	12.451 l	6.867 g	16.543 l	22.325 j	11.962 k
$I_1 K_1$	9.534 a-c	20.734 f	33.789 f	17.382 gh	9.990 ab	20.876 g	34.376 e	16.489 g
$I_1 K_2$	9.276 b-d	22.736 e	36.261 de	19.966 e	8.674 ab	22.712 f	36.901 d	19.072 e
$I_1 K_3$	8.967 c-e	20.277 g	35.996 e	18.990 f	8.653 b-d	19.998 h	36.633 d	18.182 f
$I_2 K_0$	7.177 fg	17.443 j	24.312 j	13.581 k	7.542 fg	17.634 k	24.007 i	12.887 j
$I_2 K_1$	9.934 a-c	22.990 d	36.659 d	20.288 e	10.0094 ab	23.554 e	36.725 d	19.291 e
$I_2 K_2$	10.582 a	26.473 a	41.756 a	24.377 a	10.551 a	25.908 a	42.567 a	23.555 a
$I_2 K_3$	9.634 a-c	24.462 c	39.657 b	22.990 bc	9.819 ab	24.908 b	39.942 c	21.945 c
$I_3 K_0$	9.342 bc	22.645 e	39.451 b	21.771 d	8.567 c	22.911 f	39.647 c	20.782 d
$I_3 K_1$	8.207 d-f	19.172 i	26.189 i	14.853 j	8.456 d-f	18.533 j	26.412 h	14.244 i
$I_3 K_2$	10.281 ab	25.132 b	38.609 c	22.441 cd	10.493 ab	24.655 c	39.345 c	21.687 c
$I_3 K_3$	9.902 a-c	24.356 c	41.145 a	23.582 b	9.811 ab	23.967 d	41.927 b	22.780 b
CV (%)	2.574	3.132	4.213	6.169	2.631	2.973	4.231	6.672

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

A



B

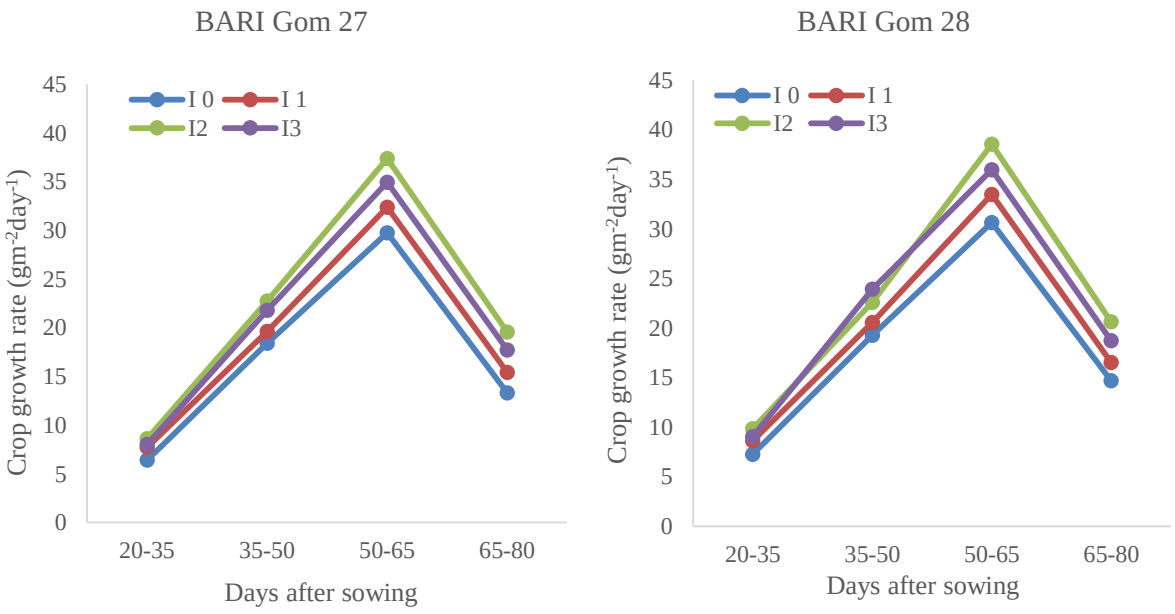
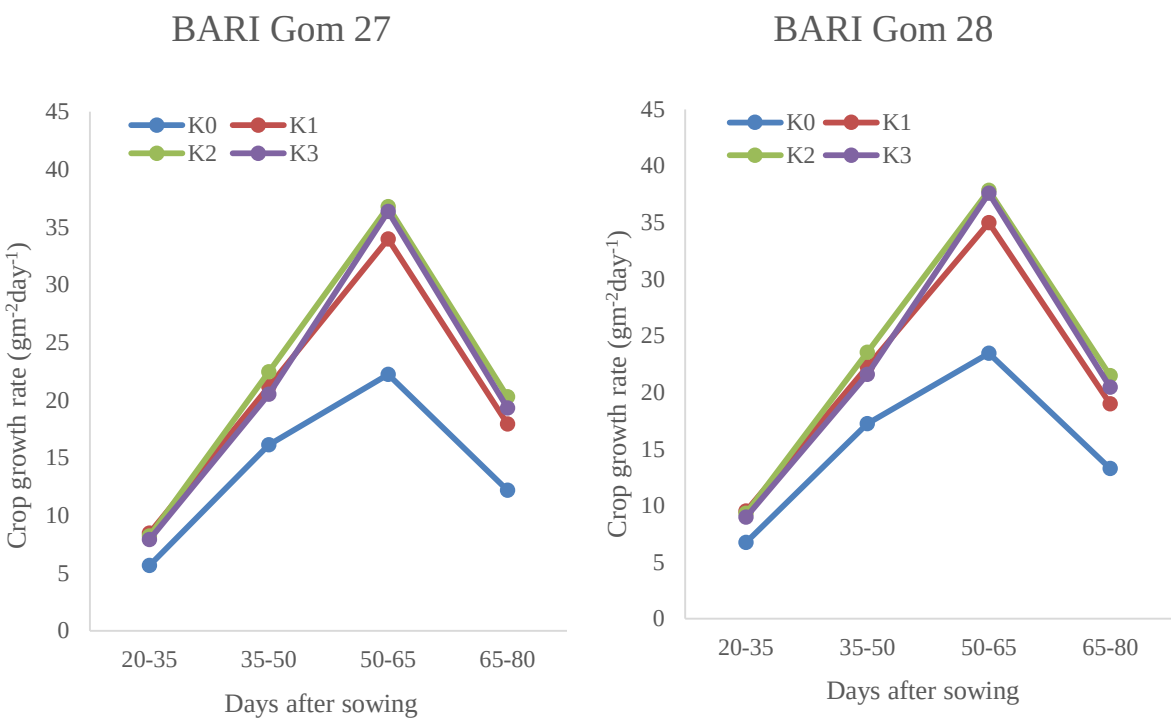


Fig. 11: Effect of irrigation on crop growth rate at different days after sowing in 2015-2016 (A) and 2016-2017 (B)

A



B

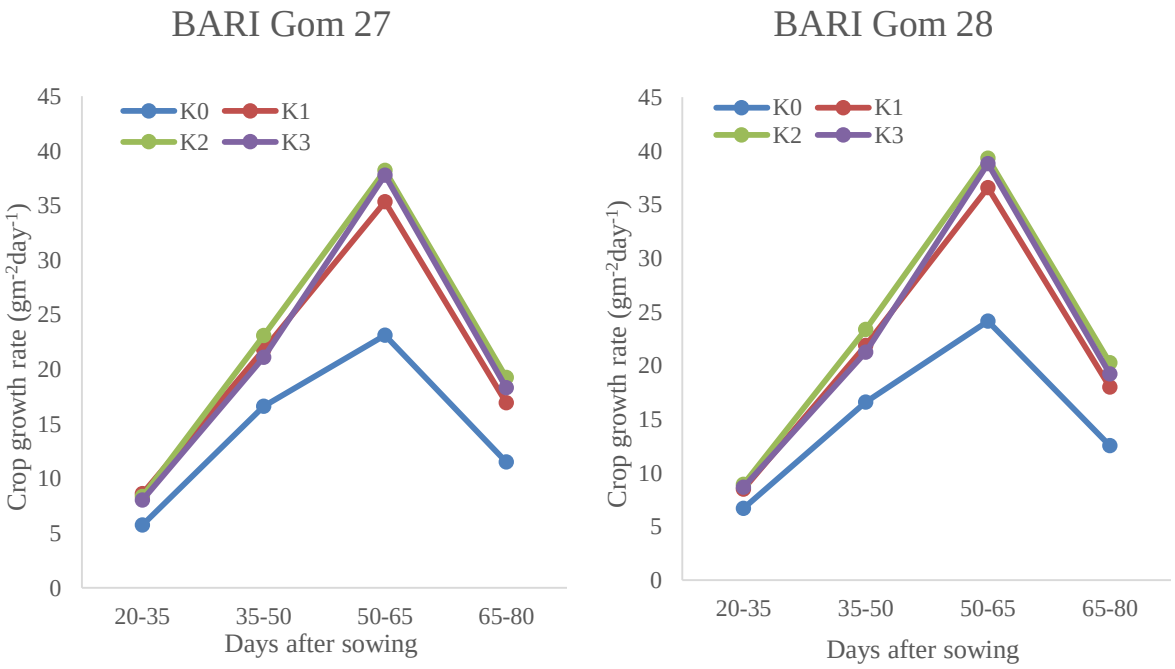


Fig. 12: Effect of potassium on crop growth rate at different days after sowing in 2015-2016 (A) and 2016-2017 (B)

4.2.4 Relative growth rate

Influence of irrigation treatments on relative growth rate (RGR) of wheat at successive days after sowing are presented in Table 25A and Fig. 13A for first year (2015-2016) and in Table 25B and Fig. 13B for second year (2016-2017) respectively. RGR is the rate of dry matter increase per unit total dry matter per unit time. Higher relative growth rate (RGR) was noticed at the early stages of growth in both the cultivars and crop growing years. In all cases RGR were higher in the early phases of plant growth and thereafter declined steady. The maximum and minimum RGR were observed in I_2 and I_0 respectively at different growth phases in both the growing seasons. This result is in agreement with that of different scientists (El-Shaer *et al.*, 1979, Saha and Paul 1995, Sarker and Paul 1998 and Rahman 2004). The reason for higher RGR values at the earlier phases of growth is possibly due to the juvenility of the plants and less effects on accumulation of dry matter. In addition to that, RGR of both cultivars decreased steadily with increasing age and plant dry weight. Decrease in RGR with increasing plant age and dry weight has been reported in wheat (Haque 1993, Rahman 1993, Tarique 2003 and Rahman 2004), in sugar beet, potato and barely (Thorne, 1960), in black gram (Pandey *et al.*, 1978), in mustard (Mondal and Paul, 1992) and in rape (Kundu, 1992). El-Zahab *et al.* (2003) stated that RGR increased steadily during early growth stage and then decreases slowly. Thorne (1961) suggested that the decrease in RGR could be attributed to self-shading of lower leaves by upper leaves. In addition, Chanda *et al.* (1987) concluded that the declining tendency in RGR with age possibly due to decline in LAR.

The effect of varieties on relative growth rate (RGR) of wheat at different growth phases are shown in Table 26A for first year (2015-2016) and in Table 26B for second year (2016-2017) respectively. Relative growth rate (RGR) was influenced significantly due to variety at all growth stages in both the years. Between the two varieties, BARI Gom 28 (V_2) produced higher RGR than BARI Gom 27 (V_1) in both the years.

Foliar spraying of potassium had significant effect on RGR during 20-35, 35-50, 50-65 and 65-80 DAS in both the years are presented in Table 27A and Fig. 14A for first year (2015-2016) and in Table 27B and Fig. 14B for second year (2016-2017) respectively. During 20-35 DAS, the highest RGR was observed in K_1, K_2 and K_3 treatments of potassium in both the growing seasons. At 35-50 DAS, the highest RGR was found in K_2 treatment which was at par with K_3 followed by K_1 in both the growing seasons. During 50-65 DAS, K_2 treatment also produced maximum RGR followed by K_3 in both the growing seasons. At 65-80 DAS, the highest RGR

were obtained in K_2 and K_3 treatments of potassium in both the growing seasons. Ahmed and Farooq (2013) reported that the RGR differed significantly over the growth stages of wheat being optimum at tillering and declined with the advancement of growth, even having negative values at maturity. The similar pattern of RGR at different phenological stages has also been confirmed by findings of Adebo (2010). Singh and Agarwal (2001) stated that the higher LAI and LAD attained through fertilization led to high photosynthetic efficiency, which contributed to higher RGR.

Relative growth rate (RGR) was significantly influenced due to the interaction effect of amount of irrigation and foliar spraying of potassium during 20-35, 35-50, 50-65 and 65-80 DAS in both the years are presented in Table 28A for first year (2015-2016) and in Table 28B for second year (2016-2017) respectively. Higher relative growth rate (RGR) was found at the early stages of crop growth in both the crop growing seasons. In all cases RGR were higher in the early phases of plant growth and thereafter declined steady. The maximum and minimum RGR were observed in I_2K_2 and I_0K_0 treatments respectively at different growth stages during the two successive growing seasons.

Table 25: Effect of irrigation on relative growth rate of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Irrigation	A. Relative growth rate (g $g^{-1}day^{-1}$) (2015-2016)				B. Relative growth rate (g $g^{-1}day^{-1}$) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
I_0	0.091 c	0.072 b	0.046 c	0.015 b	0.085 c	0.071 b	0.047 b	0.013 c
I_1	0.092 bc	0.073 b	0.047 b	0.015 b	0.095 bc	0.075 ab	0.048 b	0.015 b
I_2	0.096 a	0.077 a	0.053 a	0.018 a	0.098 a	0.077 a	0.05 a	0.017 a
I_3	0.094 b	0.074 ab	0.048 b	0.017 a	0.096 ab	0.074 ab	0.049 b	0.016 a
CV (%)	9.389	9.349	7.191	7.880	9.475	9.449	6.929	8.358

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 26: Effect of variety on relative growth rate of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Variety	A. Relative growth rate (g $g^{-1}day^{-1}$) (2015-2016)				B. Relative growth rate (g $g^{-1}day^{-1}$) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
V_1	0.092 b	0.072 b	0.048 b	0.015 b	0.094 b	0.071 b	0.048 b	0.015 a
V_2	0.094 a	0.076 a	0.05 a	0.017 a	0.094 a	0.077 a	0.05 a	0.015 a
CV (%)	9.389	9.349	7.191	7.880	9.475	9.449	6.929	8.358

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 27: Effect of potassium on relative growth rate of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Potassium	A. Relative growth rate (g $g^{-1}day^{-1}$) (2015-2016)				B. Relative growth rate (g $g^{-1}day^{-1}$) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
K_0	0.089 b	0.072 c	0.044 d	0.014 b	0.089 b	0.071 c	0.042 d	0.012
K_1	0.095 a	0.073 bc	0.047 c	0.015 b	0.094 a	0.073 bc	0.047 c	0.014
K_2	0.095 a	0.077 a	0.054 a	0.018 a	0.096 a	0.077 a	0.053 a	0.018
K_3	0.094 a	0.075 ab	0.052 b	0.018 a	0.095 a	0.076 ab	0.051 b	0.017
CV (%)	9.389	9.349	7.191	7.880	9.475	9.449	6.929	8.358

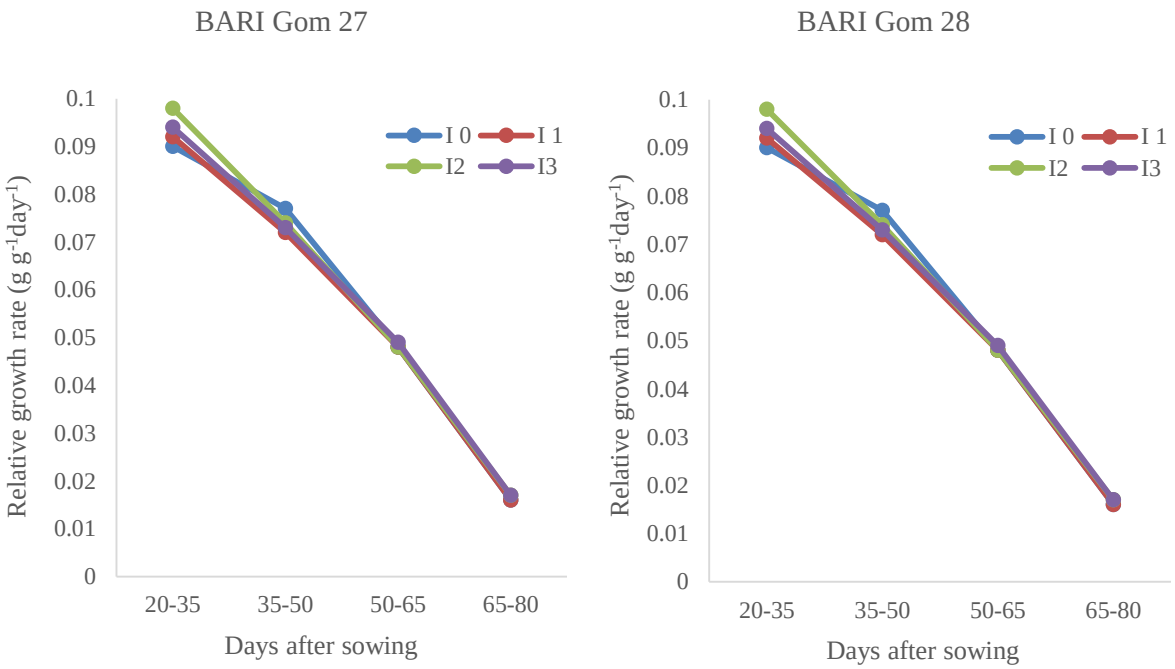
At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 28: Interaction effect of irrigation and potassium on relative growth rate of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Interaction (Irrigation × Potassium)	A. Relative growth rate (g $g^{-1}day^{-1}$) (2015-2016)				B. Relative growth rate (g $g^{-1}day^{-1}$) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
$I_0 K_0$	0.077 f	0.074 b-d	0.043 f	0.016 ab	0.077 g	0.074 bc	0.044 f	0.014 d-f
$I_0 K_1$	0.093 b-d	0.076 a-c	0.049 e	0.015 c	0.094 c-e	0.076 ab	0.048 de	0.013 g
$I_0 K_2$	0.093 b-d	0.074 b-c	0.051 b-d	0.016 ab	0.094 c-e	0.074 bc	0.050 bc	0.014 d-f
$I_0 K_3$	0.093 b-d	0.077 ab	0.044 f	0.016 ab	0.094 c-e	0.076 ab	0.052 a	0.014 d-f
$I_1 K_0$	0.087 e	0.068 d	0.048 e	0.015 c	0.088 f	0.068 d	0.044 f	0.014 d-f
$I_1 K_1$	0.093 b-d	0.073 b-d	0.049 de	0.015 c	0.094 c-e	0.073 b-d	0.048 c-e	0.014 d-f
$I_1 K_2$	0.093 b-d	0.070 cd	0.052 ab	0.016 ab	0.094 de	0.070 cd	0.049 c-e	0.015 b-d
$I_1 K_3$	0.093 b-d	0.074 b-d	0.044 f	0.016 ab	0.094 de	0.076 ab	0.052 a	0.015 b-d
$I_2 K_0$	0.092 d	0.071 b-d	0.048 e	0.016 ab	0.092 e	0.072 b-d	0.045 f	0.014 d-f
$I_2 K_1$	0.095 a-d	0.075 bc	0.050 de	0.016 ab	0.095 c-e	0.076 ab	0.048 c-e	0.015 b-d
$I_2 K_2$	0.099 a	0.082 a	0.053 a	0.017 a	0.099 a	0.082 a	0.050 bc	0.017 a
$I_2 K_3$	0.095 a-d	0.073 b-d	0.052 ab	0.017 a	0.095 c-e	0.074 bc	0.052 a	0.016 ab
$I_3 K_0$	0.094 b-d	0.073 b-d	0.045 f	0.016 b	0.094 c-e	0.073 b-d	0.044 f	0.016 ab
$I_3 K_1$	0.096 a-d	0.072 b-d	0.049 e	0.017 a	0.097 a-c	0.072 b-d	0.047 e	0.015 b-d
$I_3 K_2$	0.097 ab	0.076 a-c	0.051 b-d	0.017 a	0.098 ab	0.076 ab	0.049 cd	0.016 ab
$I_3 K_3$	0.097 ab	0.074 b-d	0.052 ab	0.018 a	0.097 a-c	0.074 bc	0.051 ab	0.017 a
CV (%)	9.389	9.349	7.191	7.880	9.475	9.449	6.929	8.358

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

A



B

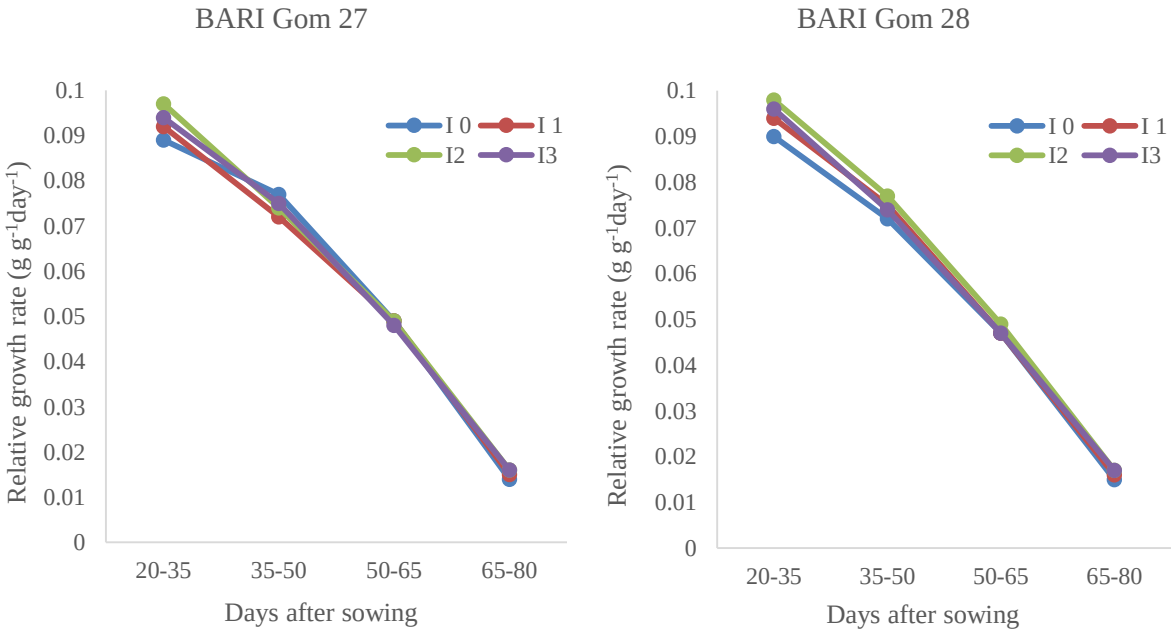
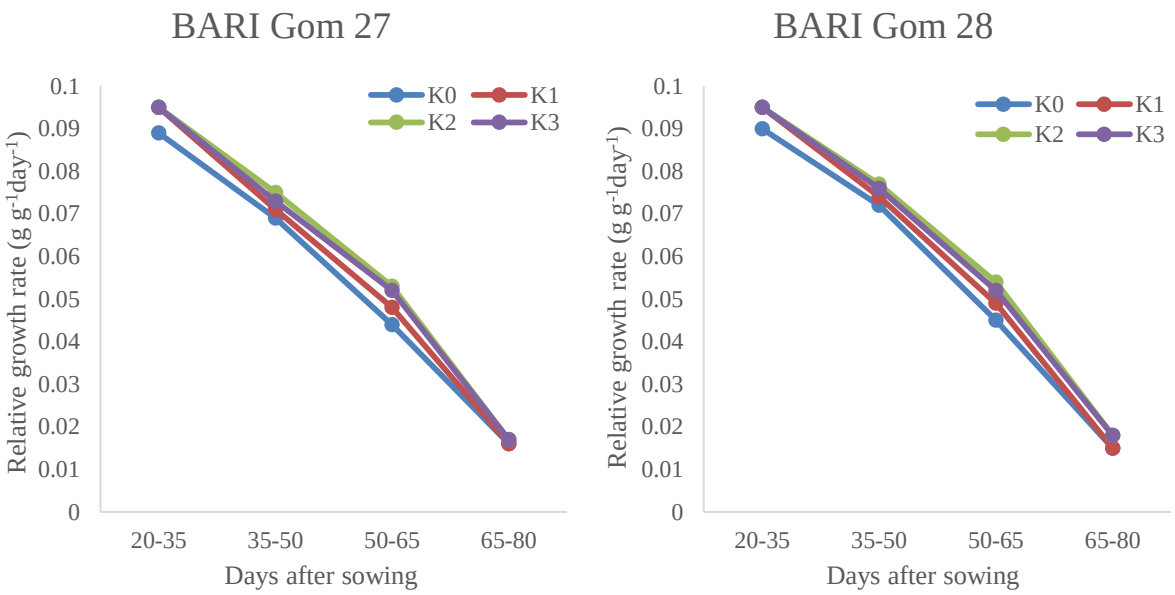


Fig. 13: Effect of irrigation on relative growth rate at different days after sowing in 2015-2016 (A) and 2016-2017 (B)

A



B

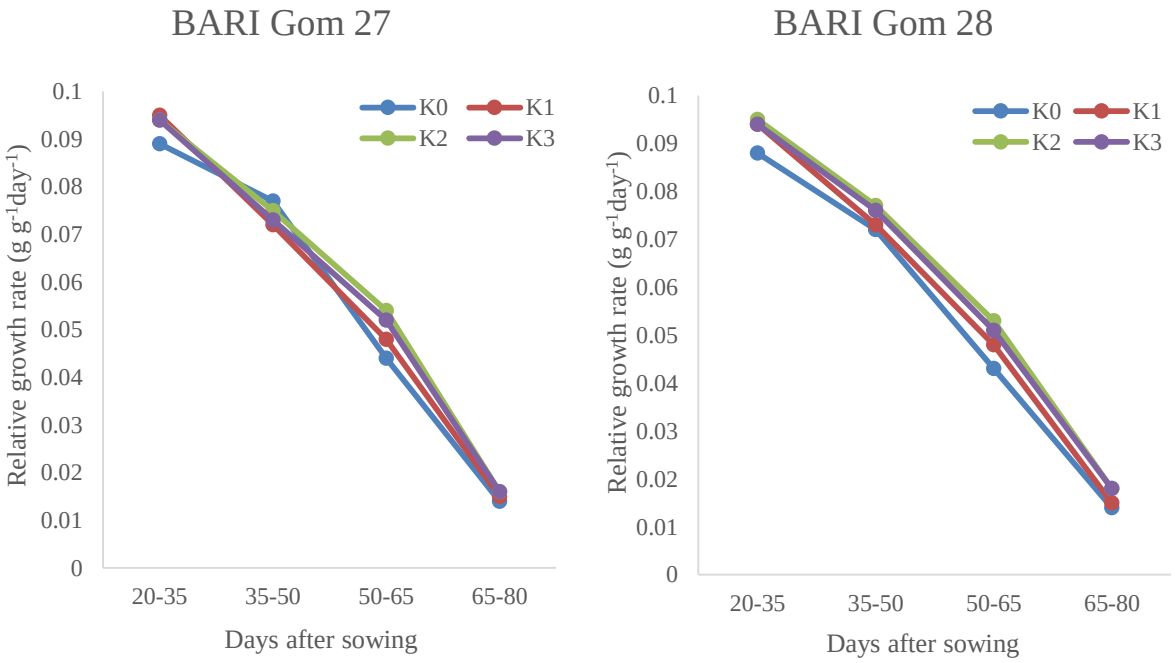


Fig. 14: Effect of potassium on relative growth rate at different days after sowing in 2015-2016 (A) and 2016-2017 (B)

4.2.5 Net assimilation rate

The rate of increase of dry weight per unit of leaf area is called net assimilation rate. The effect of irrigation treatments on net assimilation rate (NAR) at successive days after sowing are presented in Table 29A and Fig. 15A for first year (2015-2016) and in Table 29B and Fig. 15B for second year (2016-2017) respectively. Irrigation showed significant effect on net assimilation rate (NAR) within the period of 20-35, 35-50, 50-65 and 65-80 DAS in both the growing seasons. NAR in both the varieties for irrigation increased slowly with fluctuations and showed highest NAR at 50-65 DAS and then declined rapidly. In all cases, NAR were lower in the early stages of plant growth and then increased slowly in a certain period and then sharp increased thereafter declined rapidly. The highest NAR was observed in I_3 treatment which differed significantly from the remaining treatments and the lowest value was found in I_0 treatment in all the growth phases during the two successive growing seasons. Similar result was reported by Yang *et al.* (1990) in barley. Shivani *et al.* (2003) reported higher NAR under four irrigations as compared to three and two irrigation treatments. Higher NAR due to higher soil moisture was found in beans (El-Nadi 1969 and Nerkar *et al.,* 1981). Similar pattern of NAR was reported by Koller *et al.* (1970), Haloi *et al.* (1986) and Pandey *et al.* (1978) in different crops.

The effect of varieties on NAR of wheat at different growth phases are shown in Table 30A for first year (2015-2016) and in Table 30B for second year (2016-2017) respectively. Net assimilation rate (NAR) varied significantly at 50-65 and 65-80 DAS due to varieties during the two successive growing seasons. Within the period of 50-65 and 65-80 DAS, significantly higher NAR was observed in BARI Gom 28 (V_2) than BARI Gom 27 (V_1) in both the growing seasons.

The effects of foliar applications of potassium on NAR at different phases of growth are presented in Table 31A and Fig. 16A for first year (2015-2016) and in Table 31B and Fig. 16B for second year (2016-2017) respectively. During 20-35 DAS, the highest NAR was observed in K_2 treatment which was statistically similar to K_3 in both the years. At 35-50 DAS, the maximum NAR was obtained in K_2 during the two successive growing seasons. During 50-65 DAS, the highest NAR was observed in K_2 which was statistically identical to K_3 and K_1 in both the years. During 65-80 DAS, the highest NAR was found in K_2 which was statistically similar with K_3 during the two successive growing seasons. In presented study, NAR in both the varieties for foliar applications of potassium increased slowly with fluctuations and showed

highest NAR at 50-65 DAS and then declined rapidly. Similar result was reported by Yang *et al.* (1990) in barley. The maximum NAR during 50-65 DAS may be attributed by higher leaf area and dry weight of wheat plant. Singh and Agarwal (2001) stated that the higher LAI and LAD attained through fertilization led to high photosynthetic efficiency, which contributed to higher NAR. Ahmed and Farook (2013) reported similar findings in wheat.

Combination of irrigation and potassium had significant influenced on net assimilation rate (NAR) within the periods of 20-35, 35-50, 50-65 and 65-80 DAS in both the years under the presented trail are presented in Table 32A for first year (2015-2016) and in Table 32B for second year (2016-2017) respectively. From the table, it was observed that I_2K_2 treatment produced the highest NAR at all growing periods followed by I_3K_3 in both the years. With few exceptions, the lowest NAR was found in I_0K_0 treatment at all growing stages in both the growing years.

Table 29: Effect of irrigation on net assimilation rate of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Irrigation	A. Net assimilation rate (mg $cm^{-2}day^{-1}$) (2015-2016)				B. Net assimilation rate (mg $cm^{-2}day^{-1}$) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
I_0	1.254 b	1.367 c	1.539 d	0.498 c	1.327 b	1.372 c	1.501 c	0.448 d
I_1	1.329 b	1.379 bc	1.723 c	0.510 c	1.349 b	1.399 bc	1.729 b	0.478 c
I_2	1.398 a	1.564 a	2.079 a	0.565 a	1.435 a	1.532 a	1.976 a	0.537 a
I_3	1.333 b	1.403 b	1.835 b	0.532 b	1.341 b	1.443 b	1.82 b	0.5 b
CV (%)	2.739	3.234	4.761	7.157	2.745	3.078	4.641	7.459

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 30: Effect of variety on net assimilation rate of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Variety	A. Net assimilation rate (mg $cm^{-2}day^{-1}$) (2015-2016)				B. Net assimilation rate (mg $cm^{-2}day^{-1}$) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
V_1	1.325 a	1.421 a	1.697 b	0.514 b	1.369 a	1.429 a	1.723 b	0.47 b
V_2	1.333 a	1.434 a	1.891 a	0.538 a	1.357 a	1.445 a	1.79 a	0.511 a
CV (%)	2.752	3.167	4.745	7.157	2.735	3.456	4.529	7.372

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 31: Effect of potassium on net assimilation rate of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Potassium	A. Net assimilation rate (mg $cm^{-2}day^{-1}$) (2015-2016)				B. Net assimilation rate (mg $cm^{-2}day^{-1}$) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
K_0	1.204 c	1.381 c	1.73 b	0.502 b	1.257 c	1.347 c	1.677 b	0.464 b
K_1	1.308 b	1.39 c	1.811 a	0.514 b	1.343 b	1.399 b	1.775 a	0.478 b
K_2	1.414 a	1.517 a	1.823 a	0.545 a	1.444 a	1.546 a	1.793 a	0.511 a
K_3	1.388 a	1.422 b	1.812 a	0.544 a	1.409 a	1.454 b	1.783 a	0.509 a
CV (%)	2.772	3.165	4.710	7.157	2.722	3.095	4.669	7.434

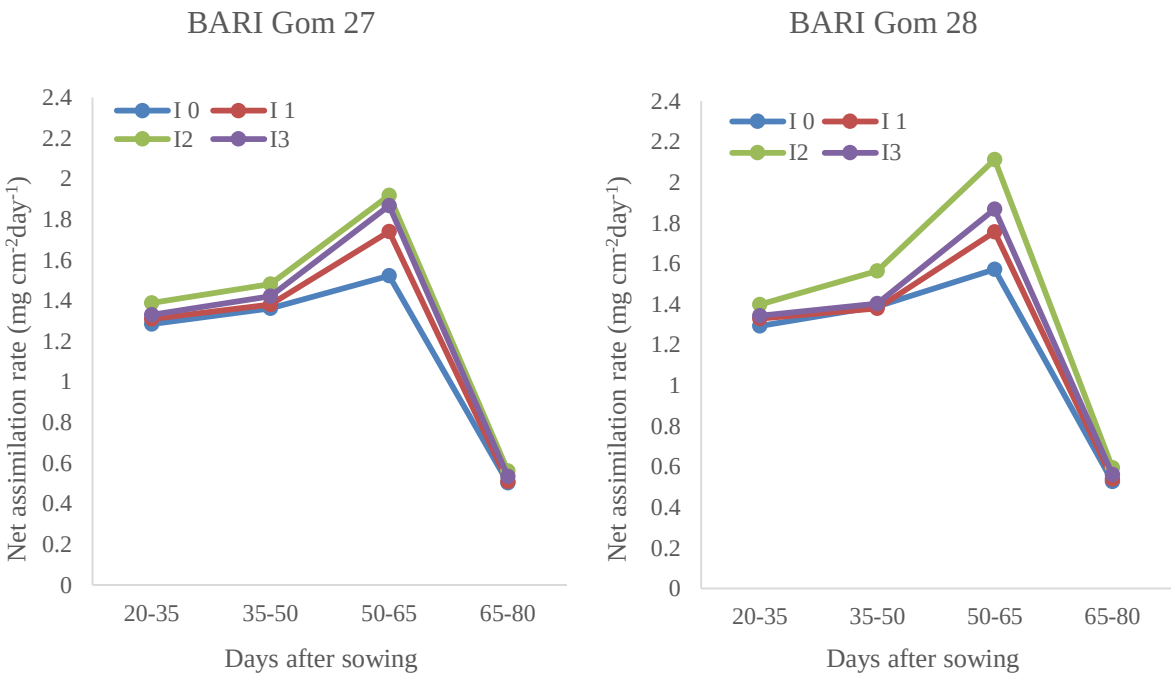
At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 32: Interaction effect of irrigation and potassium on net assimilation rate of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Interaction (Irrigation × Potassium)	A. Net assimilation rate (mg $cm^{-2}day^{-1}$) (2015-2016)				B. Net assimilation rate (mg $cm^{-2}day^{-1}$) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
$I_0 K_0$	1.145 l	1.493 c	1.370 g	0.489 fg	1.201 g	1.520 bc	1.354 f	0.445 ij
$I_0 K_1$	1.257 i	1.298 h	1.535 fg	0.476 g	1.321 f	1.319 i	1.519 ef	0.428 j
$I_0 K_2$	1.352 f	1.403 e	1.615 d-g	0.529 de	1.418 cd	1.425 f	1.599 c-e	0.475 gh
$I_0 K_3$	1.372 e	1.326 g	1.574 e-g	0.509 ef	1.442 b	1.351 h	1.558 d-f	0.460 hi
$I_1 K_0$	1.170 k	1.407 e	1.593 d-g	0.479 g	1.197 g	1.414 fg	1.586 c-f	0.451 i
$I_1 K_1$	1.292 gh	1.280 i	1.779 c-f	0.486 fg	1.324 f	1.286 j	1.772 b-d	0.454 hi
$I_1 K_2$	1.371 ef	1.443 d	1.818 b-e	0.535 cd	1.404 de	1.455 d	1.815 a-c	0.502 d-f
$I_1 K_3$	1.395 d	1.313 gh	1.781 c-f	0.529 de	1.426 bc	1.321 i	1.778 b-d	0.494 e-g
$I_2 K_0$	1.195 j	1.397 e	1.823 b-d	0.499 fg	1.204 g	1.432 ef	1.774 b-d	0.465 hi
$I_2 K_1$	1.311 g	1.374 f	1.869 bc	0.531 de	1.323 f	1.403 g	1.820 a-c	0.494 fg
$I_2 K_2$	1.472 a	1.625 a	2.134 a	0.577 a	1.511 a	1.593 a	2.047 a	0.559 a
$I_2 K_3$	1.382 de	1.501 c	1.911 a-c	0.550 b-d	1.390 e	1.450 de	1.863 ab	0.517 b-e
$I_3 K_0$	1.281 h	1.414 e	1.872 bc	0.560 a-c	1.313 f	1.507 c	1.831 a-c	0.523 b-d
$I_3 K_1$	1.382 de	1.502 c	2.003 a-c	0.544 b-d	1.410 c-e	1.467 d	1.915 ab	0.511 c-f
$I_3 K_2$	1.427 c	1.536 b	1.996 a-c	0.561 a-c	1.438 b	1.500 c	1.923 ab	0.533 a-c
$I_3 K_3$	1.453 b	1.533 b	2.031 ab	0.564 ab	1.481 ab	1.541 b	1.952 ab	0.537 ab
CV (%)	2.748	3.160	4.710	7.057	2.744	3.098	4.677	7.488

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

A



B

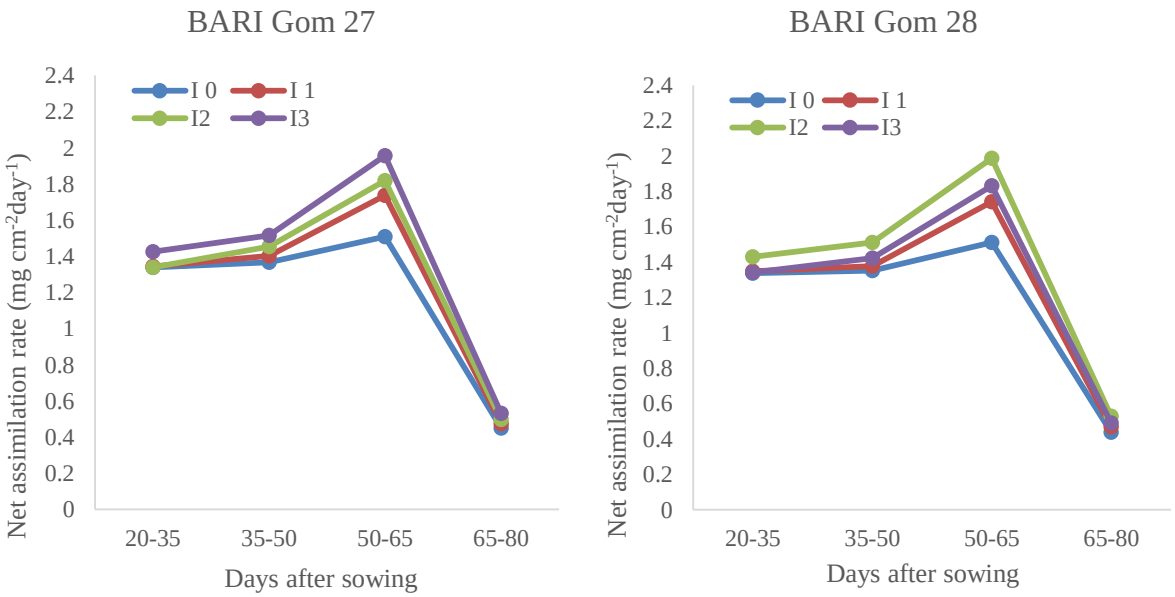
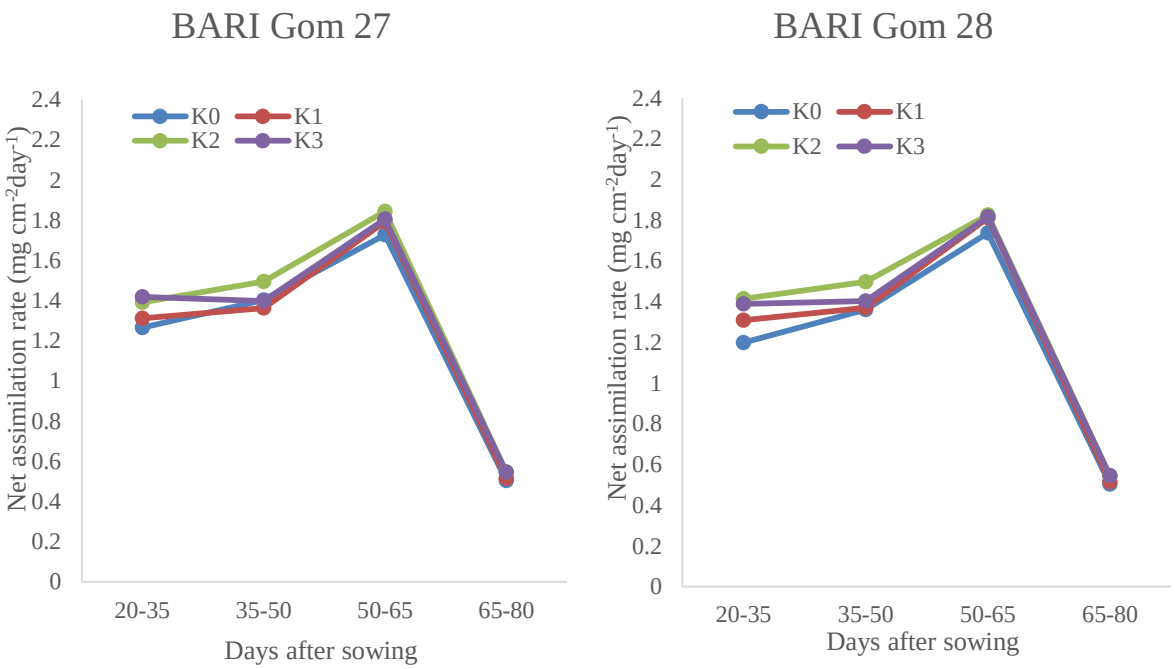


Fig. 15: Effect of irrigation on net assimilation rate at different days after sowing in 2015-2016 (A) and 2016-2017 (B)

A



B

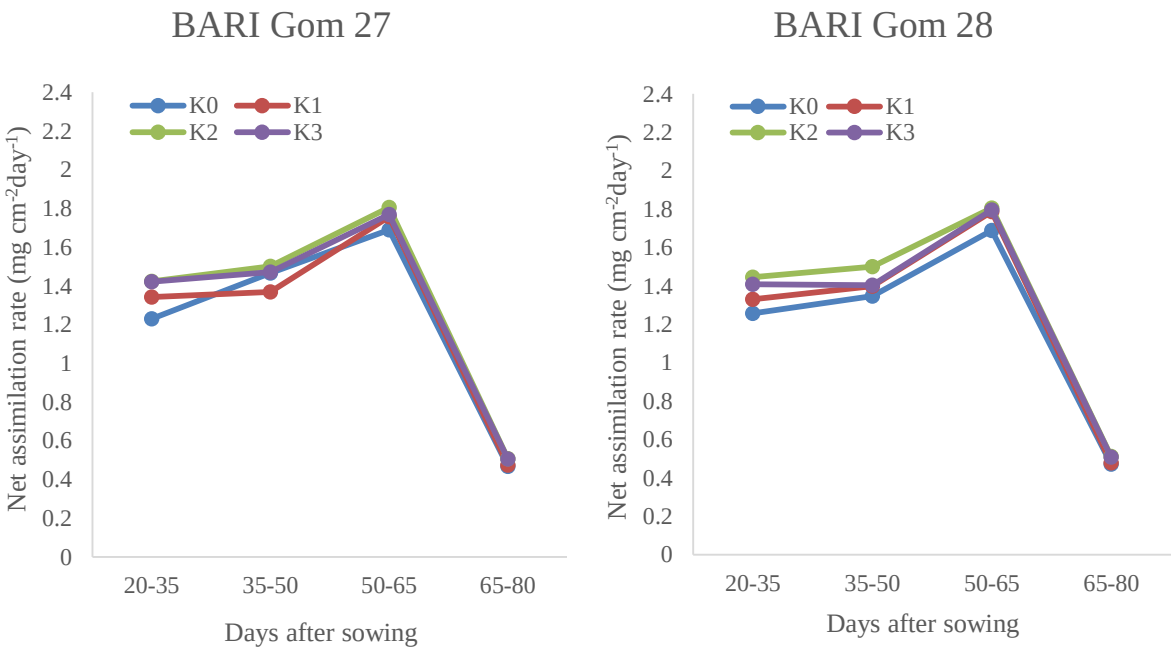


Fig. 16: Effect of potassium on net assimilation rate at different days after sowing in 2015-2016 (A) and 2016-2017 (B)

4.2.6. Leaf area ratio

Number of irrigation showed significant effect on leaf area ratio (LAR) within the period of 20-35, 35-50, 50-65 and 65-80 DAS in both the years under the presented study are shown in Table 33A and Fig.17A for first year (2015-2016) and Table 33B and Fig. 17B for second year (2016-2017) respectively. LAR was higher initially and it decreased with the crop growth as dry matter accumulation increased with time. At every stages of plant growth the highest and lowest LAR was found in I_0 and I_1 respectively in both the growing seasons. During 20-35 DAS, the highest LAR was observed in I_0 treatment which differed significantly from the remaining treatments in both the years. During 35-50, 50-65 and 65-80 DAS, the maximum LAR was found in I_0 treatment which was statistically similar with I_1 and I_3 treatments in both the growing seasons. There was a decreasing trend of LAR with increasing amount of irrigations. LAR value was higher at 20-35 DAS and decreased steadily with increasing plant age. It might be due to the abscission of mature and older leaves resulted in lower values of LAR at the later phases of growth. Similar results were reported in sugar beet, potato and barley by Thorne (1960), in black gram by Pandey *et al.* (1978), in rape by Murtaza and Paul (1986) and in wheat by Haque (1993), Rahman (1993) and Saha and Paul (1995). Haloi and Baldev (1986) also supported this and also in agreement with the result of the presented investigation. Mollah (2007) reported that the rain-fed plants had higher LAR than the irrigated plant in barley. Similar results were reported by Nahar and Paul (1998) in wheat. Kingra and Mahey (2013) reported that LAR expresses the relationship between the leaf area and total respiring plant tissues.

Leaf area ratio (LAR) was significantly influenced due to varieties at different growth stages of wheat during the two successive growing seasons are presented in Table 34A for first year (2015-2016) and Table 34B for second year (2016-2017) respectively. Significantly higher LAR was observed in BARI Gom 28 (V_2) than BARI Gom 27 (V_1) at all plant growth phases in both the years.

The effects of foliar applications of potassium on LAR at different growth phases are presented in Table 35A and Fig. 18A for first year (2015-2016) and Table 35B and Fig. 18B for second year (2016-2017) respectively. LAR was higher during vegetative crop growth period and after that it declined steadily during rest of the growth period. Leaf area ratio (LAR) did not differ significantly within the period of 20-35, 35-50, 50-65 and 65-80 DAS in both the years. The highest and lowest LAR were obtained in K_0 and K_2 treatments respectively at all crop growth

stages in both the years. This results are agreement with many other researchers. Kingra and Mahey (2013) reported that higher LAR during early vegetative growth period and after that it declined steadily during rest of the growth period as after this period, leaf area index starts declining and partitioning of dry matter increases towards reproductive parts. LAR increased more or less with the increase of potassium application. This result indicated that potassium enhanced better plant growth and physiological functions. Similar result was reported by Rahman (2004). In the presented investigation, basal application of potassium produced the highest LAR at the early stages, but in later stages, three split applications of potassium produced the highest LAR in both the years. El-Hattab *et al.* (1980) and Alam (2014) showed that potassium level had significant effect on LAR.

Leaf area ratio (LAR) was significantly influenced by the interaction of amount of irrigation and foliar applications of potassium within the period 20-35, 35-50, 50-65 and 65-80 DAS in both the growing seasons are shown in Table 36A for first year (2015-2016) and Table 36B for second year (2016-2017) respectively. During 20-35 DAS, the highest LAR was recorded by the treatment of I_0K_0 treatment which was at par with I_0K_1, I_0K_2, I_0K_3 and I_1K_0 treatments during the two successive growing seasons. Within the period of 35-50 and 50-65 DAS, the highest LAR was recorded by the treatment of I_0K_0 which was at par with I_0K_1, I_0K_2, I_0K_3, I_1K_0 and I_1K_1 in both the growing seasons. At 56-80 DAS, the highest LAR was recorded in I_0K_0 and the lowest LAR was found in I_3K_0 at all growth stages during the two successive growing seasons.

Table 33: Effect of irrigation on leaf area ratio of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Irrigation	A. Leaf area ratio (cm^2g^{-1}) (2015-2016)				B. Leaf area ratio (cm^2g^{-1}) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
I_0	59.432 a	55.474 a	37.684 a	31.696 a	59.375 a	54.693 a	37.338 a	31.408 a
I_0	53.367 b	52.954 b	36.974 b	31.057 b	53.168 b	52.434 b	36.301 b	30.883 b
I_2	48.098 c	47.529 c	34.268 c	30.065 c	49.819 c	48.731 c	33.776 c	29.997 c
I_3	50.548 bc	51.449 b	36.764 b	31.066 b	51.898 bc	51.347 b	36.188 b	30.996 b
CV (%)	7.132	5.187	4.562	3.787	7.696	5.186	4.704	3.562

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 34: Effect of variety on leaf area ratio of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Variety	A. Leaf area ratio (cm^2g^{-1}) (2015-2016)				B. Leaf area ratio (cm^2g^{-1}) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
V_1	56.427 a	53.157 a	37.369 a	31.659 a	56.635 a	53.345 a	37.166 a	31.510 a
V_2	49.295 b	50.546 b	35.476 b	30.282 b	50.495 b	50.257 b	34.636 b	30.132 b
CV (%)	7.132	5.187	4.562	3.787	7.696	5.186	4.704	3.562

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 35: Effect of potassium on leaf area ratio of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Potassium	A. Leaf area ratio (cm^2g^{-1}) (2015-2016)				B. Leaf area ratio (cm^2g^{-1}) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
K_0	53.493 a	52.505 a	37.5151 a	32.0631 a	54.361 a	52.287 a	36.553 a	31.043 a
K_1	52.929 a	52.386 a	36.3501 a	30.8981 a	53.978 a	52.030 a	35.765 a	30.883 a
K_2	52.318 a	50.309 a	35.5821 a	30.1301 a	52.393 a	50.889 a	35.542 a	30.594 a
K_2	52.705 a	52.206 a	36.2441 a	30.7921 a	53.529 a	51.997 a	35.745 a	30.762 a
CV (%)	7.132	5.187	4.562	3.787	7.696	5.186	4.704	3.562

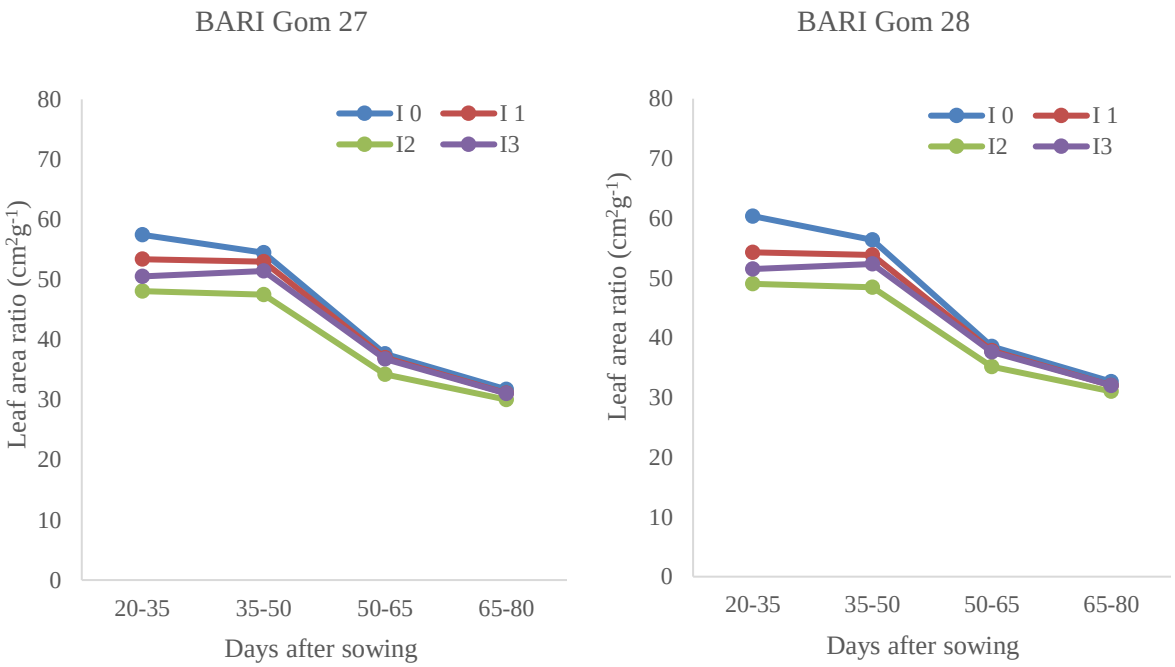
At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 36: Interaction effect of irrigation and potassium on leaf area ratio of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Interaction (Irrigation × Potassium)	A. Leaf area ratio (cm^2g^{-1}) (2015-2016)				B. Leaf area ratio (cm^2g^{-1}) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
$I_0 K_0$	61.792 a	56.932 a	37.972 a	33.008 a	61.645 a	56.133 a	36.857 a	32.461 a
$I_0 K_1$	57.342 a-d	54.954 a-c	36.991 a-d	30.886 de	57.208 a-d	54.182 a-c	36.878 a	31.014 c
$I_0 K_2$	58.710 a-c	54.260 a-c	37.887 ab	31.535 bc	58.568 a-c	53.497 a-e	36.775 ab	30.375 ef
$I_0 K_3$	59.973 ab	55.771 ab	37.811 ab	31.498 bc	59.834 ab	54.993 ab	35.903 a-d	30.976 cd
$I_1 K_0$	55.257 a-e	54.624 a-c	37.502 a-c	31.833 b	54.997 a-e	54.055 a-d	36.692 ab	31.628 b
$I_1 K_1$	53.283 b-f	53.256 a-d	37.324 a-d	31.132 cd	53.036 b-e	52.715 a-f	36.663 ab	30.935 c-e
$I_1 K_2$	51.887 b-f	50.712 c-f	35.796 ef	30.544 ef	51.644 b-e	50.188 c-g	35.165 c-e	30.349 f
$I_1 K_3$	53.125 b-f	53.337 a-d	37.354 a-d	30.853 de	52.875 b-e	52.787 a-f	36.691 ab	30.664 c-f
$I_2 K_0$	50.757 c-f	52.891 a-d	37.482 a-c	30.947 de	52.227 b-e	52.776 a-f	36.912 a	30.932 c-e
$I_2 K_1$	50.932 c-f	51.564 b-e	36.812 b-e	30.982 de	52.411 b-e	51.477 b-g	36.256 a-c	30.970 cd
$I_2 K_2$	49.795 d-f	49.841 d-f	36.244 de	31.622 b	51.233 c-e	49.758 d-g	35.702 b-d	31.624 b
$I_2 K_3$	50.612 c-f	51.435 b-e	36.555 c-e	30.613 ef	52.064 b-e	51.347 b-g	36.007 a-d	30.576 c-f
$I_3 K_0$	46.801 f	46.582 f	33.901 g	28.788 g	48.497 e	48.435 fg	34.311 e	28.915 g
$I_3 K_1$	49.008 ef	48.177 ef	34.347 g	30.142 f	50.789 c-e	49.282 e-g	34.572 e	30.288 f
$I_3 K_2$	47.783 ef	47.246 ef	34.098 g	30.876 de	49.525 de	47.776 g	34.122 e	31.020 c
$I_3 K_3$	48.724 ef	48.042 ef	34.684 fg	30.272 f	50.493 c-e	49.413 e-g	34.910 de	30.408 d-f
CV (%)	7.132	5.187	4.562	3.787	7.696	5.186	4.704	3.562

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

A



B

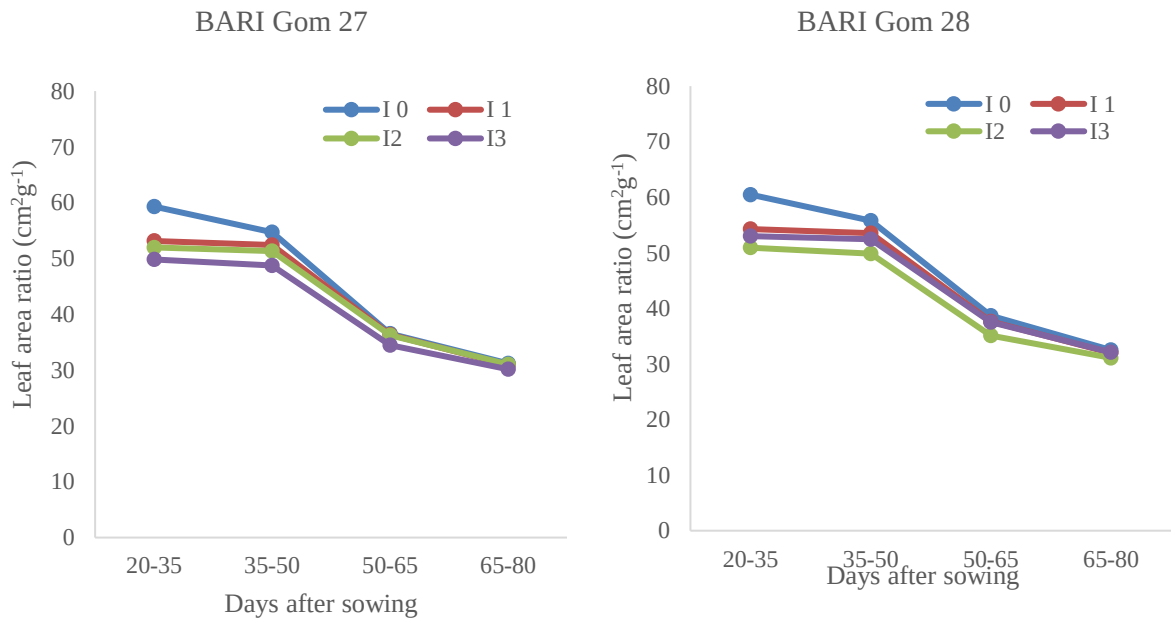
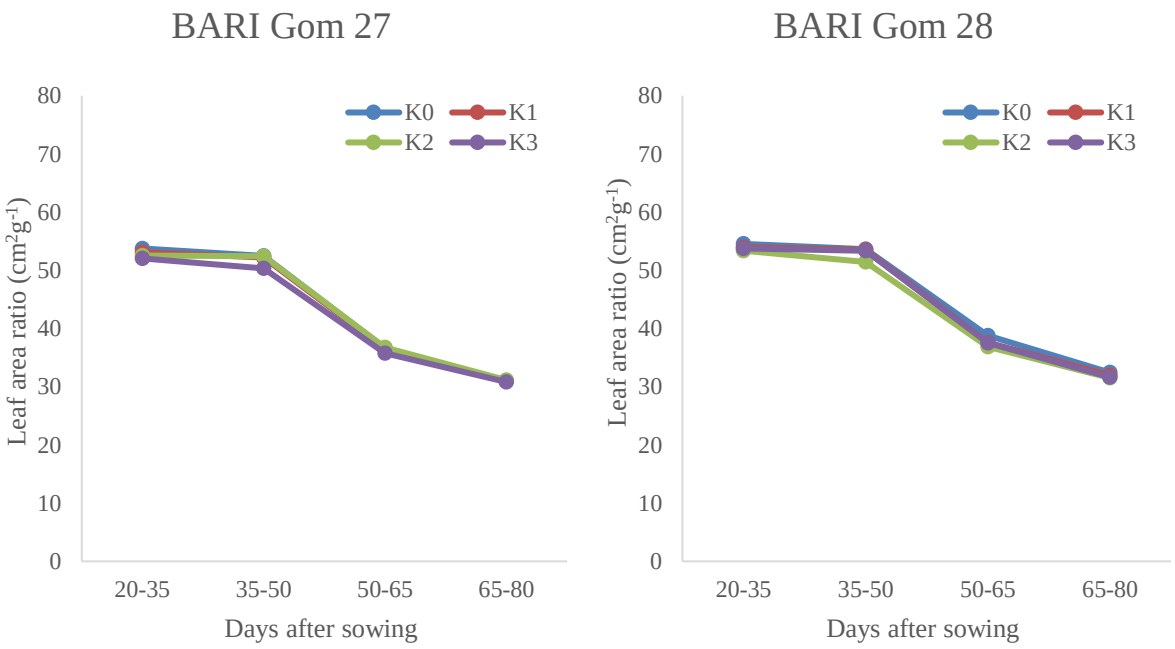


Fig. 17: Effect of irrigation on leaf area ratio (LAR) at different days after sowing in 2015-2016 (A) and 2016-2017 (B)

A



B

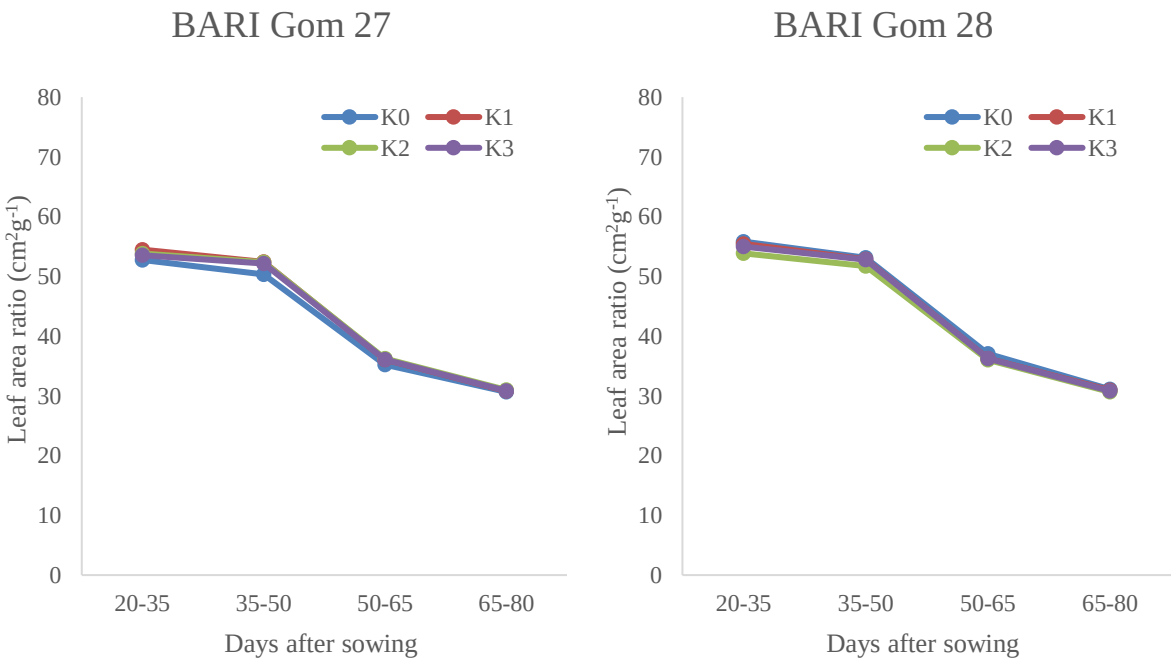


Fig. 18: Effect of potassium on leaf area ratio (LAR) at different days after sowing in 2015-2016 (A) and 2016-2017 (B)

4.2.7 Relative leaf growth rate

There was significant effect of irrigation regimes on relative leaf growth rate (RLGR) during 20-35, 35-50, 50-56 and 65-80 DAS in both the years are presented in Table 37A and Fig. 19A for first year (2015-2016) and Table 37B and Fig. 19B for second year (2016-2017) respectively. In the presented investigation, RLGR values were found to be increased with increasing irrigation amounts in both the years. During 20-35 and 35-50 DAS, the highest RLGR was observed in I_2 and I_3 treatments followed I_1 and I_0 in both the growing seasons. Within the period of 50-65 DAS, the highest RLGR was obtained in I_2 and I_3 treatments followed by I_0 during the two successive growing seasons. During 65-80 DAS, the highest RLGR was found in I_2 treatment followed by I_3 treatment in first year of experiment and I_3 in both the growing seasons. RLGR values were found to decrease with increasing plant age. The cause of decline of RLGR at the later stages was due to abscission of older leaves. It was also observed that high temperature at the later stages of growth accelerated the abscission of old leaves. Similar result was reported by Mondal and Paul (1992), Khan and Paul (1993), Rahman (1993), Saha and Paul (1995), Sarker and Paul (1998) and Sarker *et al.* (1996) in wheat. The abscission of old leaves resulted in the decline of RLGR at the later stages of growth (Pandey *et al.,* 1978). Comparatively higher RLGR in the irrigated plants than in non-irrigated plants was found by Sarker and Paul 1998, Sarker *et al.,* 1996 and Saha and Paul (1995).

Varieties had no significant effect on RLGR during all growing periods in both the years are shown in Table 38A for first year (2015-2016) and Table 38B for second year (2016-2017) respectively. Between the two varieties, BARI Gom 28 (V_2) produced higher RLGR than BARI Gom 27 (V_1) at all growing stages in both the years.

The effects of foliar applications of potassium on relative leaf growth rate (RLGR) of wheat are presented in Table 39A and Fig. 20A for first year (2015-2016) and Table 39B and Fig. 20B for second year (2016-2017) respectively. Foliar applications of potassium had significant effect on relative leaf growth rate (RLGR) during 20-35, 35-50, 50-65 and 65-80 DAS in both the years. During 20-35 and 35-50 DAS, the higher relative leaf growth rate (RLGR) was found in K_2 and K_3 treatments followed by K_1 and K_0 in both the growing seasons. During 50-65 DAS, the higher relative leaf growth rate (RLGR) was found in K_2 and K_3 treatments followed by K_1 in both the growing seasons. Within the period of 65-80, DAS K_2 treatment of potassium gave the highest RLGR followed by K_3 treatment and the lowest value was found in K_0 at all growing stages in both the growing season.

Relative leaf growth rate (RLGR) was significantly influenced by the interaction of irrigation and potassium during 20-35, 35-50, 50-65 and 65-80 DAS in both the years are shown in Table 40A for first year (2015-2016) and Table 40B for second year (2016-2017) respectively. The maximum and minimum RLGR was recorded in I_2K_2 and I_0K_0 treatments respectively at all growing stages of crop growth during the two successive growing seasons. During 35-50 and 50-65 DAS, the treatments I_2K_2 and I_2K_2 produced the highest RLGR and the lowest RLGR was found in I_0K_0 in both the growing seasons. During 65-80 DAS, the treatment of I_2K_2 gave the highest RLGR and the lowest value was found in I_0K_0 treatment during the two successive growing seasons.

Table 37: Effect of irrigation on relative leaf growth rate of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Irrigation	A. Relative leaf growth rate ($cm^2cm^{-2}day^{-1}$) (2015-2016)				B. Relative leaf growth rate ($cm^2cm^{-2}day^{-1}$) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
I_0	0.137 b	0.04 b	0.026 c	0.01 c	0.135 b	0.038 b	0.026 c	0.01 c
I_1	0.138 b	0.04 b	0.028 b	0.01 c	0.136 b	0.04 b	0.029 b	0.011 bc
I_2	0.141 a	0.046 a	0.031 a	0.016 a	0.142 a	0.045 a	0.031 a	0.016 a
I_3	0.141 a	0.046 a	0.029 a	0.012 b	0.142 a	0.045 a	0.03 a	0.012 b
CV (%)	5.754	2.871	1.483	3.559	5.833	2.952	1.451	2.558

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 38: Effect of variety on relative leaf growth rate of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Variety	A. Relative leaf growth rate ($cm^2cm^{-2}day^{-1}$) (2015-2016)				B. Relative leaf growth rate ($cm^2cm^{-2}day^{-1}$) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
V_1	0.137	0.041	0.028	0.012	0.139	0.041	0.029	0.012
V_2	0.14	0.045	0.029	0.012	0.139	0.042	0.029	0.012
CV (%)	5.754	2.871	1.483	3.559	5.833	2.952	1.451	2.558

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 39: Effect of potassium on relative leaf growth rate of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Potassium	A. Relative leaf growth rate ($cm^2cm^{-2}day^{-1}$) (2015-2016)				B. Relative leaf growth rate ($cm^2cm^{-2}day^{-1}$) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
K_0	0.137 b	0.04 b	0.026 c	0.01 c	0.137 b	0.038 b	0.027 c	0.01 c
K_1	0.135 b	0.04 b	0.029 b	0.011 bc	0.138 b	0.04 b	0.029 b	0.01c
K_2	0.142 a	0.046 a	0.031 a	0.016 a	0.141 a	0.045 a	0.03 a	0.016 a
K_3	0.142 a	0.046 a	0.03 a	0.012 b	0.141 a	0.045 a	0.03 a	0.012 b
CV (%)	5.754	2.871	1.483	3.559	5.833	2.952	1.451	2.558

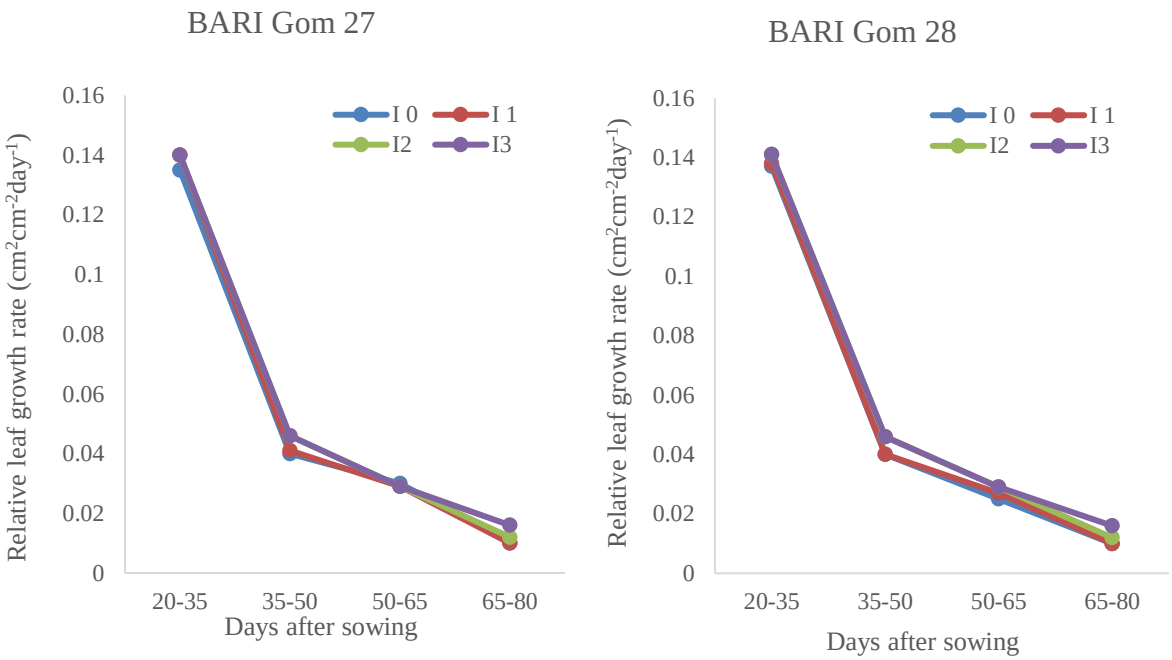
At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 40: Interaction effect of irrigation and potassium on relative leaf growth rate of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Interaction (Irrigation × Potassium)	A. Relative leaf growth rate ($cm^2cm^{-2}day^{-1}$) (2015-2016)				B. Relative leaf growth rate ($cm^2cm^{-2}day^{-1}$) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
$I_0 K_0$	0.121 e	0.033 h	0.023 f	0.015 c	0.124 e	0.033 g	0.024 g	0.015 c
$I_0 K_1$	0.141 b	0.037 f	0.028 e	0.007 h	0.141 b	0.038 e	0.030 f	0.007 h
$I_0 K_2$	0.139 bc	0.048 b	0.033 c	0.007 h	0.139 bc	0.048 b	0.033 c	0.007 h
$I_0 K_3$	0.139 bc	0.037 g	0.034 b	0.007 h	0.137 c	0.036 f	0.034 b	0.007 h
$I_1 K_0$	0.131 d	0.037 g	0.021 g	0.015 c	0.132 d	0.036 f	0.022 h	0.017 b
$I_1 K_1$	0.142 a	0.041 e	0.030 d	0.007 h	0.142 a	0.040 d	0.031 e	0.009 g
$I_1 K_2$	0.143 a	0.048 b	0.033 c	0.010 f	0.142 a	0.046 b	0.033 c	0.010 f
$I_1 K_3$	0.142 a	0.041 e	0.033 c	0.009 g	0.142 a	0.040 d	0.033 c	0.009 g
$I_2 K_0$	0.131 d	0.042 d	0.018 h	0.015 c	0.131 d	0.041 d	0.018 i	0.015 c
$I_2 K_1$	0.143 a	0.044 c	0.030 d	0.010 f	0.142 a	0.043 c	0.031 e	0.010 g
$I_2 K_2$	0.143 a	0.055 a	0.036 a	0.019 a	0.143 a	0.053 a	0.036 a	0.019 a
$I_2 K_3$	0.143 a	0.044 c	0.033 c	0.014 d	0.143 a	0.043 c	0.033 c	0.012 d
$I_3 K_0$	0.132 d	0.042 d	0.018 h	0.012 e	0.132 d	0.041 d	0.019 i	0.011 e
$I_3 K_1$	0.143 a	0.045 c	0.030 d	0.017 b	0.142 a	0.043 c	0.032 d	0.017 b
$I_3 K_2$	0.142 a	0.055 a	0.036 a	0.015 c	0.143 a	0.053 a	0.036 a	0.015 c
$I_3 K_3$	0.143 a	0.044 c	0.034 b	0.015 c	0.142 a	0.043 c	0.034 b	0.015 c
CV (%)	5.754	2.871	1.483	3.559	5.833	2.952	1.451	2.558

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

A



B

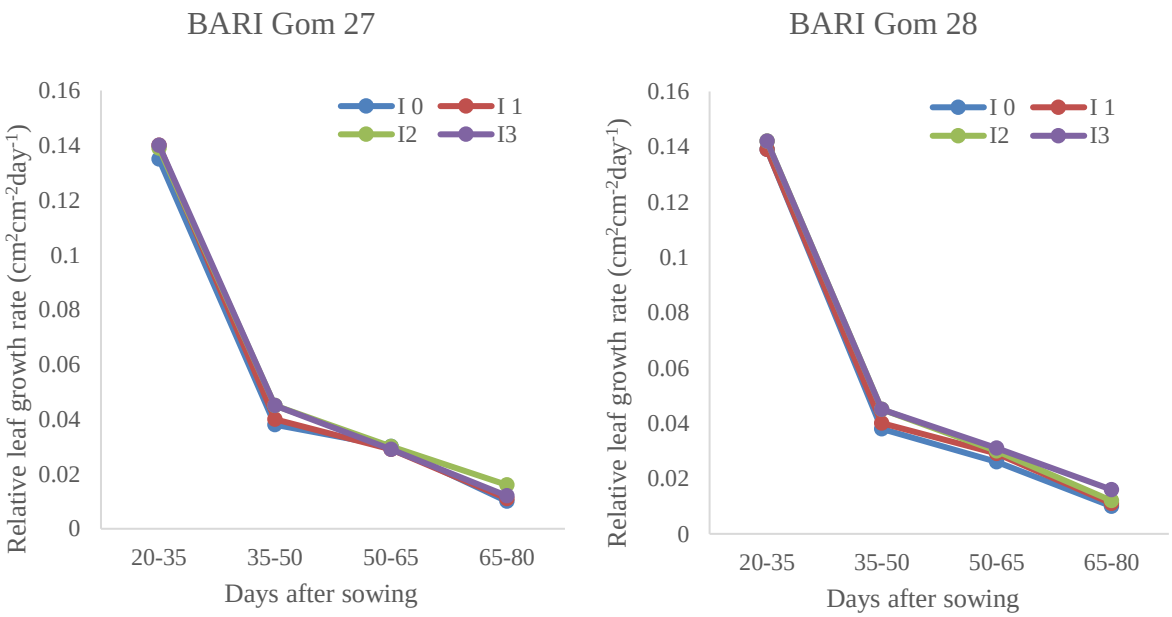
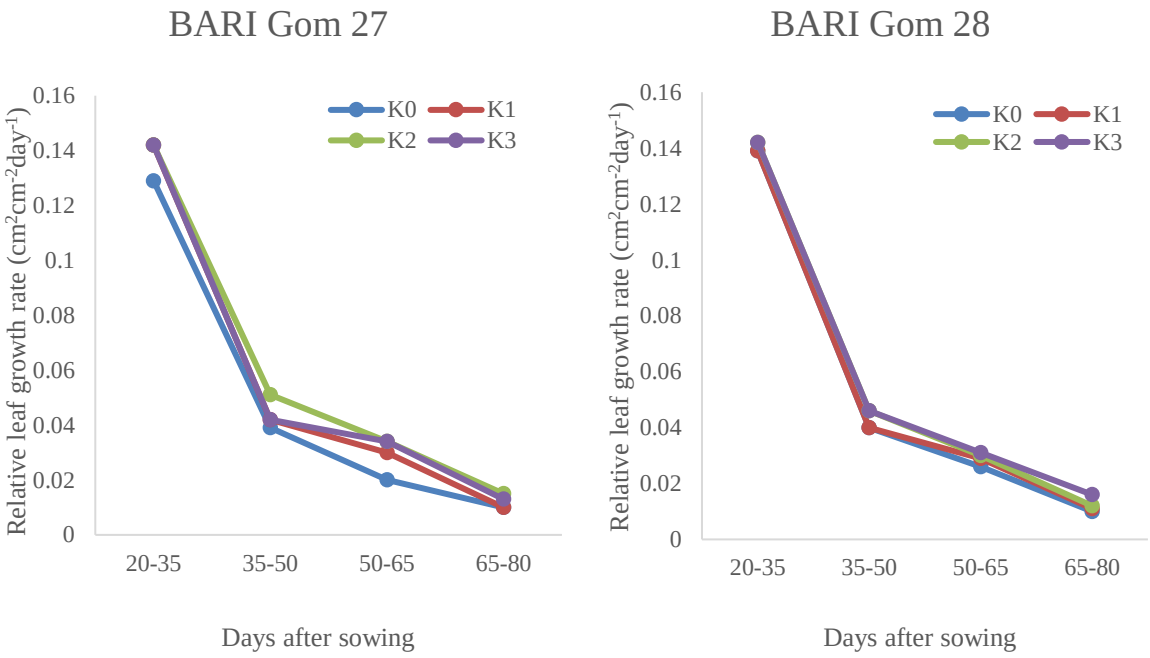


Fig. 19: Effect of irrigation on relative leaf growth rate (RLGR) at different days after sowing in 2015-2016 (A) and 2016-2017 (B)

A



B

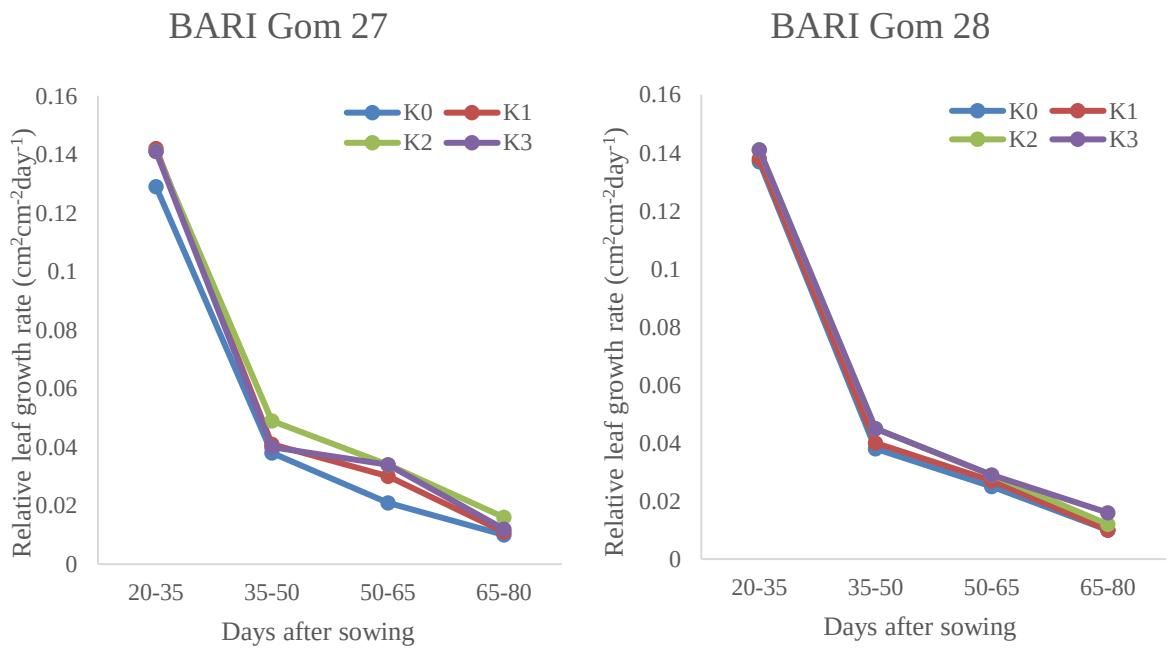


Fig. 20: Effect of potassium on relative leaf growth rate (RLGR) at different days after sowing in 2015-2016 (A) and 2016-2017 (B)

4.2.8 Specific leaf area

The effect of irrigation treatments on specific leaf area (SLA) at different growth stages are presented in Table 41A and Fig. 21A for first year (2015-2016) and Table 41B and Fig. 21B for second year (2016-2017) respectively. Irrigations showed significant effects on specific leaf area (SLA) at all the growing periods in both the growing seasons. In case of all growing periods, the highest SLA was observed in I_0 followed by I_1 and I_2 treatments and the lowest SLA was found in I_3 at all growing period in both the growing seasons. In all conditions, the higher SLA was found at the early stage of crop growth. Similar result was reported in wheat (Sarker and Paul, 1998). Zaman (2016) stated that the higher SLA was observed in water deficit condition than control in wheat (no water stress). The decline of SLA with increasing plant age was noticed in rape and turnip by Paul (1980), in jute by Saha (1983), in pearl millet by Chanda *et al.* (1987), in burley by Bahadur (2008), in wheat by Rahman (1993), Saha and Paul (1995) and Sarker and Paul (1998).

There was significant effect of variety on specific leaf area (SLA) at most of the growing periods except at 65-80 DAS are presented in Table 42A for first year (2015-2016) and Table 42B for second year (2016-2017) respectively. Within the periods of 20-35, 35-50 and 50-65 DAS, BARI Gom 28 (V_2) showed significantly higher SLA compared to BARI Gom 27 (V_1) at all growing staged in both the years.

Significant variation was observed in case of specific leaf area (SLA) with foliar applications of potassium during 50-65 and 65-80 DAS in both the years are presented in Table 43A and Fig. 22A for first year (2015-2016) and Table 43B and Fig. 22B for second year (2016-2017) respectively. Within the period of 20-35 and 35-50 DAS, SLA did not differ significantly in both the growing years. During 50-65 and 65-80 DAS, the maximum SLA was produced in K_0 treatment which was at par with K_3 and K_2 in first year of experiment (2015-2016) and only K_3 in second year of experiment (2016-2017). The minimum SLA was produced in K_2 at all crop growth stages during the two successive growing seasons. SLA values decreased with increasing plant dry weight was observed by Chanda *et al.* (1987) in pearl miller.

Different treatments of irrigation and potassium had significant influence on specific leaf area (SLA) of wheat at all the growing periods in both the years are shown in Table 44A for first year (2015-2016) and Table 44B for second year (2016-2017) respectively. The maximum SLA was achieved by the treatment of I_0K_0 at all crop growth periods in both the growing seasons.

Within the period of 20-35 DAS, the highest SLA was observed in I_0K_0 treatment which was statistically similar with I_0K_1, I_0K_2, I_0K_3, I_1K_0 and I_1K_1 treatments in both the years. Within 35-50 DAS, the highest SLA was observed in I_0K_0 treatment which was statistically similar with I_0K_1, I_0K_2, I_0K_3, I_1K_0, I_1K_1, I_1K_3 and I_2K_0 treatments in both the years. During 50-65 DAS, the highest SLA was observed in I_0K_0 treatment which was statistically similar with I_0K_2, I_0K_3, I_1K_1, I_1K_3 and I_2K_1 treatments in both the years. During 65-80 DAS, the highest SLA was observed in I_0K_0 treatment which was statistically similar with I_0K_2 and I_0K_3 treatments in both the years. The lowest SLA was found in I_3K_0 in all growth periods in both the growing seasons.

Table 41: Effect of irrigation on specific leaf area of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Irrigation	A. Specific leaf area (cm^2g^{-1}) (2015-2016)				B. Specific leaf area (cm^2g^{-1}) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
I_0	109.47 a	128.25 a	107.705 a	98.976 a	104.158 a	127.859 a	108.317 a	98.945 a
I_1	97.447 b	119.231 b	101.633 b	92.256 b	90.718 b	115.627 b	103.047 b	92.716 b
I_2	90.141 c	106.785 c	95.539 c	91.002 b	86.313 c	108.943 c	97.114 c	91.592 b
I_3	87.864 c	117.668 b	101.468 b	90.859 b	90.518 bc	115.168 b	101.848 b	93.056 b
CV (%)	7.234	8.543	9.564	8.567	18.237	17.274	9.169	8.625

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 42: Effect of variety on specific leaf area of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Variety	A. Specific leaf area (cm^2g^{-1}) (2015-2016)				B. Specific leaf area (cm^2g^{-1}) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
V_1	101.564 a	122.906 a	104.186 a	94.857 a	120.514 a	120.514 a	105.946 a	95.739 a
V_2	90.897 b	113.062 b	98.986 b	91.689 a	113.283 b	113.283 b	99.217 b	92.416 a
CV (%)	7.234	8.543	9.564	8.567	18.237	17.274	9.169	8.625

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 43: Effect of potassium on specific leaf area of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Potassium	A. Specific leaf area (cm^2g^{-1}) (2015-2016)				B. Specific leaf area (cm^2g^{-1}) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
K_0	97.59 a	119.852 a	105.307 a	97.185 a	94.281 a	118.664 a	106.267 a	97.98 a
K_1	94.324 a	117.899 a	94.615 b	82.175 b	91.023 a	116.229 a	102.621 a	97.853 a
K_2	96.099 a	115.171 a	101.637 a	96.708 a	92.771 a	114.444 a	95.685 b	83.03 b
K_3	96.909 a	119.013 a	104.786 a	97.022 a	93.632 a	118.258 a	105.751 a	97.448 a
CV (%)	7.234	8.543	9.564	8.567	18.237	17.274	9.169	8.625

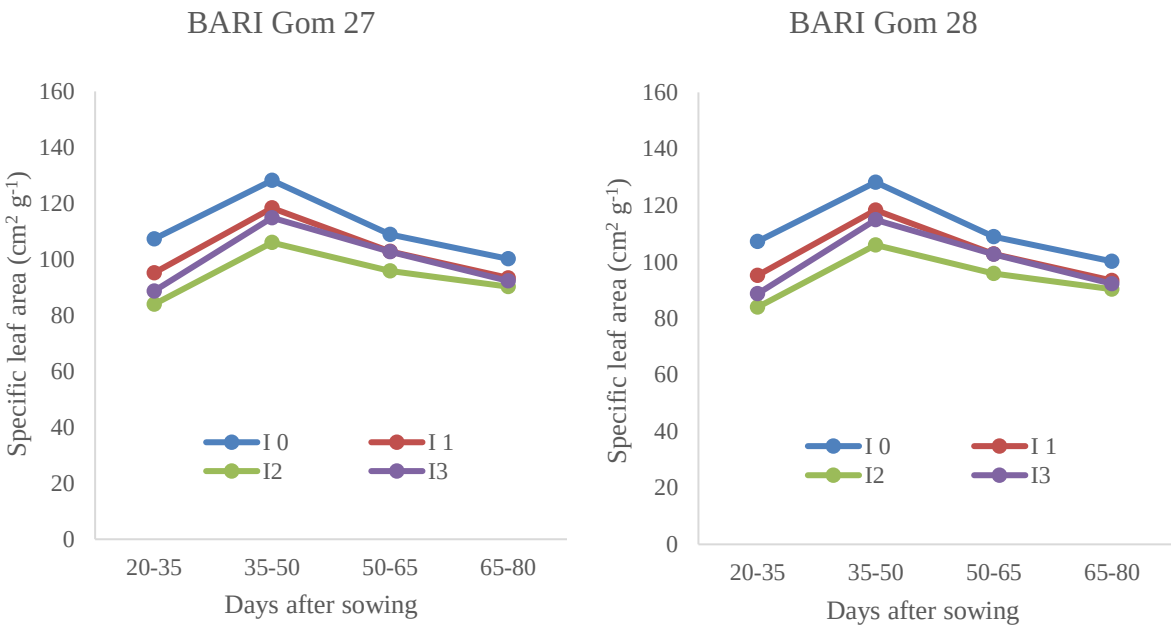
At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 44: Interaction effect of irrigation and potassium on specific leaf area of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Interaction (Irrigation × Potassium)	A. Specific leaf area (cm^2g^{-1}) (2015-2016)				B. Specific leaf area (cm^2g^{-1}) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
$I_0 K_0$	112.435 a	133.432 a	112.655 a	101.935 a	110.789 a	133.095 a	113.749 a	103.707 a
$I_0 K_1$	103.765 a-c	123.985 a-c	98.238 c-f	89.011 e	101.801 a-d	123.633 a-c	99.234 d-f	90.774 f
$I_0 K_2$	105.879 ab	126.908 a-c	108.706 ab	101.637 ab	104.982 a-c	126.556 a-c	109.841 a-c	102.225 ab
$I_0 K_3$	107.756 ab	129.872 ab	111.683 a	100.174 a-c	107.655 ab	129.519 ab	112.880 ab	104.662 a
$I_1 K_0$	99.342 a-d	121.908 a-d	95.822 ef	80.744 f	98.378 a-e	122.276 a-d	95.945 e-g	81.471 g
$I_1 K_1$	94.674 b-d	118.432 a-d	106.125 a-c	97.665 b-d	93.754 b-f	118.329 a-f	106.382 a-d	98.568 bc
$I_1 K_2$	91.789 cd	113.411 cd	102.109 b-e	95.052 d	90.873 c-f	113.5672 c-f	102.366 c-f	95.956 c-e
$I_1 K_3$	95.120 b-d	118.982 a-d	106.266 a-c	96.679 cd	94.456 b-f	119.153 a-e	106.556 a-d	97.574 cd
$I_2 K_0$	94.652 b-d	118.851 a-d	96.762 d-f	80.566 f	89.654 d-f	117.962 a-f	98.110 d-f	80.844 g
$I_2 K_1$	93.465 b-d	115.804 b-d	104.433 a-d	95.482 d	88.567 d-f	114.865 b-f	105.866 a-d	95.912 c-e
$I_2 K_2$	91.123 cd	112.671 cd	101.238 b-e	97.355 cd	85.644 ef	111.623 c-f	102.331 c-f	97.759 cd
$I_2 K_3$	93.209 b-d	115.122 b-d	103.844 b-e	94.231 d	87.765 d-f	115.064 b-f	104.451 b-e	94.562 d-f
$I_3 K_0$	87.523 d	106.611 d	90.083 f	78.787 f	81.234 f	103.262 f	89.262 g	78.662 g
$I_3 K_1$	90.382 cd	111.782 cd	90.911 c-e	93.773 d	84.435 ef	108.235 d-f	99.278 d-f	93.563 ef
$I_3 K_2$	88.231 d	108.239 d	96.539 d-f	95.429 d	82.456 f	104.690 ef	95.785 fg	95.266 c-e
$I_3 K_3$	90.345 cd	111.733 cd	99.967 c-e	93.855 d	84.387 ef	108.552 d-f	99.262 d-f	93.737 ef
CV (%)	7.234	8.543	9.564	8.567	18.237	17.274	9.169	8.625

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

A



B

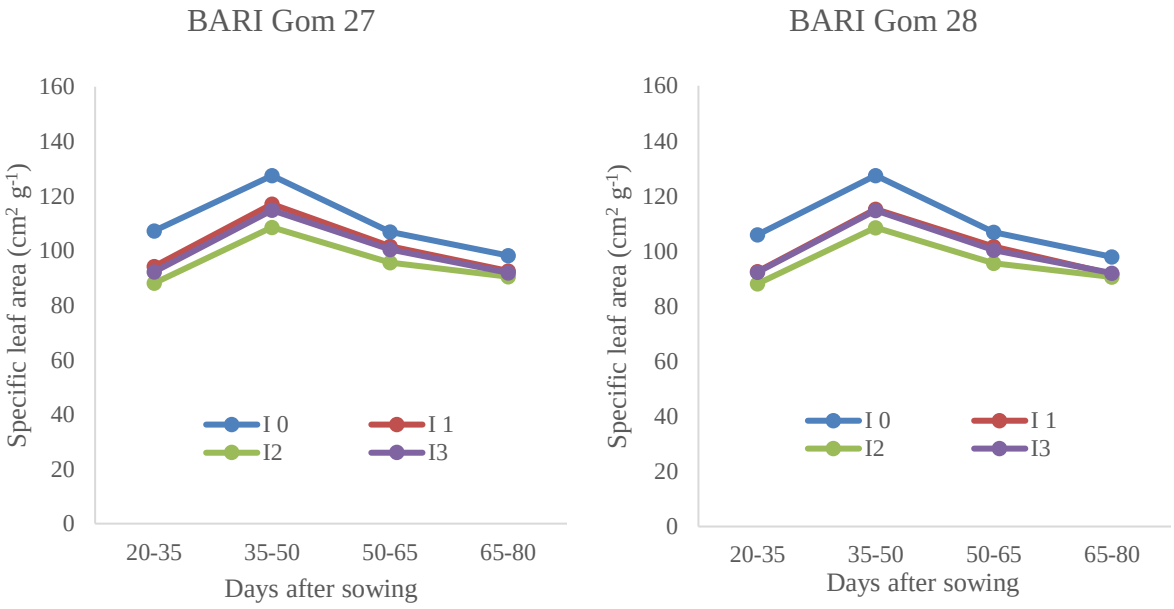
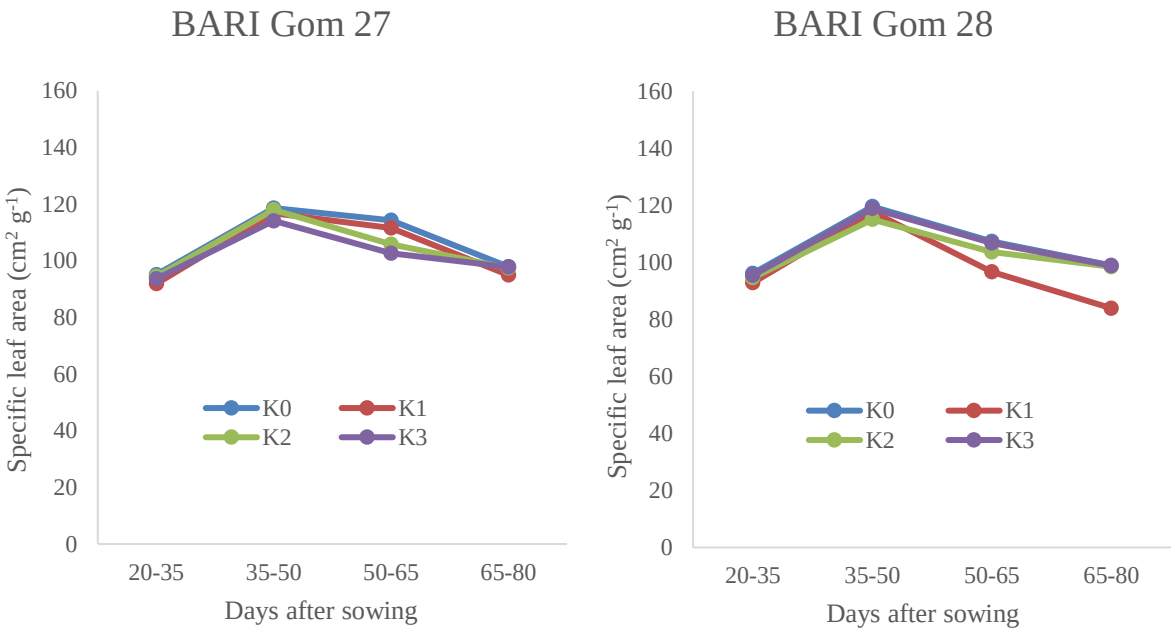


Fig. 21: Effect of irrigation on specific leaf area (SLA) at different days after sowing in 2015-2016 (A) and 2016-2017 (B)

A



B

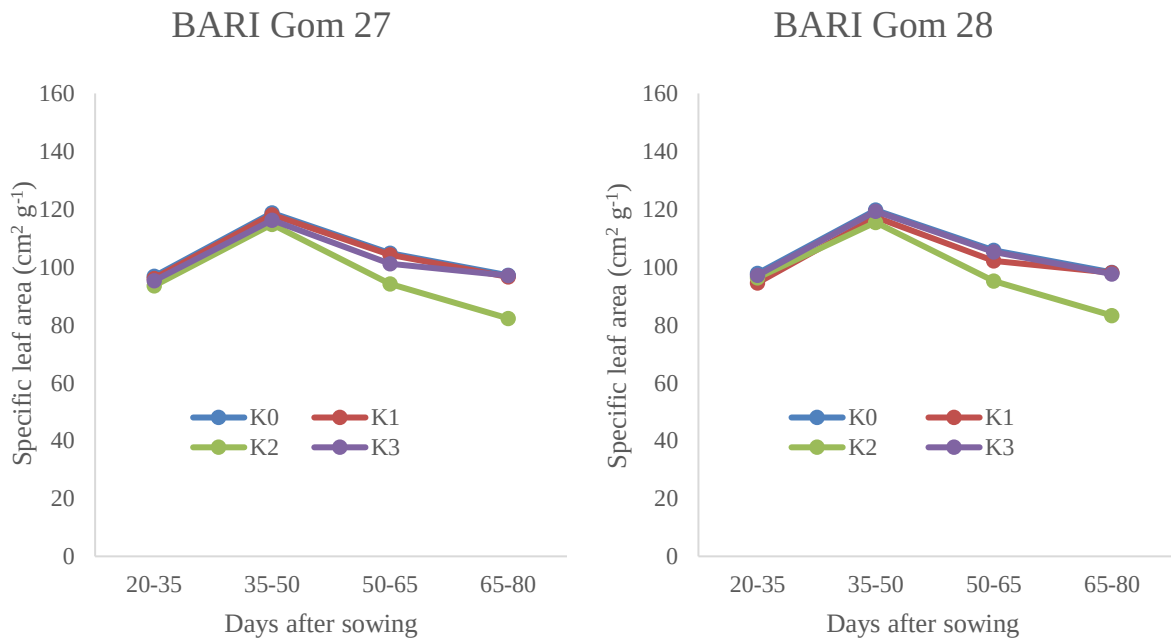


Fig. 22: Effect of potassium on specific leaf area (SLA) at different days after sowing in 2015-2016 (A) and 2016-2017 (B)

4.2.9 Leaf weight ratio

The effect of irrigation on leaf weight ratio (LWR) at different growth phases are presented in Table 45A and Fig. 23B for first year (2015-2016) and Table 45B and Fig. 23A for second year (2016-2017) respectively. During 20-25 and 35-50 DAS, the highest leaf weight ratio (LWR) was observed in I_2 and I_3 treatments which was at par with I_1 treatment in both the growing seasons. At 50-65 and 65-80 DAS, I_2 treatment exhibited higher LWR which was statistically similar with I_3 and I_1 followed by I_0 during the two successive growing seasons. The lowest LWR was shown in I_0 at all crop growth stages in both the growing seasons. In the presented study, the more LWR values were seen in irrigated plants. The increased of LWR in the irrigated plants might be due to increase leaf weight. The values of LWR showed downward drifts with age. Similar result was also found in wheat (Sarker and Paul 1998, Simane *et al.*, 1993 and Saha and Paul 1995). Saha and Paul (1995) studied LWR in wheat and reported that the sharp decrease in LWR at the later phases might be due to the sharp increase of TDM. The decline of LWR with age was also observed in wheat (Rahman, 1993). This result was also supported by Thorne (1960) and Rahman (2004) in wheat and Bahadur (2008) in barley.

LWR varied significantly due to varieties during 35-50 and 50-65 DAS while LWR did not differ significantly within the periods of 20-35 and 65-80 DAS in both the yearsss are shown in Table 46A for first year (2015-2016) and Table 46B for second year (2016-2017) respectively. Significantly higher LWR was observed in BARI Gom 28 (V_2) than BARI Gom 27 (V_1) at all growth phases in both the growing seasons.

The effects of foliar spray of potassium on leaf weight ratio (LWR) at different growth phases are presented in Table 47A and Fig. 24A for first year (2015-2016) and Table 47B and Fig. 24B for second year (2016-2017) respectively. The LWR showed a downward trend with plant age in all the treatments in both the years. LWR did not differ significantly within the period 20-35 and 35-50 DAS while LWR varied significantly within the period 50-65 and 65-80 DAS due to foliar applications of potassium during the two successive growing seasons. During 50-65 and 65-80 DAS, the highest LWR was found in K_0 and the lowest LWR was observed in K_3 in both the growing periods. The decrease of LWR was caused by increased plant dry weight and decreased LAI at the later phases. Saha and Paul (1995) observed sharp increase of total dry matter resulted in sharp decrease in LWR. Sharp decrease of LWR at the later stages in wheat was also noticed by Sarker and Paul (1998) and Nahar and Paul (1998).

LWR was significantly influenced by the interaction of irrigation and potassium during 50-65 and 65-80 DAS in both the years while LWR did not differ significantly within the periods of 20-35 and 35-50 DAS in both the years are shown in Table 48A for first year (2015-2016) and Table 48B for second year (2016-2017) respectively. During 50-65 DAS, the maximum LWR was observed in treatment of I_2K_2 which was statistically similar with I_2K_1, I_3K_1 and I_0K_1 treatments in the first year and I_3K_2, I_2K_0 and I_1K_3 treatments for second year of experiment (2016-2017). The minimum LWR was produced by the treatments of I_0K_0 at each crop growth phases in both the growing seasons.

Table 45: Effect of irrigation on leaf weight ratio of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Irrigation	A. Leaf weight ratio (g g^{-1}) (2015-2016)				B. Leaf weight ratio (g g^{-1}) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
I_0	0.538 b	0.452 b	0.353 b	0.319 b	0.533 b	0.453 b	0.351 b	0.32 b
I_1	0.541 ab	0.471 ab	0.367 a	0.336 ab	0.544 a	0.471 a	0.368 a	0.337 ab
I_2	0.557 a	0.474 a	0.369 a	0.339 a	0.548 a	0.473 a	0.37 a	0.34 a
I_3	0.553 a	0.472 a	0.366 a	0.335 ab	0.547 a	0.471 a	0.365 a	0.335 ab
CV (%)	12.678	13.642	6.452	6.442	12.876	13.345	6.431	6.582

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 46: Effect of variety on leaf weight ratio of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Variety	A. Leaf weight ratio (g g^{-1}) (2015-2016)				B. Leaf weight ratio (g g^{-1}) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
V_1	0.547 a	0.465 b	0.357 b	0.329 a	0.542 a	0.462 b	0.355 a	0.331 a
V_2	0.547 a	0.469 a	0.37 a	0.335 a	0.543 a	0.472 a	0.372 a	0.334 a
CV (%)	12.678	13.642	6.452	6.442	12.876	13.345	6.431	6.582

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 47: Effect of potassium on leaf weight ratio of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Potassium	A. Leaf weight ratio (g g^{-1}) (2015-2016)				B. Leaf weight ratio (g g^{-1}) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
K_0	0.547 a	0.462 a	0.352 b	0.317 b	0.543 a	0.466 a	0.351 b	0.316 b
K_1	0.541 a	0.467 a	0.383 a	0.318 b	0.544 a	0.466 a	0.356 b	0.319 b
K_2	0.551 a	0.47 a	0.358 a	0.376 a	0.545 a	0.469 a	0.396 a	0.377 a
K_3	0.55 a	0.467 a	0.362 a	0.318 b	0.541 a	0.465 a	0.354 b	0.32 b
CV (%)	12.678	13.642	6.452	6.442	12.876	13.345	6.431	6.582

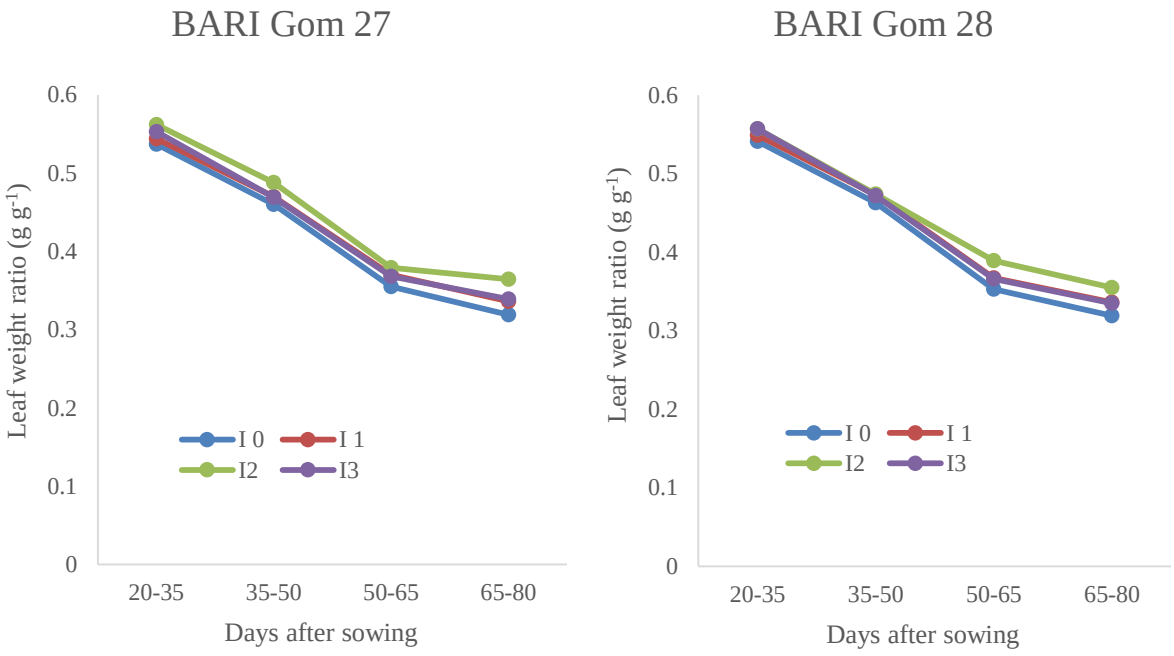
At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 48: Interaction effect of irrigation and potassium on leaf weight ratio of wheat at different days after sowing (DAS) in 2015-2016 (left) and 2016-2017 (right)

Interaction (Irrigation × Potassium)	A. Leaf weight ratio (g g^{-1}) (2015-2016)				B. Leaf weight ratio (g g^{-1}) (2016-2017)			
	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS	20-35 DAS	35-50 DAS	50-65 DAS	65-80 DAS
$I_0 K_0$	0.541 a	0.455 a	0.340 c	0.303 d	0.532 a	0.453 a	0.339 cd	0.304 d
$I_0 K_1$	0.546 a	0.471 a	0.391 a	0.364 b	0.545 a	0.453 a	0.337 d	0.305 d
$I_0 K_2$	0.535 a	0.456 a	0.344 bc	0.305 d	0.534 a	0.454 a	0.340 cd	0.306 d
$I_0 K_3$	0.535 a	0.457 a	0.343 bc	0.317 c	0.533 a	0.469 a	0.357 bc	0.318 c
$I_1 K_0$	0.542 a	0.468 a	0.359 bc	0.320 c	0.544 a	0.470 a	0.356 b-d	0.318 c
$I_1 K_1$	0.533 a	0.472 a	0.358 bc	0.383 a	0.543 a	0.473 a	0.357 bc	0.365 b
$I_1 K_2$	0.548 a	0.469 a	0.360 bc	0.325 c	0.547 a	0.472 a	0.358 bc	0.320 c
$I_1 K_3$	0.549 a	0.471 a	0.356 bc	0.304 d	0.551 a	0.471 a	0.387 a	0.326 c
$I_2 K_0$	0.554 a	0.472 a	0.361 b	0.324 c	0.541 a	0.473 a	0.397 a	0.325 c
$I_2 K_1$	0.557 a	0.470 a	0.396 a	0.391 a	0.547 a	0.469 a	0.363 b	0.326 c
$I_2 K_2$	0.552 a	0.469 a	0.402 a	0.325 c	0.550 a	0.474 a	0.400 a	0.392 a
$I_2 K_3$	0.551 a	0.473 a	0.358 bc	0.367 b	0.545 a	0.470 a	0.361 b	0.368 b
$I_3 K_0$	0.545 a	0.465 a	0.353 bc	0.317 c	0.543 a	0.469 a	0.356 b-d	0.323 c
$I_3 K_1$	0.556 a	0.468 a	0.393 a	0.323 c	0.548 a	0.466 a	0.364 b	0.325 c
$I_3 K_2$	0.555 a	0.470 a	0.360 bc	0.324 c	0.548 a	0.470 a	0.398 a	0.384 a
$I_3 K_3$	0.551 a	0.468 a	0.356 bc	0.323 c	0.544 a	0.469 a	0.360 b	0.324 c
CV (%)	12.678	13.642	6.452	6.442	12.876	13.345	6.431	6.582

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

A



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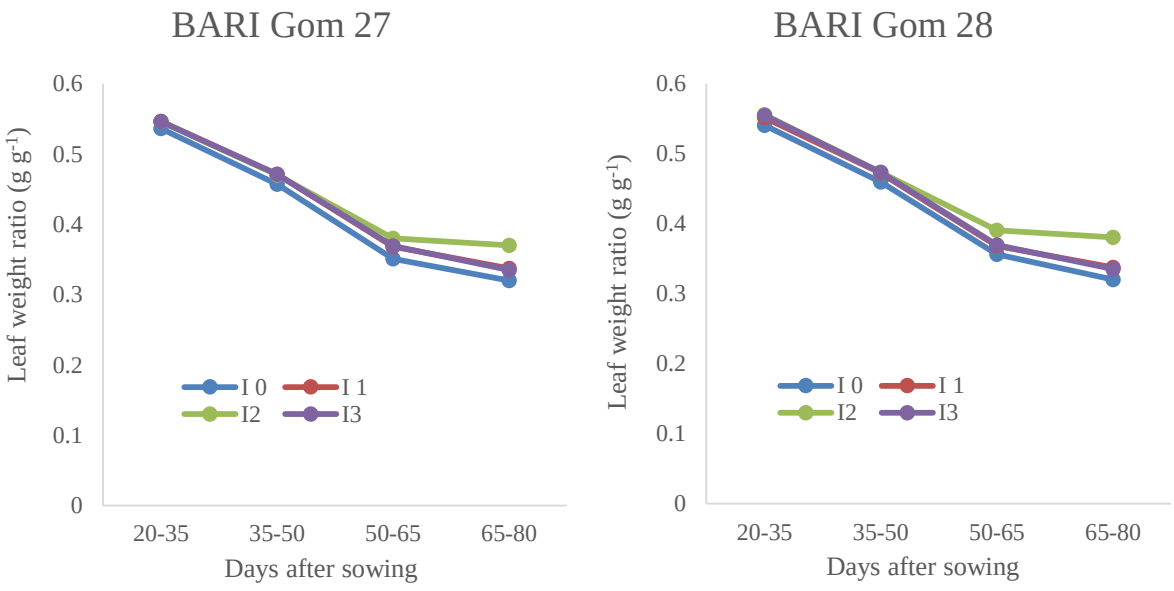


Fig. 23: Effect of irrigation on leaf weight ratio (LWR) at different days after sowing in 2015-2016 (A) and 2016-2017 (B)

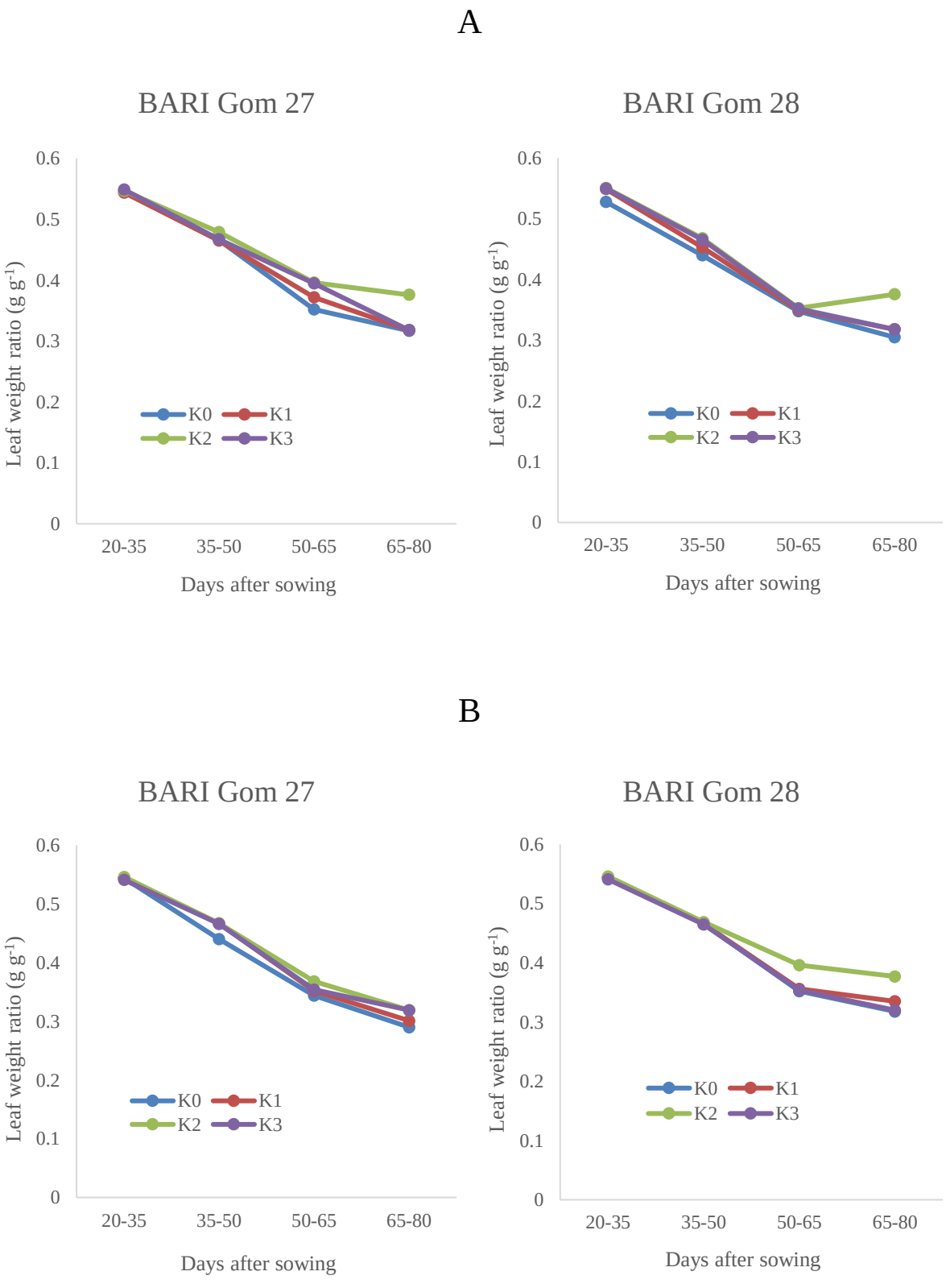


Fig. 24: Effect of potassium on leaf weight ratio (LWR) at different days after sowing in 2015-2016 (A) and 2016-2017 (B)

4.3 Different phenological stages

Number of days required for attaining different phenological stages varied significantly due to irrigation regimes in both the years are presented in Table 49 for first year (2015-2016) and Table 50 for second year (2016-2017) respectively. Days required for crown root initiation were non-significant due to irrigation in both the years. Days required for crown root initiation for all treatments were almost similar as no supplemental irrigation was applied before that stage to any treatment. But days required for booting, heading, anthesis and physiological maturity showed significant differences due to variation of irrigation levels. The time taken for booting, heading, anthesis and physiological maturity increased with increasing irrigation levels. The plants grown in I_3 (Irrigation with 4400 m^3 ha^{-1}) condition needed higher days for booting, heading, anthesis and physiological maturity followed by I_2 and I_1 treatments and I_0 plants required the lowest days for attaining these stages in both the growing seasons. It might be due to the sufficient availability of water at those stages with more uptakes of nutrients. Similar results were also reported by Pal *et al.* (1996). Day *et al.* (1970) opined that maturity of wheat plants was faster due to the drought stress at flowering and dough stages. Mostafavi and Niknejad (1983), Gales and Wilson (1979) noticed that the plants suffering water shortage matured earlier than the well-watered wheat plants. Haider (2002) and Ngwako and Mashiqa (2013) also reported similar result with wheat varieties. Bahadur (2008) also found similar results in barley.

Variety had no significant effect on phenological stages in both the years are shown in Table 51 for first year (2015-2016) and Table 52 for second year (2016-2017) respectively. Between the two varieties, BARI Gom 28 required maximum days for attaining their different phenological stages in both the growing seasons.

Foliar applications of potassium had significant effect on phenological stages in both the years are presented in Table 53 for first year (2015-2016) and Table 54 for second year (2016-2017) respectively. The more days to crown root initiation and tillering were observed in K_1 followed by K_2 and K_3 and the least days to crown root initiation and tillering were observed in K_0 in both the years. The more days to booting, heading and anthesis were recorded in case of K_2 followed by K_3 and less days were required in K_0 in both the growing seasons. In case of physiological maturity stages, more days were required in K_3 followed by K_2 and least days for physiological maturity was recorded in K_0 in both the growing seasons. Similar results were recorded by Hasina *et al.* (2011) and Aown *et al*. (2012) in wheat.

The combined effects of irrigation regimes and foliar applications of potassium on phenology are presented in Table 55 for first year (2015-2016) and Table 56 for second year (2016-2017). The interaction effect between irrigation and foliar applications of potassium were significant for the phenology of wheat. The longest time to crown root initiation was observed in I_0K_1, I_1K_1 and I_2K_1 followed by I_3K_1 and the shortest time was required in I_3K_0 followed by I_1K_0 in both the years. The maximum days required for tillering in I_1K_1, I_2K_1 and I_3K_1 followed by I_0K_1 and the minimum days required for tillering in I_0K_0 followed by I_1K_0 and I_3K_0 in both the years. The longest time to booting, heading and anthesis were recorded in I_3K_2 followed by I_3K_3 and I_2K_2 and the shortest time was needed in I_0K_0 in both the growing seasons. The maximum days needed for physiological maturity in I_3K_3 which was statistically similar with I_3K_2 and the minimum days required in I_0K_0 in both the years

Table 49: Effect of irrigation on the phenological stages of wheat in 2015-2016

Irrigation	Crown root initiation stage (days)	Tillering stage (days)	Booting stage (days)	Heading stage (days)	Anthesis stage (days)	Physiological maturity stage (days)
I_0	18.750 a	22.125 b	52.208 d	58.125 c	62.917 c	92.208 d
I_1	18.958 a	23.208 a	54.500 c	60.542 b	65.250 bc	95.167 c
I_2	18.958 a	23.542 a	56.208 b	62.500 ab	67.250 ab	98.917 b
I_3	19.083 a	23.458 a	57.875 a	63.917 a	68.583 a	102.083 a
CV (%)	6.94	7.63	4.38	4.75	3.23	2.7

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability

Table 50: Effect of irrigation on the phenological stages of wheat in 2016-2017

Irrigation	Crown root initiation stage (days)	Tillering stage (days)	Booting stage (days)	Heading stage (days)	Anthesis stage (days)	Physiological maturity stage (days)
I_0	19.125 a	22.789 b	54.036 d	60.218 c	65.056 c	93.591 d
I_1	19.338 a	23.905 a	56.408 c	62.721 b	67.469 bc	96.594 c
I_2	19.338 a	24.248 a	58.176 b	64.750 ab	69.537 ab	100.400 b
I_3	19.465 a	24.162 a	59.901 a	66.218 a	70.915 a	103.615 a
CV (%)	5.12	5.53	4.07	5.44	6.22	4.93

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 51: Effect of variety on the phenological stages of wheat in 2015-2016

Variety	Crown root initiation stage (days)	Tillering stage (days)	Booting stage (days)	Heading stage (days)	Anthesis stage (days)	Physiological maturity stage (days)
V_1	18.688 a	22.854 a	54.958 a	61.083 a	65.313 a	96.792 a
V_2	19.188 a	23.312 a	55.438 a	61.458 a	66.688 a	97.396 a
CV (%)	6.94	7.63	4.38	4.75	3.23	2.76

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 52: Effect of variety on the phenological stages of wheat in 2016-2017

Variety	Crown root initiation stage (days)	Tillering stage (days)	Booting stage (days)	Heading stage (days)	Anthesis stage (days)	Physiological maturity stage (days)
V_1	19.062 a	23.540 a	56.882 a	63.282 a	67.533a	98.244 a
V_2	19.571 a	24.012 a	57.378 a	63.671 a	68.955 a	98.856 a
CV (%)	5.12	5.53	4.07	5.44	6.22	4.93

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 53: Effect of potassium on the phenological stages of wheat in 2015-2016

Potassium level	Crown root initiation stage (days)	Tillering stage (days)	Booting stage (days)	Heading stage (days)	Anthesis stage (days)	Physiological maturity stage (days)
K_0	17.583 d	21.500 c	52.500 c	56.958 c	61.458 c	92.333 c
K_1	20.708 a	24.458 a	55.167 b	60.917 b	65.208 b	95.875 b
K_2	19.167 b	23.500 b	57.083 a	64.708 a	69.208 a	99.417 a
K_3	18.292 c	22.875 b	56.042 ab	62.500 b	68.125 a	100.750 a
CV (%)	6.94	7.63	4.38	4.75	3.23	2.76

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 54: Effect of potassium on the phenological stages of wheat in 2016-2017

Potassium level	Crown root initiation stage (days)	Tillering stage (days)	Booting stage (days)	Heading stage (days)	Anthesis stage (days)	Physiological maturity stage (days)
K_0	17.935 d	22.145 c	54.338 c	59.009 c	63.548 c	93.718 c
K_1	21.123 a	25.192 a	57.098 b	63.110 b	67.425 b	97.313 b
K_2	19.550 b	24.205 b	59.081 a	67.038 a	71.561 a	100.908 a
K_3	18.658 c	23.561 b	58.003 ab	64.750 b	70.441 a	102.261 a
CV (%)	5.12	5.53	4.07	5.44	6.22	4.93

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 55: Interaction effect of irrigation and potassium on the phenological stages of wheat in 2015-2016

Interaction (irrigation x potassium)	Crown root initiation stage (days)	Tillering stage (days)	Booting stage (days)	Heading stage (days)	Anthesis stage (days)	Physiological maturity stage (days)
$I_0 K_0$	17.833 c-e	20.833 f	49.500 j	53.833 i	58.333 i	88.333 h
$I_0 K_1$	20.833 a	23.333 a-d	52.333 i	58.000 g	62.500 gh	90.500 g
$I_0 K_2$	19.333 a-c	22.500 c-e	53.833 gh	61.333 de	65.833 d-f	94.167 f
$I_0 K_3$	18.333 c-e	21.833 d-f	53.167 hi	59.333 fg	65.000 ef	95.833 e
$I_1 K_0$	17.667 de	21.667 ef	51.833 i	56.333 h	60.833 h	90.833 g
$I_1 K_1$	20.833 a	24.833 a	54.500 f-h	60.167 ef	64.500 e-g	94.000 f
$I_1 K_2$	19.000 b-d	23.500 a-c	56.333 de	63.833 c	68.333 c	97.000 de
$I_1 K_3$	18.333 c-e	22.833 b-e	55.333 ef	61.833 d	67.333 cd	98.833 c
$I_2 K_0$	17.833 c-e	21.833 d-f	53.833 gh	58.333 g	62.833 gh	93.833 f
$I_2 K_1$	20.833 a	24.833 a	55.833 d-f	61.833 d	66.000 de	97.667 cd
$I_2 K_2$	19.000 b-d	24.167 ab	58.333 b	66.333 ab	70.833 ab	101.333 b
$I_2 K_3$	18.167 c-e	23.333 a-d	56.833 cd	63.500 c	69.333 bc	102.833 b
$I_3 K_0$	17.000 e	21.667 ef	54.833 fg	59.333 fg	63.833 fg	96.333 de
$I_3 K_1$	20.333 ab	24.833 a	58.000 bc	63.667 c	67.833 cd	101.333 b
$I_3 K_2$	19.333 a-c	23.833 a-c	59.833 a	67.333 a	71.833 a	105.167 a
$I_3 K_3$	18.333 c-e	23.500 a-c	58.833 ab	65.333 b	70.833 ab	105.500 a
CV (%)	6.94	7.63	4.38	4.75	3.23	2.76

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 56: Interaction effect of Irrigation and Potassium on the phenological stages of wheat in 2016-2017

Interaction (Irrigation × Potassium)	Crown root initiation stage	Tillering stage	Booting stage	Heading stage	Anthesis stage	Physiological maturity stage
$I_0 K_0$	18.190 c-e	21.458 f	51.233 j	55.771 i	60.317 i	89.658 h
$I_0 K_1$	21.250 a	24.033 a-d	54.165 i	60.088 g	64.625 gh	91.858 g
$I_0 K_2$	19.720 a-c	23.175 c-e	55.718 gh	63.541 de	68.072 d-f	95.579 f
$I_0 K_3$	18.700 c-e	22.488 d-f	55.028 hi	61.469 fg	67.210 ef	97.271 e
$I_1 K_0$	18.020 de	22.317 ef	53.648 i	58.361 h	62.902 h	92.196 g
$I_1 K_1$	21.250 a	25.578 a	56.408 f-h	62.333 ef	66.693 e-g	95.410 f
$I_1 K_2$	19.380 b-d	24.205 a-c	58.305 de	66.131 c	70.657 c	98.455 de
$I_1 K_3$	18.700 c-e	23.518 b-e	57.270 ef	64.059 d	69.623 cd	100.316 c
$I_2 K_0$	18.190 c-e	22.488 d-f	55.718 gh	60.433 g	64.970 gh	95.241 f
$I_2 K_1$	21.250 a	25.578 a	57.788 d-f	64.059 d	68.244 de	99.132 cd
$I_2 K_2$	19.380 b-d	24.892 ab	60.375 b	68.721 ab	73.242 ab	102.853 b
$I_2 K_3$	18.530 c-e	24.033 a-d	58.823 cd	65.786 c	71.691 bc	104.376 b
$I_3 K_0$	17.340 e	22.317 ef	56.753 fg	61.469 fg	66.004 fg	97.778 de
$I_3 K_1$	20.740 ab	25.578 a	60.030 bc	65.959 c	70.140 cd	102.853 b
$I_3 K_2$	19.720 a-c	24.548 a-c	61.928 a	69.757 a	74.276 a	106.744 a
$I_3 K_3$	18.710 c-e	24.205 a-c	60.893 ab	67.687 b	73.242 ab	107.083 a
CV (%)	5.12	5.53	4.07	5.44	6.22	4.93

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

4.4 Plant height, dry weight and leaf area at different phenological stages

4.4.1 Crown root initiation stage

The effect of irrigation on plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} at the crown root initiation stage are presented in Table 57A for first year (2015-2016) and in Table 57B for second year (2016-2017) respectively. Irrigation had significant effect on leaf dry weight plant^{-1}, stem dry weight plant^{-1} and total dry weight plant^{-1} at crown root initiation (CRI) stage in both the years. At crown root initiation stage (CRI stage), the highest plant height was recorded in I_3 (Irrigation with 4400 m^3 ha^{-1}) which was statistically identical to all other treatments in both the growing seasons and the minimum plant height was recorded in I_0 in both the growing seasons. The maximum leaf dry weight plant^{-1}, stem dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} was recorded in I_2 which was statistically identical to I_3 and I_1 and the minimum values were recorded in I_0 in both the growing seasons. Plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} were almost similar up to the crown root initiation stage, as no supplemental irrigation was applied before that stage to any treatment. This findings is in agreement with Sarker *et al*. (2013) and Mesbah (2009).

Leaf dry weight plant^{-1}, stem dry weight plant^{-1} and total dry weight plant^{-1} varied significantly due to varieties at crown root initiation (CRI) stage in both the years and plant height and leaf area plant^{-1} did not differ significantly due to varieties at crown root initiation (CRI) stage in both the years are shown in Table 58A for first year (2015-2016) and in Table 58B for second year (2016-2017) respectively Higher leaf dry weight plant^{-1}, stem dry weight plant^{-1} and total dry weight plant^{-1} were observed in BARI Gom 28 (V_2) than BARI Gom 27 (V_1) at crown root initiation (CRI) stage during the two successive growing seasons.

Plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} at crown root initiation (CRI) stage were significantly influenced due to foliar applications of potassium in both the years are presented in Table 59A for first year (2015-2016) and in Table 59B for second year (2016-2017) respectively. The highest plant height was recorded in K_1 followed by K_2 and the lowest plant height was found in K_0 at CRI stage in both the growing seasons. Maximum leaf dry weight plant^{-1}, stem dry weight plant^{-1}, total dry weight plant^{-1} was recorded in K_2 which was statistically identical to K_3 and K_1 and the minimum values were recorded in K_0 at CRI stage in both the seasons. At CRI stage, the highest leaf area plant^{-1} was shown in K_2 followed by K_1 and the minimum leaf area plant^{-1} was found in K_1 in

both growing seasons. Khursheed and Mahammad (2015) reported that potassium fertilizer significantly increased plant height, shoot dry weight and leaf area. Similar findings were reported by Hasina *et al.* (2011) and Aown *et al*. (2012) in wheat.

Interaction effect of irrigation and potassium had significant effect on plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} at crown root initiation (CRI) stage in both the years are shown in Table 60A for first year (2015-2016) and in Table 60B for second year (2016-2017) respectively. With a few exceptions, the highest plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1}was observed in irrigated plant with I_1K_1, I_2K_1 and I_3K_1 and the lowest value was obtained in I_0K_0 at crown root initiation (CRI) stage in both the years.

Table 57: Effect of irrigation on plant height, dry weights and leaf area of wheat at crown root initiation stage in 2015-2016 (A) and 2016-2017 (B)

Irrigation	A. 2015-2016					B.2016-2017				
	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
I_0	20.380 a	0.142 b	0.120 b	0.262 b	10.105 a	20.769 a	0.144 b	0.122 b	0.266 b	10.281 a
I_1	20.281 a	0.167 a	0.134 a	0.301 a	10.145 a	20.639 a	0.170 a	0.136 a	0.306 a	10.323 a
I_2	20.244 a	0.169 a	0.142 a	0.306 a	10.181 a	20.605 a	0.172 a	0.140 a	0.314 a	10.345 a
I_3	20.435 a	0.168 a	0.135 a	0.303 a	10.159 a	20.785 a	0.171 a	0.138 a	0.309 a	10.343 a
CV (%)	9.542	10.420	8.221	7.512	4.651	8.879	9.563	7.657	8.021	5.423

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 58: Effect of variety on plant height, dry weights and leaf area of wheat at crown root initiation stage in 2015-2016 (A) and 2016-2017 (B)

Variety	A. 2015-2016					B.2016-2017				
	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
V_1	20.261 a	0.149 b	0.122 b	0.271 b	10.154 a	20.624 a	0.151 b	0.124 b	0.275 b	10.330 a
V_2	20.409 a	0.175 a	0.142 a	0.317 a	10.141 a	20.775 a	0.177 a	0.145 a	0.323 a	10.316 a
CV (%)	9.542	10.420	8.221	7.512	4.651	8.879	9.563	7.657	8.021	5.423

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 59: Effect of potassium on plant height, dry weights and leaf area of wheat at crown root initiation stage in 2015-2016 (A) and 2016-2017 (B)

Potassium	A. 2015-2016					B.2016-2017				
	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
K_0	19.026 d	0.131 b	0.106 b	0.237 b	8.669 c	19.367 d	0.133b	0.108 b	0.241 b	8.817 d
K_1	21.589 a	0.174 a	0.141 a	0.315 a	10.499 b	21.976 a	0.176 a	0.143 a	0.319 a	10.681 b
K_2	20.616 b	0.177 a	0.144 a	0.321 a	11.092 a	20.986 b	0.180 a	0.147 a	0.327 a	11.284 a
K_3	20.109 c	0.165 a	0.137 a	0.302 a	10.331 c	20.469 c	0.168 a	0.140 a	0.308 a	10.510 c
CV (%)	9.542	10.420	8.221	7.512	4.651	8.879	9.563	7.657	8.021	5.423

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 60: Interaction effect of irrigation and potassium on plant height, dry weights and leaf area of wheat at crown root initiation stage in 2015-2016 (A) and 2016-2017 (B)

Interaction (Irrigation× Potassium)	A. 2015-2016					B.2016-2017				
	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
I_0K_0	19.175 d	0.126 d	0.102 d	0.228 e	8.636 e	19.542 d	0.128 d	0.104 d	0.232 e	8.793 e
I_0K_1	21.522 ab	0.151 b-d	0.129 a-c	0.280 b-e	11.059 a	21.933 a	0.153 b-d	0.131 a-c	0.284 b-e	11.260 a
I_0K_2	20.659 c	0.148 cd	0.127 a-c	0.275 c-e	10.439 bc	21.054 c	0.150 cd	0.129 a-c	0.279 c-e	10.628 bc
I_0K_3	20.163 c	0.142 cd	0.123 b-d	0.265 de	10.286 d	20.549 c	0.144 cd	0.125 b-d	0.269 de	10.473 d
I_1K_0	18.916 d	0.132 d	0.106 cd	0.238 e	8.693 e	19.251 d	0.134 d	0.108 cd	0.242 e	8.838 e
I_1K_1	21.516 ab	0.186 a	0.150 a	0.336 a	11.098 a	21.896 ab	0.189 a	0.153 a	0.342 a	11.283 a
I_1K_2	20.618 c	0.182 ab	0.145 ab	0.327 a-c	10.508 b	20.983 c	0.185 ab	0.147 ab	0.332 a-c	10.683 b
I_1K_3	20.072 c	0.171 a-c	0.142 ab	0.313 a-d	10.336 cd	20.426 c	0.174 a-c	0.144 ab	0.318 a-d	10.508 d
I_2K_0	18.978 d	0.132 d	0.107 cd	0.239 e	8.651 e	19.317 d	0.134 d	0.109 cd	0.243 e	8.803 e
I_2K_1	21.579 a	0.184 a	0.149 a	0.333 ab	11.091 a	21.964 a	0.187 a	0.152 a	0.339 ab	11.287 a
I_2K_2	20.425 c	0.181 ab	0.144 ab	0.325 a-c	10.505 b	20.789 c	0.184 ab	0.147 ab	0.331 a-c	10.690 b
I_2K_3	19.994 c	0.173 a-c	0.142 ab	0.315 a-d	10.335 cd	20.351 c	0.176 a-c	0.144 ab	0.320 a-d	10.517 d
I_3K_0	19.034 d	0.136 d	0.110 cd	0.246 e	8.694 e	19.361 d	0.137d	0.112 cd	0.249 e	8.840 e
I_3K_1	21.737 a	0.187 a	0.150 a	0.337 a	11.118 a	22.110 a	0.190 a	0.153 a	0.343 a	11.305 a
I_3K_2	20.763 bc	0.183 a	0.147 a	0.330 ab	10.546 b	21.119 bc	0.186 a	0.150 a	0.336 ab	10.723 b
I_3K_3	20.205 c	0.173 a-c	0.143 ab	0.316 a-d	10.366 cd	20.551 c	0.176 a-c	0.145 ab	0.321 a-d	10.540 cd
CV (%)	9.542	10.420	8.221	7.512	4.651	8.879	9.563	7.657	8.021	5.423

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

4.4.2 Tillering stage

Irrigation had significant effect on plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1} and total dry weight plant^{-1} and no significant effect on leaf area plant^{-1} at tillering stage in both the years are presented in Table 61A for first year (2015-2016) and in Table 61B for second year (2016-2017) respectively. The highest plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1} and total dry weight plant^{-1} was recorded in I_2 which was statistically identical to I_3 and I_1 and lowest values for above parameters were recorded in I_0 at tillering stage during the two successive growing seasons. No significant variation was found in case of leaf area plant^{-1} at tillering stage in both growing seasons. Many other scientists reported similar findings in wheat (Mollah and Paul, 2011, Naeem Sarwar, 2010, Pandit *et al.*, 2001 and Nahar and Paul, 1998). Similar result was reported by Abdorrahmani *et al.* (2005) and Ashok and Sharma (2004) in wheat.

Leaf dry weight plant^{-1}, stem dry weight plant^{-1} and total dry weight plant^{-1} varied significantly due to varieties at tillering stage in both the years are shown in Table 62A for first year (2015-2016) and Table 62B for second year (2016-2017) respectively. Higher leaf dry weight plant^{-1}, stem dry weight plant^{-1} and total dry weight plant^{-1} were observed in BARI Gom 28 (V_2) than BARI Gom 27 (V_1) at tillering stage during the two successive growing seasons.

Foliar applications of potassium had significant effects on plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} at tillering stage in both the years are presented in Table 63A for first year (2015-2016) and in Table 63B for second year (2016-2017) respectively. During tillering stage, the highest plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1} and total dry weight plant^{-1} was recorded in K_2 which was statistically identical to K_3 and K_1 and lowest values were recorded in K_0 at tillering stage during the two successive growing seasons. The maximum leaf area plant^{-1} was observed in K_2 which was statically identical to K_3 and K_1 and the minimum leaf area plant^{-1} was observed in K_0 at tillering stage in both the growing seasons. Khursheed and Mahammad (2015) reported that potassium significantly increased plant height, shoot dry weight and leaf area. Chaturvedi (2006) reported that plant height and TDM increased with increasing potassium availability at all critical stages. Ananda (2004) reported that foliar application of potassium recorded maximum plant height of wheat. Wagan *et al.* (2002) reported that potassium applied in three split doses significantly increased plant height.

Plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} in both the years varied significantly due to interaction of irrigation and potassium at tillering stage are shown in Table 64A for first year (2015-2016) and in Table 64B for second year (2016-2017) respectively. With a few exceptions, irrigated plants with foliar application of potassium were produced the highest plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} in both the years. The lowest values of plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} were obtained in I_0K_0 during the two successive growing years.

Table 61: Effect of irrigation on plant height, dry weights and leaf area of wheat at tillering stage in 2015-2016 (A) and 2016-2017 (B)

Irrigation	A. 2015-2016					B. 2016-2017				
	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
I_0	33.549 b	0.544 b	0.483 b	1.027 b	77.411 a	34.195 b	0.554 b	0.493 b	1.047 b	78.891 a
I_1	38.428 a	0.664 a	0.562 a	1.226 a	83.215 a	39.167 a	0.676 a	0.572 a	1.248 a	84.605 a
I_2	38.464 a	0.684 a	0.579 a	1.263 a	83.328 a	39.205 a	0.696 a	0.590 a	1.286 a	84.624 a
I_3	38.529 a	0.724 a	0.612 a	1.336 a	83.409 a	39.270 a	0.738 a	0.624 a	1.362 a	84.706 a
CV (%)	5.563	7.206	3.682	9.484	6.062	6.847	8.331	4.569	8.452	5.789

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 62: Effect of variety on plant height, dry weights and leaf area of wheat at tillering stage in 2015-2016 (A) and 2016-2017 (B)

Variety	A. 2015-2016					B. 2016-2017				
	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
V_1	37.182 a	0.614 b	0.523 b	1.137 b	81.586 a	37.898 a	0.625 b	0.533 b	1.158 b	82.947 a
V_2	37.303 a	0.694 a	0.595 a	1.289 a	82.096 a	38.020 a	0.707 a	0.607 a	1.314 a	83.466 a
CV (%)	5.563	7.206	3.682	9.484	6.062	6.847	8.331	4.569	8.452	5.789

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 63: Effect of potassium on plant height, dry weights and leaf area of wheat at tillering stage in 2015-2016 (A) and 2016-2017 (B)

Potassium	A. 2015-2016					B. 2016-2017				
	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
K_0	29.594 b	0.494 b	0.429 b	0.923 b	60.107 c	30.163 b	0.503 b	0.437 b	0.940 b	61.191 c
K_1	38.966 a	0. 0.679 a	0.584 a	1.263 a	86.092 b	39.689 a	0.692 a	0.595 a	1.287 a	87.529 b
K_2	40.671 a	0.730 a	0.621 a	1.351 a	93.174 a	41.453 a	0.744 a	0.633 a	1.377 a	94.730 a
K_3	39.739 a	0.712 a	0.602 a	1.314 a	86.992 b	40.531 a	0.726 a	0.614 a	1.340 a	89.377 b
CV (%)	5.563	7.206	3.682	9.484	6.062	6.847	8.331	4.569	8.452	5.789

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 64: Interaction effect of irrigation and potassium on plant height, dry weights and leaf area of wheat at tillering stage in 2015-2016 (A) and 2016-2017 (B)

Interaction (Irrigation× Potassium)	A. 2015-2016					B. 2016-2017				
	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
I_0K_0	28.254 g	0.398 f	0.342 h	0.740 e	53.960 h	28.798 g	0.405 f	0.348 h	0.753 e	54.991 h
I_0K_1	36.111 d	0.609 b-d	0.544 b-f	1.153 bc	90.148 b	36.806 d	0.620 b-d	0.554 b-f	1.174 bc	91.871 b
I_0K_2	35.154 e	0.597 cd	0.534 c-f	1.131 bc	83.555 f	35.831 e	0.608 cd	0.544 c-f	1.152 bc	85.152 f
I_0K_3	34.677 e	0.571 de	0.514 d-f	1.085 c	81.982 f	35.345 e	0.582 de	0.524 d-f	1.106 c	83.549 f
I_1K_0	29.749 f	0.478 ef	0.415gh	0.893 de	62.050 g	30.322 f	0.487 ef	0.423 gh	0.910 de	63.086 g
I_1K_1	42.191 a	0.750 a	0.632 ab	1.382 a	94.296 a	43.002 a	0.765 a	0.644 ab	1.409 a	95.871 a
I_1K_2	41.330 b	0.734 a	0.607 a-c	1.341 a	89.239 b-d	42.125 b	0.748 a	0.619 a-d	1.367 a	90.730 b-d
I_1K_3	40.442 c	0.693 a-c	0.592 a-e	1.285 ab	87.277 e	41.219 c	0.706 a-c	0.603 a-e	1.309 ab	88.735 e
I_2K_0	30.091 f	0.514 de	0.455 fg	0.969 cd	62.288 g	30.670 f	0.524 de	0.464 fg	0.988 cd	63.257 g
I_2K_1	42.223 a	0.764 a	0.641 a	1.405 a	94.056 a	43.036 a	0.778 a	0.653 a	1.431 a	95.519 a
I_2K_2	41.170 b	0.745 a	0.619 a-c	1.364 a	89.375 b-d	41.963 b	0.759 a	0.631 a-c	1.390 a	90.765 b-d
I_2K_3	40.373 c	0.711 ab	0.602 a-d	1.313 ab	87.593 c-e	41.150 c	0.724 ab	0.614 a-d	1.338 ab	88.956 c-e
I_3K_0	30.281 f	0.585 d	0.505 e-g	1.090 c	62.457 g	30.863 f	0.596 d	0.515 e-g	1.111 c	63.428 g
I_3K_1	42.158 a	0.797 a	0.668 a	1.465 a	94.195 a	42.968 a	0.812 a	0.681 a	1.493 a	95.660 a
I_3K_2	41.410 b	0.774 a	0.647 a	1.421 a	89.469 bc	42.206 b	0.789 a	0.660 a	1.449 a	90.861 bc
I_3K_3	40.266 c	0.741 a	0.629 ab	1.370 a	87.515 de	41.040 c	0.755 a	0.641 ab	1.396 a	88.876 de
CV (%)	5.563	7.206	3.682	9.484	6.062	6.847	8.331	4.569	8.452	5.789

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

4.4.3 Booting stage

Irrigation treatments had significant influence on plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} at booting stage in both the years are presented in Table 65A for first year (2015-2016) and in Table 65B for second year (2016-2017) respectively. The highest plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1} and total dry weight plant^{-1} was observed in I_2 which was at par with I_3 and followed by I_1 and the lowest values was found in I_0 (no irrigation) in both the years. Leaf area plant^{-1} was not statistically significant at booting stage due to irrigation levels. The maximum and minimum leaf area plant^{-1} was recorded in I_2 and I_0 respectively in both growing seasons. This finding was supported by Wu *et al.* (2011) who obtained increased plant height with increasing amount of irrigations. Similar result was reported in wheat by Nahar and Paul 1998, Rahman *et al.,* 2001 and Shen *et al.,* 2001. Sher and Parvender (2006) reported that dry matter accumulation increased with increasing irrigation levels. Alam *et al.* (2003) reported that three irrigation were exhibited the highest value of plant height and leaf area. Mollah and Paul (2011) stated that plant height increased with the increase of irrigation in barley. Similar result was also reported in wheat by Pandit *et al.,* 2001, Rahman *et al.,* 2001 and Naeem Sarwar 2010. Abdorrahmani *et al.* (2005) reported that two irrigations produced highest TDM and moisture stress reduced TDM production. Ashok and Sharma (2004) observed that the irrigation treatments increased TDM.

Plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} did not differ significantly due to varieties at booting stage in both the years are shown in Table 66A for first year (2015-2016) and in Table 66B for second year (2016-2017) respectively. Between the two varieties, higher plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} were observed in BARI Gom 28 (V_2) than BARI Gom 27 (V_1) during the two successive growing seasons.

Plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} in both the years varied significantly due to foliar applications of potassium at booting stage are presented in Table 67A for first year (2015-2016) and in Table 67B for second year (2016-2017) respectively. The highest plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} were obtained in K_2 in both the years. The lowest plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} was recorded in K_0 during the two successive growing seasons. Dry matter accumulation at all the stages increased with increasing levels of potassium application

(Desoky *et al*., 2017). Amal *et al*. (2011) reported that potassium fertilizer significantly increased plant height, shoot dry weight and leaf area. Chaturvedi (2006) reported that plant height and TDM increased with increasing potassium availability at all critical stages.

Interaction effects of irrigation and potassium had significant influence on plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} at booting stage in both the years are shown in Table 68A for first year (2015-2016) and in Table 68B for second year (2016-2017) respectively. The highest plant height, leaf dry weight plant^{-1} stem dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} at booting stage were observed in I_3K_2 and the lowest values were found in I_0K_0 during the two successive growing seasons.

Table 65: Effect of irrigation on plant height, dry weights and leaf area of wheat at booting stage in 2015-2016 (A) and 2016-2017 (B)

Irrigation	A. 2015-2016					B. 2016-2017				
	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
I_0	64.502 c	2.326 c	2.842 c	5.168 c	238.534 a	65.710 c	2.367 c	2.893 c	5.260 c	243.070 a
I_1	69.449 bc	2.594 b	3.055 bc	5.649 b	240.472 a	70.767 bc	2.637 b	3.110 bc	5.747 b	244.607 a
I_2	75.148 a	2.828 a	3.358 a	6.186 a	261.109 a	76.562 a	2.876 a	3.417 a	6.293 a	265.724 a
I_3	73.780 ab	2.719 ab	3.272 ab	5.991 ab	255.049 a	75.172 ab	2.768 ab	3.330 ab	6.098 ab	259.591 a
CV (%)	3.749	5.557	5.305	3.483	8.528	3.749	5.808	5.306	3.483	9.537

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 66: Effect of variety on plant height, dry weights and leaf area of wheat at booting stage in 2015-2016 (A) and 2016-2017 (B)

Variety	A. 2015-2016					B. 2016-2017				
	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
V_1	70.719 a	2.577 a	3.095 a	5.672 a	245.118 a	72.052 a	2.621 a	3.151 a	5.772 a	249.496 a
V_2	70.721 a	2.657 a	3.168 a	5.825 a	252.464 a	72.054 a	2.703 a	3.224 a	5.927 a	257.000 a
CV (%)	3.749	5.557	5.305	3.483	8.528	3.749	5.808	5.306	3.483	9.537

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 67: Effect of potassium on plant height, dry weights and leaf area of wheat at booting stage in 2015-2016 (A) and 2016-2017 (B)

Potassium	A. 2015-2016					B. 2016-2017				
	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
K_0	59.713 b	2.142 c	2.590 c	4.732 c	179.033 b	60.838 b	2.179 c	2.636 c	4.815 c	182.239 b
K_1	73.724 a	2.695 b	3.226 b	5.921 b	271.007 a	75.113 a	2.742 b	3.283 b	6.025 b	275.863 a
K_2	76.131 a	2.893 a	3.430 a	6.323 a	277.871 a	77.566 a	2.943 a	3.491 a	6.434 a	282.850 a
K_3	73.312 a	2.737 b	3.281 ab	6.018 ab	267.253 a	74.694 a	2.784 b	3.340 ab	6.124 ab	272.041 a
CV (%)	3.749	5.557	5.305	3.483	8.528	3.749	5.808	5.306	3.483	9.537

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 68: Interaction effect of irrigation and potassium on plant height, dry weights and leaf area of wheat at booting stage in 2015-2016 (A) and 2016-2017 (B)

Interaction (Irrigation× Potassium)	A. 2015-2016					B. 2016-2017				
	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
I_0K_0	55.420 l	1.969 h	2.366 k	4.335 j	171.230 g	56.458 l	2.004 h	2.408 k	4.412 j	174.488 g
I_0K_1	66.893 h	2.408 f	2.890 h	5.298 f	261.023 ef	68.146 h	2.450 f	2.941 h	5.391 f	265.988 ef
I_0K_2	68.793 g	2.527 e	3.077 fg	5.604 e	265.313 c-f	70.081 g	2.571 e	3.132 fg	5.703 e	270.358 c-f
I_0K_3	66.902 h	2.399 f	3.035 g	5.434 ef	256.568 f	68.155 h	2.441 f	3.090 g	5.531 ef	261.447 f
I_1K_0	59.159 k	2.103 g	2.543 j	4.646 i	181.223 g	60.282 k	2.138 g	2.590 j	4.728 i	184.339 g
I_1K_1	71.937 f	2.712 d	3.130 ef	5.842 d	261.052 ef	73.302 f	2.758 d	3.187 ef	5.945 d	265.541 ef
I_1K_2	75.414 e	2.846 c	3.334 d	6.180 c	263.693 d-f	76.845 e	2.894 c	3.395 d	6.289 c	268.227 d-f
I_1K_3	71.287 f	2.715 d	3.211 e	5.926 d	255.921 f	72.639 f	2.761 d	3.269 e	6.030 d	260.322 f
I_2K_0	61.510 j	2.186 g	2.688 i	4.874 h	180.820 g	62.670 j	2.225 g	2.735 i	4.960 h	184.040 g
I_2K_1	77.690 c	2.851 c	3.410 b-d	6.261 c	277.328 a-e	79.156 c	2.902 c	3.470 b-d	6.372 c	282.266 a-e
I_2K_2	79.179 b	3.008 b	3.611 a	6.619 b	287.401 ab	80.673 b	3.062 b	3.674 a	6.736 b	292.518 ab
I_2K_3	76.742 d	2.831 c	3.382 cd	6.213 c	274.649 b-f	78.190 d	2.881 c	3.442 cd	6.323 c	279.539 b-f
I_3K_0	62.762 i	2.309 f	2.763 i	5.072 g	182.859 g	63.943 i	2.348 f	2.811 i	5.159 g	186.091 g
I_3K_1	78.374 bc	2.808 cd	3.474 bc	6.282 c	284.625 a-c	79.848 bc	2.856 cd	3.535 bc	6.391 c	289.657 a-c
I_3K_2	81.140 a	3.192 a	3.699 a	6.891 a	295.078 a	82.666 a	3.247 a	3.764 a	7.011 a	300.294 a
I_3K_3	78.316 bc	3.001 b	3.495 b	6.496 b	281.873 a-d	79.790 c	3.053 b	3.557 b	6.610 b	286.856 a-d
CV (%)	3.749	5.557	5.305	3.483	8.528	3.749	5.808	5.306	3.483	9.537

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability

4.4.4 Heading stage

Effect of irrigation was significant on plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} at heading stage in both the years are presented in Table 69 for first year (2015-2016) and in Table 70 for second year (2016-2017) respectively. At heading stage, the highest plant height was obtained in I_2 which was statically identical to I_3 followed by I_1 and the lowest value was obtained in I_0 during the two successive growing seasons. The leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1} and total dry weight plant^{-1} at heading stage was obtained in I_2 which was statistically significant with I_3 followed by I_1 in both the years and the lowest values was observed in I_0 during the two successive growing seasons. In case of leaf area plant^{-1}, no significant variation was observed within irrigation treatments. Similar results were reported by other researchers (Ali and Amin, 2007, Abdorrahmani *et al.*, 2005, and Alam *et al.*, 2003) in wheat. Pandit *et al.*, 2001 and Naeem Sarwar, 2010 and Pal and Upasani, 2007 observed that four irrigations produced highest TDM than other irrigation treatments.

Varieties had no significant effect on plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} at heading stage in both the years are presented in Table 71 for first year (2015-2016) and in Table72 for second year (2016-2017) respectively. Between the two varieties, higher plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1} total dry weight plant^{-1} and leaf area plant^{-1} were observed in BARI Gom 28 (V_2) and BARI Gom 27 (V_1) gave lowest values at heading stage in both the years.

Plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} were significantly influenced by foliar applications of potassium at heading stage in both the years are presented in Table 73 for first year (2015-2016) and in Table 74 for second year (2016-2017). The highest plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} were produced in K_2 and the lowest value was obtained in K_0 in both the years. Khursheed and Mahammad (2015) reported that K significantly increased plant height, shoot dry weight and leaf area. Chaturvedi (2006) reported that plant height and TDM increased with increasing potassium availability at all critical stages. Ananda (2004) found that foliar application of potassium applied in three split doses significantly increased plant height.

Plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} at heading stage varied significantly due to the interaction of irrigation and potassium in both the years are shown in Table 75 for first year (2015-2016) and in Table 76 for second year (2016-2017) respectively. The highest plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} were produced in I_3K_2 in both the years. The results were statistically similar with I_2K_2 for stem dry weight plant^{-1} in the second year (2016-2017). The lowest plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} were observed in I_0K_0 during the two successive growing seasons.

Table 69: Effect of irrigation on plant height, dry weights and leaf area of wheat at heading stage in 2015-2016

Irrigation	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Spike dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
I_0	68.498 b	2.458 c	2.854 c	0.29 b	5.602 c	250.480 a
I_1	72.954 b	2.770 b	3.067 bc	0.294 b	6.131bc	250.752 a
I_2	81.952 a	3.073 a	3.370 a	0.400 a	6.843 a	271.993 a
I_3	79.183 a	2.921 ab	3.285 ab	0.330 ab	6.536 ab	264.948 a
CV (%)	4.006	6.670	6.453	6.011	6.103	7.346

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 70: Effect of irrigation on plant height, dry weights and leaf area of wheat at heading stage in 2016-2017

Irrigation	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Spike dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
I_0	69.642 b	2.479 c	2.905 c	0.304 b	5.689 c	252.611 a
I_1	74.165 b	2.794 b	3.122 bc	0.291 b	6.207 bc	252.886 a
I_2	83.262 a	3.098 a	3.429 a	0.374 a	6.901 a	274.308 a
I_3	80.417 a	2.946 ab	3.343 ab	0.333 ab	6.622 ab	267.204 a
CV (%)	3.569	5.887	5.441	7.890	3.456	9.229

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 71: Effect of variety on plant height, dry weights and leaf area of wheat at heading stage in 2015-2016

Variety	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Spike dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
V_1	75.646 a	2.765 a	3.108 a	0.329 a	6.202 a	255.822 a
V_2	75.648 a	2.846 a	3.180 a	0.329 a	6.355 a	263.264 a
CV (%)	4.006	6.670	6.453	6.011	6.103	7.346

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 72: Effect of variety on plant height, dry weights and leaf area of wheat at heading stage in 2016-2017

Variety	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Spike dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
V_1	76.870 a	2.789 a	3.163 a	0.326 a	6.278 a	258.000 a
V_2	76.873 a	2.870 a	3.237 a	0.325 a	6.432 a	265.504 a
CV (%)	3.569	5.887	5.441	7.890	3.456	9.229

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 73: Effect of potassium on plant height, dry weights and leaf area of wheat at heading stage in 2015-2016

Potassium	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1}(g)	Spike dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
K_0	64.447 b	2.246 c	2.602 c	0.152 c	5.000 c	188.539 b
K_1	79.298 a	2.927 b	3.238 b	0.350 b	6.515 b	281.962 a
K_2	81.027 a	3.117 a	3.443 a	0.413 a	6.973 a	288.837 a
K_3	77.815 a	2.932 ab	3.293 ab	0.399 a	6.624 b	278.834 a
CV (%)	4.006	6.670	6.453	6.011	6.103	7.346

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 74: Effect of potassium on plant height, dry weights and leaf area of wheat at heading stage in 2016-2017

Potassium	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1}(g)	Spike dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
K_0	65.493 b	2.265 c	2.648 c	0.149 c	5.063 c	190.144 b
K_1	80.581 a	2.952 b	3.296 b	0.347 b	6.595 b	284.362 a
K_2	82.339 a	3.143 a	3.504 a	0.410 a	7.057 a	291.295 a
K_3	79.074 a	2.957 ab	3.352 ab	0.396 a	6.705 b	281.208 a
CV (%)	3.569	5.887	5.441	7.890	3.456	9.229

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 75: Interaction effect of irrigation and potassium on plant height, dry weights and leaf area of wheat at heading stage in 2015-2016

Interaction (Irrigation× Potassium)	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1}(g)	Spike dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
I_0K_0	61.370 k	2.081 i	2.378 k	0.123 o	4.582 i	180.286 e
I_0K_1	71.333 h	2.516 f	2.902 h	0.252 k	5.67 f	273.823 cd
I_0K_2	70.573 h	2.720 e	3.090 fg	0.367 g	6.177 e	278.818 b-d
I_0K_3	70.715 h	2.517 f	3.048 g	0.268 j	5.833 f	268.991 cd
I_1K_0	63.820 j	2.210 h	2.556 j	0.132 n	4.898 h	190.336 e
I_1K_1	75.963 f	2.913 d	3.142 ef	0.342 h	6.397 d	272.058 cd
I_1K_2	78.415 e	3.066 c	3.346 d	0.419 e	6.831 c	276.043 b-d
I_1K_3	73.618 g	2.893 d	3.223 e	0.371 f	6.487 d	264.570 d
I_2K_0	64.413 j	2.286 h	2.700 i	0.170 m	5.156 h	190.255 e
I_2K_1	84.737 c	3.073 c	3.422 b-d	0.341 i	6.836 c	287.485 a-c
I_2K_2	86.080 b	3.251 b	3.623 a	0.460 b	7.334 b	294.793 ab
I_2K_3	81.500 d	3.072 c	3.394 cd	0.443 c	6.909 c	287.261 a-c
I_3K_0	68.183 i	2.406 g	2.775 i	0.185 l	5.366 g	193.280 e
I_3K_1	85.160 c	3.206 b	3.486 bc	0.428 d	7.120 b	294.483 ab
I_3K_2	89.040 a	3.430 a	3.711 a	0.494 a	7.635 a	305.692 a
I_3K_3	85.426 bc	3.248 b	3.508 b	0.461 b	7.217 b	294.516 ab
CV (%)	4.006	6.670	6.453	6.011	6.103	7.346

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 76: Interaction effect of irrigation and potassium on plant height, dry weights and leaf area of wheat at heading stage in 2016-2017

Interaction (Irrigation× Potassium)	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1}(g)	Spike dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
I_0K_0	62.398 k	2.099 i	2.420 k	0.129 o	4.648 i	181.821 e
I_0K_1	72.526 h	2.537 f	2.953 h	0.252 k	5.742 f	276.154 cd
I_0K_2	71.751 h	2.743 e	3.145 fg	0.368 g	6.256 e	281.191 b-d
I_0K_3	71.895 h	2.538 f	3.102 g	0.278 j	5.918 f	271.280 cd
I_1K_0	64.882 j	2.229 h	2.602 j	0.132 n	4.963 h	191.956 e
I_1K_1	77.222 f	2.938 d	3.199 ef	0.352 h	6.489 d	274.374 cd
I_1K_2	79.715 e	3.093 c	3.407 d	0.424 e	6.924 c	278.393 b-d
I_1K_3	74.839 g	2.918 d	3.282 e	0.373 f	6.537 d	266.822 d
I_2K_0	65.420 j	2.306 h	2.747 i	0.163 m	5.216 h	191.874 e
I_2K_1	86.056 c	3.100 c	3.482 b-d	0.345 i	6.927 c	289.932 a-c
I_2K_2	87.423 b	3.279 b	3.686 a	0.435 c	7.40 b	297.302 ab
I_2K_3	82.770 d	3.098 c	3.454 cd	0.433 d	6.985 c	289.706 a-c
I_3K_0	69.273 i	2.426 g	2.824 i	0.169 l	5.419 g	194.925 e
I_3K_1	86.518 c	3.233 b	3.547 bc	0.433 d	7.213 b	296.990 ab
I_3K_2	90.466 a	3.459 a	3.776 a	0.469 a	7.704 a	308.294 a
I_3K_3	86.790 bc	3.276 b	3.569 b	0.456 b	7.301 b	297.023 ab
CV (%)	3.569	5.887	5.441	7.890	3.456	9.229

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

4.4.5 Anthesis stage

Plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} were influenced significantly by different levels of irrigation at anthesis period in both the years are presented in Table 77 for first year (2015-2016) and in Table 78 for second year (2016-2017) respectively. The highest plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1} and total dry weight plant^{-1} were observed in I_2 which was at par with I_3 followed by I_1 and the lowest values was found in I_0 in both the years. In case of leaf area plant^{-1}, no significant variation was observed within irrigation treatments. The highest and lowest value of leaf area plant^{-1} was recorded in I_2 and I_0 respectively during the two successive growing seasons. This findings was in agreement with Islam (1997), Ashok and Sharma (2004), Sarker and Paul 1997, Rahman *et al.* (2001) and Shen *et al.* (2001) in wheat plants. Alam *et al.* (2003) reported that three irrigations were exhibited the highest value of plant height and leaf area. Similar result was reported in wheat (Pandit *et al.*, 2001, Rahman *et al.*, 2001 and Naeem Sarwar 2010). Pal and Upasani (2007) observed that four irrigations produced highest TDM than other irrigation treatments.

Plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} did not differ significantly due to varieties at anthesis stage in both the years are shown in Table 79 for first year (2015-2016) and in Table 80 for second year (2016-2017) respectively. Between the two varieties, higher plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} were observed in BARI Gom 28 (V_2) than BARI Gom 27 (V_1) at the anthesis stage in both the growing seasons.

Foliar applications of potassium had significant effect on plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} at anthesis stage in both the years are presented in Table 81 for first year (2015-2016) and in Table 82 for second year (2016-2017) respectively. The highest plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} were obtained in K_2 and the lowest values were obtained in K_0 in both the years. This results also supported the findings of Awasthi and Bhan, (1993) who reported the potassium encourages plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1} total dry weight plant^{-1} and leaf area plant^{-1}. Ananda (2004) also reported that foliar application of potassium applied in three split doses significantly increased plant height.

Interaction effect between irrigation and potassium had significant influence on plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} at anthesis stage in both the years are shown in Table 83 for first year (2015-2016) and in Table 84 for second year (2016-2017) respectively. The highest values for above parameters were observed in I_3K_2 and the lowest values were found in I_0K_0 during the two successive growing seasons.

Table 77: Effect of irrigation on plant height, dry weights and leaf area of wheat at anthesis stage in 2015-2016

Irrigation	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Spike dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
I_0	77.134 c	2.587 c	3.267 c	1.203 c	7.057 c	261.063 a
I_1	79.838 bc	2.865 b	3.479 bc	1.490 b	7.834 b	262.616 a
I_2	87.952 a	3.229 a	3.782 a	1.723 a	8.734 a	281.162 a
I_3	84.626 ab	3.079 ab	3.697 ab	1.572 ab	8.348 ab	275.043 a
CV (%)	6.773	4.442	5.229	5.393	4.789	7.889

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 78: Effect of irrigation on plant height, dry weights and leaf area of wheat at anthesis stage in 2016-2017

Irrigation	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Spike dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
I_0	78.041 c	2.607 c	3.317 c	1.228 c	7.152 c	263.028 a
I_1	81.284 bc	2.890 b	3.535 bc	1.520 b	7.945 b	263.803 a
I_2	89.626 a	3.256 a	3.841 a	1.760 a	8.857 a	283.058 a
I_3	86.251 ab	3.104 ab	3.755 ab	1.607 ab	8.466 ab	276.495 a
CV (%)	5.544	6.204	5.232	6.507	5.064	8.007

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 79: Effect of variety on plant height, dry weights and leaf area of wheat at anthesis stage in 2015-2016

Variety	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Spike dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
V_1	82.140 a	2.900 a	3.521 a	1.494 a	7.915 a	266.273 a
V_2	82.635 a	2.981 a	3.591 a	1.500 a	8.071 a	273.669 a
CV (%)	6.773	4.442	5.229	5.393	4.789	7.889

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 80: Effect of variety on plant height, dry weights and leaf area of wheat at anthesis stage in 2016-2017

Variety	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Spike dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
V_1	83.646 a	2.923 a	3.575 a	1.529 a	8.027 a	275.348 a
V_2	83.955 a	3.005 a	3.649 a	1.529 a	8.183 a	267.843 a
CV (%)	5.544	6.204	5.232	6.507	5.064	8.007

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 81: Effect of potassium on plant height, dry weights and leaf area of wheat at anthesis stage in 2015-2016

Potassium	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Spike dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1}(cm^2)
K_0	71.748 c	2.425 c	3.199 c	1.122 c	6.746 c	196.630 c
K_1	83.948 b	3.000 b	3.664 b	1.528 b	8.192 b	293.263 ab
K_2	88.239 a	3.291 a	3.655 a	1.732 a	8.678 a	301.646 a
K_3	85.615 ab	3.045 b	3.704 ab	1.606 ab	8.355 b	288.346 b
CV (%)	6.773	4.442	5.229	5.393	4.789	7.889

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 82: Effect of potassium on plant height, dry weights and leaf area of wheat at anthesis stage in 2016-2017

Potassium	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Spike dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1}(cm^2)
K_0	72.976 c	2.444 c	3.061 c	1.148 c	6.653 c	197.810 c
K_1	85.388 b	3.024 b	3.708 b	1.560 b	8.292 b	295.029 ab
K_2	89.755 a	3.318 a	3.916 a	1.768 a	9.002 a	303.461 a
K_3	87.084 ab	3.070 b	3.764 ab	1.640 ab	8.474 b	290.083 b
CV (%)	5.544	6.204	5.232	6.507	5.064	8.007

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 83: Interaction effect of irrigation and potassium on plant height, dry weights and leaf area of wheat at anthesis stage in 2015-2016

Interaction (Irrigation× Potassium)	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Spike dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1}(cm^2)
I_0K_0	68.537 m	2.169 j	2.790 k	1.005 l	5.964 l	188.397 f
I_0K_1	78.470 i	2.626 g	3.314 h	1.176 i	7.116 i	285.506 c-e
I_0K_2	81.376 g	2.866 f	3.502 fg	1.412 f	7.780 g	291.005 b-e
I_0K_3	80.152 h	2.687 g	3.460 g	1.220 h	7.367 h	279.346 e
I_1K_0	69.928 l	2.360 i	2.968 j	1.024 k	6.352 k	198.061 f
I_1K_1	81.497 fg	2.952 f	3.554 ef	1.534 e	8.040 f	284.588 de
I_1K_2	85.332 e	3.195 de	3.759 d	1.734 c	8.688 d	290.414 b-e
I_1K_3	82.597 f	2.952 f	3.636 e	1.667 d	8.255 e	277.401 e
I_2K_0	72.858 k	2.504 h	3.112 i	1.143 j	6.759 j	198.492 f
I_2K_1	86.884 d	3.143 e	3.834 b-d	1.659 d	8.636 d	297.528 a-e
I_2K_2	90.929 b	3.491 b	4.035 a	1.742 c	9.268 b	308.341 ab
I_2K_3	87.833 cd	3.180 de	3.806 d	1.745 c	8.731 d	295.812 b-e
I_3K_0	75.670 j	2.668 g	3.188 i	1.317 g	7.173 i	201.566 f
I_3K_1	88.940 c	3.275 cd	3.898 bc	1.743 c	8.916 c	305.430 a-c
I_3K_2	95.319 a	3.612 a	4.123 a	2.039 a	9.774 a	316.824 a
I_3K_3	91.878 b	3.361 c	3.919 b	1.794 b	9.074 c	300.827 a-d
CV (%)	6.773	4.442	5.229	5.393	4.789	7.889

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 84: Interaction effect of irrigation and potassium on plant height, dry weights and leaf area of wheat at anthesis stage in 2016-2017

Interaction (Irrigation× Potassium)	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Spike dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
I_0K_0	69.341 m	2.186 j	2.833 k	1.026 l	6.045 m	189.820 f
I_0K_1	79.393 i	2.646 g	3.366 h	1.200 i	7.212 j	287.654 c-e
I_0K_2	82.334 g	2.888 f	3.557 fg	1.440 f	7.885 h	293.191 b-e
I_0K_3	81.095 h	2.708 g	3.514 g	1.244 h	7.466 i	281.447 e
I_1K_0	71.195 l	2.381 i	3.014 j	1.047 k	6.442 l	198.956 f
I_1K_1	82.972 g	2.979 f	3.611 ef	1.565 e	8.155 g	285.874 de
I_1K_2	86.878 e	3.223 de	3.819 d	1.768 c	8.811 e	291.727 b-e
I_1K_3	84.092 f	2.979 f	3.694 e	1.700 d	8.373 f	278.655 e
I_2K_0	74.257 k	2.524 h	3.160 i	1.170 j	6.854 k	199.540 f
I_2K_1	88.553 d	3.168 e	3.894 b-d	1.695 d	8.757 e	299.099 a-e
I_2K_2	92.676 b	3.518 b	4.099 a	1.780 c	9.397 b	309.968 ab
I_2K_3	89.520 d	3.204 de	3.866 cd	1.783 c	8.853 de	297.373 b-e
I_3K_0	77.110 j	2.691 g	3.236 i	1.346 g	7.273 j	202.925 f
I_3K_1	90.633 c	3.302 cd	3.959 bc	1.780 c	9.041 cd	307.490 a-c
I_3K_2	97.133 a	3.643 a	4.188 a	2.081 a	9.912 a	318.961 a
I_3K_3	93.627 b	3.390 c	3.981 b	1.832 b	9.203 c	302.856 a-d
CV (%)	5.544	6.204	5.232	6.507	5.064	8.007

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

4.4.6 Physiological maturity stage

The plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} at physiological maturity stage as affected by irrigation in both the years are presented in Table 85 for first year (2015-2016) and in Table 86 for second year (2016-2017) respectively. The maximum plant height was recorded in I_2 which was statistically identical to I_3 and the minimum plant height was recorded in I_0 at physiological maturity stage in both the growing seasons. The highest leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} were produced in I_2 which was at par with I_3 and the lowest values were obtained in I_0 in both the years. Similar findings were reported by Basunia, (2000), Dong *et al.* (2013), Mandal *et al.* (2002), Pandit *et al.* (2001), Rahman *et al.* (2001) and Naeem Sarwar, 2010). Alam *et al.* (2003) reported that three irrigation exhibited the highest value of plant height and leaf area.

Varieties had no significant effect on plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} at physiological maturity stage in both the years are presented in Table 87 for first year (2015-2016) and in Table 88 for second year (2016-2017) respectively. Higher plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} were observed in BARI Gom 28 (V_2) than BARI Gom 27 (V_1) during the two successive growing seasons.

Plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} were influenced significantly by foliar application of potassium at physiological maturity stage in both the years are presented in Table 89 for first year (2015-2016) and in Table 90 for second year (2016-2017) respectively. The highest plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} were obtained in K_2 and the lowest values were found in K_0 in both the growing seasons. This result is also supported by Wagan *et al.*, 2002. Bellido *et al.* (2000) reported that the amount of total dry matter was increased with increasing potassium fertilizer application. Khursheed and Mahammad (2015) reported that potassium significantly increased plant height, shoot dry weight and leaf area. Ananda (2004) reported that foliar application of potassium recorded maximum plant height of wheat. Wagan *et al.* (2002) reported that potassium applied in three split doses significantly increased plant height.

Different treatment combinations of irrigation and potassium on plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} had significant influence at physiological maturity stage in both the years are shown in Table 91 for first year (2015-2016) and in Table 92 for second year (2016-2017) respectively. The highest plant height, leaf dry weight plant^{-1}, stem dry weight plant^{-1}, spike dry weight plant^{-1}, total dry weight plant^{-1} and leaf area plant^{-1} at physiological maturity stage were observed in I_3K_2 and the lowest values were recorded in I_0K_0 during the two successive growing seasons.

Table 85: Effect of irrigation on plant height, dry weights and leaf area of wheat at physiological maturity stage in 2015-2016

Irrigation	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Spike dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
I_0	85.695 b	1.468 c	3.816 d	3.361 b	8.645 c	183.537 b
I_1	89.509 b	1.675 b	4.116 c	3.750 ab	9.541 bc	185.582 b
I_2	100.583 a	1.882 a	4.768 a	4.386 a	11.036 a	206.660 a
I_3	96.146 a	1.788 ab	4.554 b	3.906 ab	10.248 ab	196.386 ab
CV (%)	5.123	6.342	5.098	5.269	4.133	8.033

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 86: Effect of irrigation on plant height, dry weights and leaf area of wheat at physiological maturity stage in 2016-2017

Irrigation	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Spike dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
I_0	87.332 b	1.494 c	3.966 d	3.347 c	8.807 c	187.011b
I_1	90.993 b	1.704 b	4.241 c	3.739 bc	9.684 bc	189.154 b
I_2	102.050 a	1.915 a	4.927 a	4.341 a	11.183 a	208.516 a
I_3	97.543 a	1.818 ab	4.712 b	3.861 ab	10.391 ab	200.120 ab
CV (%)	4.561	7.562	6.830	6.564	5.135	8.116

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 87: Effect of variety on plant height, dry weights and leaf area of wheat at physiological maturity stage in 2015-2016

Variety	Plant height (cm)	Leaf dry weight plant^{-1}(g)	Stem dry weight plant^{-1}(g)	Spike dry weight plant^{-1} (g)	Total dry weight plant^{-1}(g)	Leaf area plant^{-1} (cm^2)
V_1	92.862 a	1.663 a	4.278 a	3.850 a	9.791 a	189.361 a
V_2	93.105 a	1.743 a	4.349 a	3.851 a	9.944 a	196.722 a
CV (%)	5.123	6.342	5.098	5.269	4.133	8.033

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 88: Effect of variety on plant height, dry weights and leaf area of wheat at physiological maturity stage in 2016-2017

Variety	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Spike dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
V_1	94.356 a	1.692 a	4.425 a	3.821 a	9.938 a	199.953 a
V_2	94.603 a	1.774 a	4.498 a	3.822 a	10.094 a	192.448 a
CV (%)	4.561	7.562	6.830	6.564	5.135	8.116

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 89: Effect of potassium on plant height, dry weights and leaf area of wheat at physiological maturity stage in 2015-2016

Potassium	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Spike dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
K_0	82.406 b	1.322 c	4.020 b	1.889 c	7.231 c	164.625 c
K_1	94.369 a	1.788 b	4.322 a	4.293 b	10.403 b	199.703 ab
K_2	98.689 a	1.953 a	4.509 a	4.802 a	11.264 a	209.706 a
K_3	96.469 a	1.750 b	4.403 a	4.418 b	10.571 ab	198.131 b
CV (%)	5.123	6.342	5.098	5.269	4.133	8.033

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 90: Effect of potassium on plant height, dry weights and leaf area of wheat at physiological maturity stage in 2016-2017

Potassium	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Spike dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
K_0	83.733 b	1.345 c	4.158 b	1.837 c	7.340 c	167.311 c
K_1	95.888 a	1.819 b	4.472 a	4.270 b	10.561 b	202.988 ab
K_2	100.276 a	1.987 a	4.662 a	4.784 a	11.433 a	213.129 a
K_3	98.021 a	1.780 b	4.554 a	4.396 b	10.730 b	201.375 b
CV (%)	4.561	7.562	6.830	6.564	5.135	8.116

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 91: Interaction effect of irrigation and potassium on plant height, dry weights and leaf area of wheat at physiological maturity stage in 2015-2016

Interaction (Irrigation× Potassium)	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Spike dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1}(cm^2)
I_0K_0	76.545 m	1.105 k	3.542 i	1.843 o	6.490 k	148.137 h
I_0K_1	86.981 j	1.528 h	3.847 h	3.722 l	9.097 g	198.010 b-e
I_0K_2	90.357 h	1.724 g	3.919 gh	4.079 j	9.722 f	203.117 b-d
I_0K_3	88.896 i	1.514 hi	3.955 g	3.799 k	9.268 g	193.065 b-e
I_1K_0	79.707 l	1.251 j	3.870 gh	1.848 n	6.969 j	160.910 gh
I_1K_1	90.718 h	1.786 e-g	4.201 ef	4.125 i	10.112 e	191.581 c-e
I_1K_2	94.889 f	1.927 cd	4.241 ef	4.623 e	10.791 d	195.361 b-e
I_1K_3	92.722 g	1.734 fg	4.151 f	4.403 h	10.288 e	186.295 d-f
I_2K_0	84.939 k	1.417 i	4.264 e	1.596 p	7.277 i	169.975 fg
I_2K_1	97.552 e	1.872 c-e	4.428 d	4.579 f	10.879 d	201.926 b-d
I_2K_2	102.356 c	2.034 ab	4.887 b	4.977 c	11.898 b	212.102 ab
I_2K_3	99.738 d	1.831 d-f	4.638 c	4.471 g	10.940 d	201.541 b-d
I_3K_0	88.434 i	1.515 hi	4.402 d	2.267 m	8.184 h	179.479 e-g
I_3K_1	102.226 c	1.966 bc	4.811 b	4.748 d	11.525 c	207.295 bc
I_3K_2	107.154 a	2.128 a	4.988 a	5.529 a	12.645 a	228.244 a
I_3K_3	104.519 b	1.919 cd	4.870 b	5.000 b	11.789 b	211.622 a-c
CV (%)	5.123	6.342	5.098	5.269	4.133	8.033

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 92: Interaction effect of irrigation and potassium on plant height, dry weights and leaf area of wheat at physiological maturity stage in 2016-2017

Interaction (Irrigation× Potassium)	Plant height (cm)	Leaf dry weight plant^{-1} (g)	Stem dry weight plant^{-1} (g)	Spike dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)	Leaf area plant^{-1} (cm^2)
I_0K_0	78.008 m	1.125 j	3.685 i	1.803 o	6.613 k	150.988 h
I_0K_1	88.643 j	1.555 g	3.999 h	3.714 l	9.268 g	201.821 b-d
I_0K_2	92.084 h	1.754 f	4.074 gh	4.076 j	9.904 f	207.025 b-d
I_0K_3	90.595 i	1.541 gh	4.109 g	3.792 k	9.442 g	196.780 b-e
I_1K_0	81.029 l	1.273 i	3.986 h	1.815 n	7.074 j	163.956 gh
I_1K_1	92.222 h	1.818 ef	4.328 ef	4.119 i	10.265 e	195.208 c-e
I_1K_2	96.462 f	1.961 b-d	4.372 ef	4.622 e	10.955 d	199.060 b-e
I_1K_3	94.259 g	1.765 f	4.279 f	4.399 h	10.443 e	189.822 d-f
I_2K_0	86.173 k	1.441 h	4.412 e	1.526 p	7.379 i	173.207 fg
I_2K_1	98.969 e	1.903 c-e	4.588 d	4.539 f	11.030 d	205.766 b-d
I_2K_2	103.843 c	2.068 ab	5.051 b	4.944 c	12.063 b	216.135 ab
I_2K_3	101.187 d	1.861 d-f	4.798 c	4.432 g	11.091 d	205.373 b-d
I_3K_0	89.723 ij	1.542 gh	4.550 d	2.201 m	8.293 h	181.091 e-g
I_3K_1	103.716 c	2.000 bc	4.972 b	4.705 d	11.677 c	209.157 b-d
I_3K_2	108.717 a	2.166 a	5.153 a	5.495 a	12.814 a	230.294 a
I_3K_3	106.043 b	1.953 cd	5.031 b	4.961 b	11.945 b	213.523 a-c
CV (%)	4.561	7.562	6.830	6.564	5.135	8.116

At specific days after sowing, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

4.5 Water Relations

4.5.1 Moisture retention capacity

Effect of irrigation on moisture retention capacity (MRC) at all the time of the day in both the years showed significant variation are presented in Table 93 for first year (2015-2016) and in Table 94 for second year (2016-2017) respectively. Maximum MRC were found at the initial stages or early hours of the day but MRC decreased gradually at the later part of the day. The highest MRC was found at 8:30am and lowest was found at 5:30pm during the two successive growing seasons. This might be due to increased dryness and also because of higher transpiration rates. At every occasion, the highest MRC was obtained in I_2 followed by I_3 and the lowest value were found in I_0 at all the time of the day in both the years. The plants with irrigation exhibited higher moisture retention capacity (MRC) whereas lower was found with no irrigated plants. This result was in agreement with Bahadur (2008) in barley. Sarker *et al.* (1999) also found higher moisture retention capacity (MRC) in *Opata* under irrigated condition. Similar results were also found by Haider (2002) in different wheat varieties grown under various soil moisture regimes.

Moisture retention capacity (MRC) did not differ significantly due to varieties at all the time of the day in both the years are given in Table 95 for first year (2015-2016) and in Table 96 for second year (2016-2017) respectively. Higher moisture retention capacity (MRC) were found in BARI Gom 28 (V_2) than BARI Gom 27 (V_1) during the two successive growing seasons.

Moisture retention capacity (MRC) was significantly influenced by foliar application of potassium at all the time of the day in both the years are presented in Table 97 for first year (2015-2016) and in Table 98 for second year (2016-2017) respectively. In both the growing seasons, flag leaf of wheat plants exhibited maximum MRC at 8:30am and thereafter decreased gradually at the later part of the day. The highest MRC was found in K_2 which was statistically similar with K_3 and K_1 in both the growing seasons and the lowest value was observed in K_0 at all the time of the day during the two successive growing seasons. Shabbir *et al*. (2015) reported that supplemental foliar fertilization of potassium, nitrogen and phosphorous alone or in different combinations significantly improved the water relations, gas exchange characteristics and nutrient contents of wheat. Similar results were obtained by Lindhauer (1989) who reported that fine K nutrition not only increased plant total dry mass and leaf area, but also improved the water retention in plant tissues under drought stress.

Interaction effect of irrigation and potassium had significant influence on moisture retention capacity (MRC) at all the time of the day in both the years are presented in Table 99 for first year (2015-2016) and in Table 100 for second year (2016-2017) respectively. The highest MRC was observed in I_2K_2 followed by I_3K_3 and I_3K_2 in both the years. Minimum MRC value was observed in I_0K_0, which was followed by I_0K_1 in both the crop growing seasons.

Table 93: Effect of irrigation on moisture retention capacity (%) of wheat in 2015-2016

Irrigation	Time of the day						
	8:30	9:30	10:30	11:30	01:00	3:30	5:30
I_0	74.027 d	69.242d	66.905 d	64.137 d	63.363 d	62.025 d	59.989 d
I_1	76.495 c	72.652	69.866 c	68.944 c	66.371 c	63.185 c	57.513 c
I_2	80.179 a	76.232	75.589 a	72.001 a	69.708 a	64.924 a	63.897 a
I_3	78.014 b	75.269	72.226 b	71.140 b	67.420 b	64.047 b	59.966 b
CV (%)	5.832	4.661	4.745	6.552	4.699	4.231	5.432

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 94: Effect of irrigation on moisture retention capacity (%) of wheat in 2016-2017

Irrigation	Time of the day						
	8:30	9:30	10:30	11:30	01:00	3:30	5:30
I_0	72.232 d	69.609 d	67.541 a	65.046 d	62.511 d	61.497 d	59.422 d
I_1	74.818 c	72.032 c	70.198 c	68.799 c	66.320 c	62.656 c	56.945 c
I_2	80.190 a	75.614 a	73.799 a	70.926 a	69.309 a	64.395 a	63.329 a
I_3	78.288 b	73.641 b	70.859 b	69.045 b	66.393 b	63.518 b	59.398 b
CV (%)	4.360	5.411	5.632	5.720	5.915	6.791	6.397

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 95: Effect of variety on moisture retention capacity (%) of wheat in 2015-2016

Variety	Time of the day						
	8:30	9:30	10:30	11:30	01:00	3:30	5:30
V_1	77.124 a	73.307 a	71.112 a	69.039 a	66.713 a	63.130 a	60.436 a
V_2	77.234 a	73.390 a	71.181 a	69.073 a	66.719 a	63.960 a	60.246 a
CV (%)	5.832	4.661	4.745	6.552	4.699	4.231	5.432

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 96: Effect of variety on moisture retention capacity (%) of wheat in 2016-2017

Variety	Time of the day						
	8:30	9:30	10:30	11:30	01:00	3:30	5:30
V_1	76.234 a	72.486 a	70.841 a	67.996 a	65.641 a	62.903 a	59.591 a
V_2	76.175 a	72.566 a	69.92 a	68.432 a	66.584 a	62.985 a	59.727a
CV (%)	4.360	5.411	5.632	5.720	5.915	6.791	6.397

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 97: Effect of potassium on moisture retention capacity (%) of wheat in 2015-2016

Potassium	Time of the day						
	8:30	9:30	10:30	11:30	01:00	3:30	5:30
K_0	76.160 b	71.820 b	69.693 b	67.614 b	65.296 b	62.105 b	58.960 b
K_1	76.800 ab	73.167 ab	70.916 ab	68.816 ab	66.520 ab	63.396 ab	60.177 ab
K_2	78.252 a	74.611 a	72.395 a	70.302 a	67.956 a	64.769 a	61.550 a
K_3	77.503 a	73.798 a	71.582 a	69.490 a	67.092 a	63.910 a	60.677 a
CV (%)	5.832	4.661	4.745	6.552	4.699	4.231	5.432

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 98: Effect of potassium on moisture retention capacity (%) of wheat in 2016-2017

Potassium	Time of the day						
	8:30	9:30	10:30	11:30	01:00	3:30	5:30
K_0	74.105 b	70.484 b	68.386 b	66.315 b	63.955 b	60.809 b	57.775 b
K_1	76.417 ab	72.774 ab	70.615 ab	68.44 ab	66.184 ab	63.118 ab	59.811 ab
K_2	77.125 a	73.41 a	71.288 a	69.12 a	66.761 a	63.636 a	60.315 ab
K_3	77.882 a	74.229 a	72.107 a	69.939 a	67.633 a	64.503 a	61.195 a
CV (%)	4.360	5.411	5.632	5.720	5.915	6.791	6.397

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 99: Interaction effect of irrigation and potassium on moisture retention capacity (%) of wheat in 2015-2016

Interaction (irrigation × potassium)	Time of the day							
	8:30	9:30	10:30	11:30	12:30	2:00	3:30	5:30
I_0 K_0	72.944 j	69.111 j	67.125 i	65.061 j	62.755 j	59.574 j	56.344 h	52.282 i
I_0 K_1	73.704 j	70.014 ij	67.793 hi	65.735 ij	63.407 ij	60.251 ij	57.045 gh	52.894 hi
I_0 K_2	74.628 i	70.808 hi	68.583 gh	66.449 hi	64.119 hi	60.954 hi	57.729 fg	53.548 gh
I_0 K_3	74.582 i	70.923 hi	68.707 gh	66.618 hi	64.289 hi	61.122 hi	57.859 fg	53.680 gh
I_1 K_0	75.706 h	71.686 gh	69.437 fg	67.382 gh	65.065 gh	61.875 gh	58.627 f	54.478 g
I_1 K_1	76.496 gh	72.708 fg	70.490 ef	68.380 fg	66.070 fg	62.896 fg	59.831 de	55.631 f
I_1 K_2	76.725 e-g	72.887 ef	70.662 e	68.600 ef	66.103 fg	62.950 f	59.742 e	55.521 f
I_1 K_3	77.271 e-g	73.350 ef	71.100 e	69.023 ef	66.651 ef	63.485 ef	60.297 de	56.114 ef
I_2 K_0	76.544 f-h	72.896 ef	70.829 e	68.706 ef	66.419 ef	63.264 ef	60.038 de	55.842 ef
I_2 K_1	77.562 e	73.760 de	71.539 de	69.466 de	67.195 de	64.052 de	60.855 cd	56.655 de
I_2 K_2	82.402 a	78.434 a	76.228 a	74.077 a	71.750 a	68.559 a	65.298 a	61.134 a
I_2 K_3	78.551 d	74.631 d	72.411 d	70.320 der	67.849 d	64.674 d	61.468 c	57.286 d
I_3 K_0	79.459 c	75.779 c	73.589 c	71.534 c	69.176 c	65.968 c	62.850 b	58.633 c
I_3 K_1	77.416 ef	73.535 ef	71.329 e	69.256 ef	66.895 d-f	63.714 d-f	60.546 c-e	56.513 d-f
I_3 K_2	80.091 bc	76.180 bc	73.835 bc	71.676 bc	69.400 bc	66.242 bc	63.034 b	58.845 bc
I_3 K_3	80.785 b	76.881 b	74.689 b	72.609 b	70.311 b	67.137 b	63.897 b	59.687 b
CV (%)	5.832	4.661	4.745	6.552	4.699	4.231	5.432	5.832

In a column, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 100: Interaction effect of irrigation and potassium on moisture retention capacity (%) of wheat in 2016-2017

Interaction (irrigation × potassium)	Time of the day							
	8:30	9:30	10:30	11:30	12:30	01:00	3:30	5:30
I_0 K_0	71.339 i	68.559 j	67.534 i	64.494 j	62.209 j	59.296 j	54.873 h	52.840 i
I_0 K_1	73.085 i	69.408 ij	67.201 hi	65.162 ij	62.853 ij	59.737 ij	56.567 gh	52.454 hi
I_0 K_2	73.000 h	70.195 hi	67.984 gh	65.870 hi	63.559 hi	60.434 hi	57.246 fg	53.103 gh
I_0 K_3	75.052 g	71.066 gh	68.836 fg	66.795 gh	64.496 gh	61.346 gh	58.136 f	54.025 g
I_1 K_0	73.954 h	70.309 hi	68.107 gh	66.037 hi	63.727 hi	60.600 hi	57.375 fg	53.234 gh
I_1 K_1	75.834 fg	72.079 fg	69.880 ef	67.783 fg	65.492 fg	62.359 fg	59.330 de	55.169 f
I_1 K_2	76.061 ef	72.256 ef	70.050 e	68.001 ef	65.525 fg	62.412 f	59.242 e	55.059 f
I_1 K_3	76.603 ef	72.715 ef	70.484 e	68.421 ef	66.069 ef	62.943 ef	59.793 de	55.647 ef
I_2 K_0	75.867 fg	72.280 ef	70.222 e	68.107 ef	65.839 ef	62.723 ef	59.536 de	55.378 ef
I_2 K_1	76.876 e	73.136 de	70.925 de	68.860 de	66.607 de	63.505 de	60.345 cd	56.183 de
I_2 K_2	81.716 a	77.770 a	75.5 93 a	73.431 a	71.123 a	67.974 a	64.751 a	60.625 a
I_2 K_3	77.856 d	73.999 d	71 .790 d	69.707 d	67.256 d	64.122 d	60.954 c	56.810 d
I_3 K_0	78.756 c	75.138 c	72.958 c	70.910 c	68.571 c	65.404 c	62.324 b	58.145 c
I_3 K_1	76.772 e	72.912 ef	70.736 e	68.652 ef	66.310 d-f	63.170 d-f	60.039 c-e	56.042 d-e
I_3 K_2	79.425 bc	75.535 bc	73.221 bc	71.051 bc	68.794 bc	65.676 bc	62.506 b	58.356 bc
I_3 K_3	79.912 b	76.229 b	74.068 b	71.976 b	69.696 b	66.563 b	63.362 b	59.190 b
CV (%)	4.360	5.411	5.632	5.720	5.915	6.791	6.397	4.360

In a column, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability

4.5.2 Relative leaf water content of leaf (%)

Effect of irrigation on relative leaf water content (RLWC) of flag leaf of wheat plants during anthesis showed significant variation are presented in Table 101A for first year (2015-2016) and in Table 101B for second year (2016-2017) respectively. The highest RLWC was observed in I_2 at every occasion of the day in both the years. The results were statistically similar with I_3 in both the years except at 4:30pm in the second year experiment. The lowest RLWC was found in I_0 in both the years. The irrigated plants of both the varieties at different times of the day always had higher RLWC than the rain-fed plants (no irrigation) in both the years. This results also supported the findings of Raza *et al*. (2013), Lawlor and Cornic, (2002) and Erickson *et al*. (1991) who reported that RLWC signals the internal water balance of plant tissue leading to changes in tissue water content and thereby its dry weight. In the present study, RLWC were significantly reduced by creating water stress. Fanaei *et al*. (2009) noticed that that the highest relative water content was found from the plot where imposed adequate irrigation and lower RLWC was recorded from the no irrigation plot. Similar results was reported by Zareian *et al*. (2014) and Unyayar *et al*. (2004) who concluded that under drought stress the relative leaf water content was decreased. This result was in agreement with Begum and Paul (1993), Rahman (1993), Sarker *et al.* (1999), Paul *et al.* (2002) and Haider (2002).

Relative leaf water content (RLWC) did not vary significantly due to varieties at every occasion of the day in both the years are presented in Table 102A for first year (2015-2016) and in Table 102B for second year (2016-2017) respectively. The higher RLWC was observed in BARI Gom 28 (V_2) and the lower was observed in BARI Gom 27 (V_1) at every occasion of the day in both the years. RLWC of both the varieties was higher in the morning, decreased during noon, showing some recovery in the afternoon.

Relative leaf water content (RLWC) varied significantly due to foliar applications of potassium at every occasion of the day in both the growing seasons are presented in Table 103A for first year (2015-2016) and in Table 103B for second year (2016-2017) experiment respectively. The highest RLWC was at 8:00am but at midday it decreased, while it increased gradually at the later part of the day. The highest RLWC was recorded in K_2 at every occasion of the day in both the years. That was statistically similar with K_1 and K_3 for 8:00 am and K_3 for 12:00 noon and 4:30 pm in both the years. The lowest values were found in control (K_0). Lindhauer (1989) reported that potassium imparts a beneficial effect on plants to overcome soil moisture stress. Relative water content was decreased under moisture stress condition in wheat genotypes

compared with normal irrigation. Spraying potassium iodide enhanced relative water content especially under moisture stress condition. Hasanuzzaman *et al.* (2018) also concluded that, optimal K fertilization helped plants to mitigate the effect of the water deficit through better water use efficiency (WUE), which was related to the lower leaf ET and increase the relative leaf water (RWC) in leaf. These observations were in full agreement with the finding of Desoky *et al.* (2017), Mirbahar *et al.* (2009) and Rahman (2004). Siddique *et al.* (2000) reported that adequate K not only increased plant total dry matter and leaf area, but also improved the water retention capacity and relative water content (RWC) in plant tissues under drought stress. Egilla *et al.* (2005) and Kant and Kafkafi, (2002) also reported that adequate K status facilitate osmotic adjustment, which maintains higher turgor pressure, RLWC and lower osmotic potential, thus improving the ability of plants to tolerate drought stress.

Interaction effect of irrigation and potassium had significant influence on relative leaf water content (RLW) at every occasion of the day in both the years are presented in Table 104A for first year (2015-2016) and Table 104B for second year (2016-2017) respectively. The highest RLWC at every occasion of the day was recorded in I_2K_2 during the two successive growing seasons which was statistically similar with I_3K_3 at 4:30 pm in both the growing seasons. The lowest RLWC was found in I_0K_0 during the two successive growing seasons.

.Table 101: Effect of irrigation on relative leaf water content (%) of wheat in 2015-2016 (A) and 2016-2017 (B)

Irrigation	A. Relative leaf water content (%)			B. Relative leaf water content (%)		
	8:00 am	12:00 noon	4:30 pm	8:00 am	12:00 noon	4:30 pm
I_0	82.061 b	62.879 d	73.635 c	82.983 b	63.779 d	76.347 c
$I_{1,}$	83.021 b	65.049 c	76.385 bc	84.102 b	65.768 c	77.474 bc
I_2	87.484 a	68.457 a	79.146 a	87.882 a	67.996 a	79.636 a
I_3	86.282 a	67.706 b	79.054 a	85.925 a	67.876 a	77.914 b
CV (%)	2.983	3.311	2.123	2.932	3.002	3.019

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 102: Effect of variety on relative leaf water content (%) of wheat in 2015-2016 (A) and 2016-2017 (B)

Variety	A. Relative leaf water content (%)			B. Relative leaf water content (%)		
	8:00 am	12:00 noon	4:30 pm	8:00 am	12:00 noon	4:30 pm
V_1	84.016 a	68.082 a	75.177 a	84.316 a	65.516 a	75.548 a
V_2	85.075 a	63.962 a	76.123 a	85.797 a	67.194 a	79.451 a
CV (%)	2.983	3.311	2.123	2.932	3.002	3.019

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability

Table 103: Effect of potassium on relative leaf water content (%) of wheat in 2015-2016 (A) and 2016-2017 (B)

Potassium	A. Relative leaf water content (%)			B. Relative leaf water content (%)		
	8:00 am	12:00 noon	4:30 pm	8:00 am	12:00 noon	4:30 pm
K_0	80.874 b	62.973 c	74.906 c	82.74 b	63.432 c	75.627 c
K_1	84.566 a	64.116 b	76.885 b	85.538 a	64.579 b	77.621 b
K_2	86.958a	68.603 a	78.524 a	86.366 a	69.083 a	79.272 a
K_3	86.449 a	68.398 ab	77.906 a	86.248 a	68.324 ab	78.851 a
CV (%)	2.983	3.311	2.123	2.932	3.002	3.019

In a column, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability

Table 104: Interaction effect of irrigation and potassium on relative leaf water content (%) of wheat in 2015-2016 (A) and 2016-2017 (B)

Interaction (irrigation x potassium)	A. Relative leaf water content (%)			B. Relative leaf water content (%)		
	8:00 am	12:00 noon	4:30 pm	8:00 am	12:00 noon	4:30 pm
I_0 K_0	80.435 h	62.782 j	73.894 i	80.673 h	63.123 j	73.977 i
I_0 K_1	82.654 g	63.878 i	75.745 f-h	83.089 g	64.254 i	76.885 f-h
I_0 K_2	83.657 ef	65.645 fg	76.892 ef	84.264 ef	66.058 fg	77.345 ef
I_0 K_3	83.432 fg	65.342 h	76.422 e-g	83.455 fg	65.486 h	76.456 e-g
I_1 K_0	80.764 h	63.856 i	74.456 hi	81.368 h	64.284 i	75.065 hi
I_1 K_1	83.344 fg	64.874 h	76.289 e-g	83.822 fg	65.367 h	76.820 e-g
I_1 K_2	84.879 d	66.563 cd	77.445 de	85.478 d	66.867 cd	78.343 de
I_1 K_3	84.764 d	65.951 e-g	77.308 de	85.678 d	66.234 e-g	77.878 de
I_2 K_0	82.698 g	65.305 gh	75.267 gh	83.138 g	65.873 gh	75.786 gh
I_2 K_1	85.891 c	66.566 de	77.378 de	86.387 c	66.755 de	77.834 de
I_2 K_2	88.487 a	69433 a	80.845 a	89.907 a	69.450 a	81.456 a
I_2 K_3	87.652 b	67.509 b	77.188 bc	87.878 b	67.345 b	79.765 bc
I_3 K_0	87.294 b	66.945 c	78.456 cd	87.454 b	67.654 c	79.347 cd
I_3 K_1	84.327 de	66.174 d-f	76.578 e-g	84.734 de	66.545 d-f	77.145 e-g
I_3 K_2	87.569 b	67.667 b	78.482 cd	87.677 b	68.133 b	79.519 cd
I_3 K_3	87.548 b	67.867 b	80.238 ab	88.568 b	68.245 b	81.864 ab
CV (%)	2.983	3.311	2.123	2.932	3.002	3.019

In a column, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability

4.6 Biochemical characteristics

4.6.1. Chlorophyll content of flag leaf

Irrigation treatments showed significant effects on chlorophyll a, chlorophyll b, total chlorophyll content and chlorophyll a : b of leaf in both the years. The effect of irrigation treatments on chlorophyll a, chlorophyll b, total chlorophyll content and chlorophyll a : b in both the years are presented in Table 105 for first year (2015-2016) and in Table 106 for second year (2016-2017) respectively. Irrigated plants had higher chlorophyll a, chlorophyll b and total chlorophyll than the no irrigated (I_0) plants in flag leaf. In the study, I_2 treatments contained the highest chlorophyll a, chlorophyll b and total chlorophyll which was statistically similar with I_3 and followed by I_1 treatment in both the years. Chlorophyll a, chlorophyll b and total chlorophyll in flag leaf was found lower in I_0 treatment (no irrigation). Similar result was reported by Sarker *et al.* (1999), Chandrasekar *et al.* (2000), Nyachiro *et al.* (2001), Haider (2002), Haider and Paul (2003), Mollah (2007) and Abdelraouf *et al.* (2013). Paul *et al.* (2002) also showed that irrigated plants had higher chlorophyll content than rain-fed plants in wheat. High chlorophyll contents might contribute to higher photosynthetic rate and significant positive correlation between chlorophyll content and photosynthesis rate (Thomas *et al.*, 2005). Silaeva and Tkachuk (1982) reported that chloroplasts, photosynthetic membranes and the amount of thylaloid grana decreased with the intensification of soil water stress. The highest chlorophyll a:b was recorded in I_1 treatment which was statistically at par with I_2 and I_1 treatments in both the years. This result was in agreement with Ashraf *et al.* (2001) in pearl millet, where they observed no significant effect on chlorophyll a : b ratio but a slight increase was observed under water deficit condition. Ashraf *et al.* (1994) noticed that chlorophyll a : b increased under rain-fed conditions and the effect was more pronounced in the drought susceptible varieties. Abdrakhimov *et al.* (1996) reported that total chlorophyll and chlorophyll a : b ratio in wheat leaves were not affected by water shortage.

Chlorophyll content did not varied significantly due to variety in both the years are shown in Table 107 for first year (2015-2016) and in Table 108 for second year (2016-2017) respectively. But varieties had significant effect on chlorophyll a : b ratio. The highest chlorophyll a : b ratio was recorded in BARI Gom 28 (V_2) in both the years.

Chlorophyll a, chlorophyll b, total chlorophyll and chlorophyll a : b ratios were significantly influenced by foliar applications of potassium in both the years are given in Table 109 for first year (2015-2016) and in Table 110 for second year (2016-2017) respectively. The highest

chlorophyll a, chlorophyll b and total chlorophyll content were recorded in K_2 treatment of potassium which was at par with K_3 treatment of potassium in both the years. The highest chlorophyll a : b was recorded in K_1 treatment of potassium which was statistically similar with K_2 and control (K_0). The lowest chlorophyll a, chlorophyll b and total chlorophyll were found in control (K_0) plant in both the years. Very close link between total chlorophyll and potassium content was observed and many investigators proved that potassium is not only a constituent of the plant structure but it also has a regulatory function in several biochemical processes related to protein synthesis, carbohydrate metabolism, and enzyme activation (Hasanuzzaman *et al.*, 2018). Application of potassium at the rate of 2% alleviated all negative effect on plants that trigger photosynthesis and results increased production (Desoky *et al*., 2017). Chlorophyll content is approximately proportional to leaf potassium content, too (Bojovic and Markovic, 2009). Abdelraouf *et al.* (2013) reported that potassium fertilizer levels significantly affected chlorophyll content in wheat. Decreasing level of fertilizer significantly decreased chlorophyll content.

The interaction effects of irrigation amounts and foliar application of potassium were significant for chlorophyll a, chlorophyll b and total chlorophyll content in both the years are shown in Table 111 for first year (2015-2016) and in Table 112 for second year (2016-2017) respectively. The highest amount of chlorophyll a, chlorophyll b and total chlorophyll was found I_2 K_2 treatments followed by I_3K_2 and I_3K_3 treatments respectively. The lowest amounts of chlorophyll a, chlorophyll b and total chlorophyll were observed in I_0K_0 treatments in plants in both the years.

4.6.2. Proline accumulation

Irrigation regimes showed significant effect on proline accumulation of flag leaf of wheat in both the years are presented in Table 105 for first year (2015-2016) and in Table 106 for second year (2016-2017) respectively. Proline accumulation decreased with increasing irrigation frequencies and amount of water. Significantly the highest amount of proline was observed in I_0 (no irrigation) treatment followed by I_1 and I_2 treatments during the two successive growing seasons and the lowest was recorded in I_3. This results were agreement with the findings of Haider and Paul (2003) and Chandra *et al.* (2004) who reported that water stress increased proline accumulation in wheat. Mostajeran and Eichi (2009) stated that drought has significant correlation with solute accumulation like proline and varieties which accumulate high proline need to be considered in future context of climate variability. The least amount of proline was

accumulated in I_2 treatment in both the years. Irrigation regimes had significant effect on proline accumulation in flag leaf of both the varieties for both the years and significant increases in proline accumulation were noticed due to limited water supply in the presented investigation. Lower proline content in the irrigated plants was noticed in both the varieties and it might be due to the oxidation of proline in the irrigated condition as free proline converted to glutamic acid and other compounds under non-stress condition. Paul *et al.* (2002) also noticed lower proline content in the irrigated wheat plants. Similar results were also reported by Al-Tabbal *et al.* (2005) and Ashraf *et al.* (1994) in wheat and Bahadur (2008) in barley. Singh and Patel (1996) reported that water stress at any growth stage in wheat increased respiration rate as well as proline accumulation. Accumulation of proline could also serve as a readily available energy and potassium source for use upon the relief of stress (Blum and Eborcon 1976). Proline accumulation can also be used as a source of energy (Stewart 1972).

Proline accumulation did not differ significantly due to variety in both the years are shown in Table 107 for first year (2015-2016) and in Table 108 for second year (2016-2017) respectively. Between the two varieties, some higher amount of proline content was observed in BARI Gom 28 (V_2).

Potassium treatments had significant effect on proline accumulation in both the growing seasons are presented in Table 109 for first year (2015-2016) and in Table 110 for second year (2016-2017) respectively. Significantly the highest amount of proline was accumulated in K_0 which was statistically similar with K_1 and followed by K_3 applications of potassium in both the years. The lowest amount of proline was accumulated in treatment K_2 during the two successive growing seasons.

Proline accumulation varied significantly due to the interaction of irrigation and potassium in both the years are given in Table 111 for first year (2015-2016) and in Table 112 for second year (2016-2017) respectively. The highest amount of proline was observed in I_0K_0 treatment in both the years which was statistically identical to I_0K_1 treatments in wheat plants. The lowest amount of proline accumulation was noticed in I_2K_2 treatments in wheat plants in both the growing seasons.

Table 105: Effect of irrigation regimes on Chlorophyll and Proline content of wheat in 2015-2016

Irrigation	Chlorophyll a (mg g^{-1})	Chlorophyll b (mg g^{-1})	Chlorophyll a+b (mg g^{-1})	Chlorophyll a:b	Proline accumulation (µg g^{-1} fresh wt.)
I_0	1.982 c	0.702 c	2.66 c	2.863 ab	190.539 a
I_1	2.256 bc	0.791 bc	3.022 bc	2.872 a	178.962 b
I_2	2.597 a	0.992 a	3.558 a	2.637 b	144.184 c
I_3	2.441 ab	0.871 ab	3.298 ab	2.838 ab	125.135 d
CV (%)	2.069	3.058	2.578	5.365	6.597

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 106: Effect of irrigation regimes on Chlorophyll and Proline content of wheat in 2016-2017

Irrigation	Chlorophyll a (mg g^{-1})	Chlorophyll b (mg g^{-1})	Chlorophyll a+b (mg g^{-1})	Chlorophyll a:b	Proline accumulation (µg g-1 fresh wt.)
I_0	2.02 c	0.718 c	2.729 c	2.753 ab	194.214 a
I_1	2.301 bc	0.809 bc	3.082 bc	2.779 a	182.276 b
I_2	2.639 a	1.018 a	3.648 a	2.912 b	127.489 d
I_3	2.483 ab	0.874 ab	3.352 ab	2.766 ab	146.929 c
CV (%)	2.123	2.547	2.334	5.365	6.598

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 107: Effect of Variety on Chlorophyll and Proline content of wheat in 2015-2016

Variety	Chlorophyll a (mg g^{-1})	Chlorophyll b (mg g^{-1})	Chlorophyll a+b (mg g^{-1})	Chlorophyll a:b	Proline accumulation (µg g^{-1} fresh wt.)
V_1	2.312 a	0.819 a	3.113 a	2.866 a	159.516 a
V_2	2.325 a	0.859 a	3.156 a	2.739 a	159.894 a
CV (%)	2.069	3.058	2.578	5.365	6.597

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 108: Effect of Variety on Chlorophyll and Proline content of wheat in 2016-2017

Variety	Chlorophyll a (mg g^{-1})	Chlorophyll b (mg g^{-1})	Chlorophyll a+b (mg g^{-1})	Chlorophyll a:b	Proline accumulation (µg g^{-1} fresh wt.)
V_1	2.31 a	0.831 a	3.202 a	2.843 a	162.531 a
V_2	2.412 a	0.878 a	3.203 a	2.762 a	162.923 a
CV (%)	2.123	2.547	2.334	5.365	6.598

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 109: Effect of Potassium on Chlorophyll and Proline content of wheat in 2015-2016

Potassium	Chlorophyll a (mg g^{-1})	Chlorophyll b (mg g^{-1})	Chlorophyll a+b (mg g^{-1})	Chlorophyll a:b	Proline accumulation (µg g^{-1} fresh wt.)
K_0	1.894 b	0.665 b	2.536 b	2.806 ab	173.141 a
K_1	2.027 b	0.687 b	2.665 b	2.81 a	163.42 ab
K_2	2.731 a	1.07 a	3.769 a	2.786 b	147.911 c
K_3	2.622 a	0.935 a	3.568 a	2.81 ab	154.349 bc
CV (%)	2.069	3.058	2.578	5.365	6.597

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 110: Effect of Potassium on Chlorophyll and Proline content of wheat in 2016-2017

Potassium	Chlorophyll a (mg g^{-1})	Chlorophyll b (mg g^{-1})	Chlorophyll a+b (mg g^{-1})	Chlorophyll a:b	Proline accumulation (µg g^{-1} fresh wt.)
K_0	1.948 b	0.692 b	2.652 b	2.816 ab	176.414 a
K_1	2.051 b	0.716 b	2.779 b	2.869 a	166.51 ab
K_2	2.782 a	1.067 a	3.764 a	2.824 ab	150.712 b
K_3	2.663 a	0.944 a	3.617 a	2.702 b	157.27 ab
CV (%)	2.123	2.547	2.334	5.365	6.598

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 111: Interaction effect of Irrigation and Potassium on Chlorophyll and Proline content of wheat in 2015-2016

Interaction (Irrigation× Potassium)	Chlorophyll a (mg g^{-1})	Chlorophyll b (mg g^{-1})	Chlorophyll a+b (mg g^{-1})	Chlorophyll a:b	Proline accumulation (µg g^{-1} fresh wt.)
I_0 K_0	1.764 l	0.624 f	2.389 j	2.826 a	198.366 a
I_0 K_1	1.808 kl	0.641 f	2.450 j	2.821 a	195.147 a
I_0 K_2	2.144 e-g	0.758 d-f	2.902 e-g	2.831 a	187.786 b
I_0 K_3	2.232 e	0.785 c-f	3.017 e	2.845 a	180.869 c
I_1 K_0	1.883 jk	0.669 ef	2.552 ij	2.817 a	188.868 b
I_1 K_1	2.063 f-h	0.678 ef	2.744 gh	3.045 a	182.480 c
I_1 K_2	2.506 d	0.883 b-e	3.389 d	2.839 a	175.514 d
I_1 K_3	2.588 d	0.946 b-d	3.448 d	2.736 ab	168.842 e
I_2 K_0	1.948 ij	0.694 ef	2.641 hi	2.807 a	155.944 f
I_2 K_1	2.021 hi	0.723 d-f	2.744 gh	2.796 a	149.017 g
I_2 K_2	3.140 a	1.408 a	4.257 a	2.403 b	108.332 k
I_2 K_3	2.969 b	1.051 b	4.020 b	2.817 a	138.268 h
I_3 K_0	2.820 c	1.001 bc	3.821 c	2.824 a	133.609 h
I_3 K_1	2.057 gh	0.732 d-f	2.789 f-h	2.813 a	149.379 g
I_3 K_2	2.164 ef	0.769 c-f	2.933 ef	2.813 a	127.032 i
I_3 K_3	2.991 b	1.065 b	4.056 b	2.808 a	115.831 j
CV (%)	2.069	3.058	2.578	5.365	6.597

In a column, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 112: Interaction effect of Irrigation and Potassium on Chlorophyll and Proline content of wheat in 2016-2017

Interaction (Irrigation× Potassium)	Chlorophyll a (mg g^{-1})	Chlorophyll b (mg g^{-1})	Chlorophyll a+b (mg g^{-1})	Chlorophyll a:b	Proline accumulation (µg g^{-1} fresh wt.)
I_0 K_0	1.796 l	0.636 f	2.431 j	2.826 a	202.184 a
I_0 K_1	1.841 kl	0.653 f	2.493 j	2.821 a	198.902 a
I_0 K_2	2.182 e-g	0.771 d-f	2.953 e-g	2.831 a	191.400 b
I_0 K_3	2.271 e	0.799 c-f	3.071 e	2.845 a	184.350 c
I_1 K_0	1.919 jk	0.681 ef	2.601 ij	2.817 a	192.399 b
I_1 K_1	2.103 f-h	0.691 ef	2.796 gh	3.045 a	185.892 c
I_1 K_2	2.554 d	0.900 b-e	3.454 d	2.839 a	178.795 d
I_1 K_3	2.637 d	0.964 b-d	3.513 d	2.736 ab	171.999 e
I_2 K_0	1.982 ij	0.706 ef	2.688 hi	2.807 a	158.888 f
I_2 K_1	2.057 hi	0.736 d-f	2.973 gh	2.796 a	151.830 g
I_2 K_2	3.197 a	1.434 a	4.334 a	2.403 b	110.367 k
I_2 K_3	2.870 c	1.019 bc	3.889 c	2.817 a	140.879 h
I_3 K_0	3.021 b	1.070 b	4.091 b	2.824 a	136.131 h
I_3 K_1	2.095 gh	0.745 d-f	2.840 f-h	2.813 a	152.185 g
I_3 K_2	2.203 ef	0.783 c-f	2.987 ef	2.813 a	129.418 i
I_3 K_3	3.045 b	1.085 b	4.130 b	2.808 a	118.007 j
CV (%)	2.123	2.547	2.334	5.365	6.598

In a column, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

4.7 Grain growth parameters

4.7.1 Number of spikelets spike^{-1}

The number of spikelets spike^{-1} of wheat was significantly affected by different irrigation regimes at all plant growth stages are presented in Table 113A and Fig. 25A for first year (2015-2016) and in Table 113B and Fig. 25B for second year (2016-2017) respectively. The highest number of spikelets spike^{-1} was recorded in I_2 which was statistically similar with I_3 and the lowest number of spikelets spike^{-1} was found in I_0 at all crop growth stages in both the years. This results supported the findings of Nasri (2005) and Rad *et al*. (2005) who reported that drought stress at anthesis badly affected the plant production by triggering severe diminution in number of spikelets spike^{-1}. Aown *et al.* (2012) and Richards *et al.* (2001) also reported that the number of grains per spike were decreased adversely under water stress. Shah *et al.* (2017), Sarwar *et al.* (2010), Plaut *et al.* (2004), Dencic *et al*. (2000) and Shehzadi (1999) concluded that spikelets spike^{-1} were more sensitive to drought stress in different wheat cultivars. This result is corroborated with Abdorrahmani *et al.* (2005), Afzal *et al.* (2006), Bahadur (2008) and Mollah and Paul (2011) in barley, Rahman *et al.* (2001), Haider (2002), Rahman (2004), Naeem Sarwar *et al.* (2010), Muhammad *et al.* (2012), Atikullah *et al.* (2014) and Zaman *et al.* (2016) in wheat. Similar results were also observed by Ali and Amin (2007) in wheat where they found that irrigated plants had big effect on number of spikelets spike^{-1}.

Number of spikelets spike^{-1} was not statistically significant in both the years for variety are shown in Table 114A for first year (2015-2016) and in Table 114B for second year (2016-2017) respectively. Between the two varieties, higher spikelets spike^{-1} was found in BARI Gom 28 (V_2) in 35 DAA in both the years whereas the lowest was found in Gom 27 (V_1) in 14 DAA during the two successive growing seasons.

The effects of foliar application of potassium was found significant in respect to number of spikelets spike^{-1} at all stages in both the growing seasons are shown in Table115A and Fig. 26A for first year (2015-2016) and in Table 115B and Fig. 26B for second year (2016-2017) respectively. The data of the present investigation stated that, the maximum number of spikelets spike^{-1} was recorded from K_2 which was at par with K_3 followed by K_1 and the minimum number of spikelets spike^{-1} was recorded from K_0. Similar trend was observed in the second year experiment where the maximum and minimum ones were recorded from K_2 and K_0 respectively. This findings is corroborated with the findings of Khan *et al.* (2014) and Bly and Woodward, (2003) who reported that optimum potassium level enhanced the production of

spikelets spike^{-1}. This findings is also good agreement with Desoky *et al*. (2017) who concluded that potassium can counteract the adverse effect of drought stress on growth characters as well as yield and its components of wheat plants. Similar result were also reported by Tabatabaii *et al.* (2011) and Shah *et al.* (2017) in wheat.

Different treatments combination of irrigation and potassium had significant influence on number of spikelets spike^{-1} of wheat at different days after anthesis (DAA) during the two successive growing seasons are shown in Table 116A for first year (2015-2016) and in Table 116B for second year (2016-2017) respectively. From the table, it was observed that, I_2K_2 gave the highest number of spikelets spike^{-1} which was statistically identical with I_3K_2 and I_3K_3 at all sampling dates in both the years. The lowest value was obtained in I_0K_0 at all the crop growth stages in both the years.

Table 113: Effect of irrigation on number of spikelets spike^{-1} of wheat at different day after anthesis (DAA) in 2015-2016 (left) and 2016-2017 (right)

Irrigation	A. Number of spikelets spike^{-1} (2015-2016)					B. Number of spikelets spike^{-1} (2016-2017)				
	7 DAA	14 DAA	21 DAA	28 DAA	35 DAA	7 DAA	14 DAA	21 DAA	28 DAA	35 DAA
I_0	14.978 c	15.727 c	15.928 c	15.337 c	15.705 c	15.825 c	16.150 c	16.475 c	16.649 c	16.88 c
I_1	16.623 bc	16.647 bc	16.656 bc	16.69 bc	16.774 bc	16.986 bc	17.061 bc	17.322 bc	17.45 bc	17.293 bc
I_2	18.436 a	18.544 a	18.768 a	19.137 a	19.055 a	19.131 a	18.768 a	19.099 a	19.307 a	19.341 a
I_3	17.367 ab	17.335 ab	17.574 ab	18.094 ab	17.991 ab	17.739 ab	18.090 ab	18.027 ab	18.349 ab	18.313 ab
CV (%)	11.937	12.661	13.341	12.687	14.498	13.572	15.469	14.123	13.312	15.419

At specific days after anthesis, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 114: Effect of variety on number of spikelets spike^{-1} of wheat at different day after anthesis (DAA) in 2015-2016 (left) and 2016-2017 (right)

Variety	A. Number of spikelets spike^{-1} (2015-2016)					B. Number of spikelets spike^{-1} (2016-2017)				
	7 DAA	14 DAA	21 DAA	28 DAA	35 DAA	7 DAA	14 DAA	21 DAA	28 DAA	35 DAA
V_1	16.794 a	16.976 a	17.079 a	17.613 a	17.364 a	17.574 a	17.433 a	17.789 a	17.92 a	17.975 a
V_2	16.908 a	17.152 a	17.384 a	17.016 a	17.398 a	17.266 a	17.601 a	17.672 a	17.958 a	17.938 a
CV (%)	11.937	12.661	13.341	12.687	14.498	13.572	15.469	14.123	13.312	15.419

At specific days after anthesis, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 115: Effect of potassium on number of spikelets spike^{-1} of wheat at different day after anthesis (DAA) in 2015-2016 (left) and 2016-2017 (right)

Potassium	A. Number of spikelets spike^{-1} (2015-2016)					B. Number of spikelets spike^{-1} (2016-2017)				
	7 DAA	14 DAA	21 DAA	28 DAA	35 DAA	7 DAA	14 DAA	21 DAA	28 DAA	35 DAA
K_0	14.608 c	14.627 c	14.544 c	14.618 c	14.65 c	14.936 c	15.035 c	15.209 c	15.296 c	15.116 c
K_1	16.90 b	17.306 b	17.428 b	17.443 b	17.534 b	17.622 b	17.594 b	17.794 b	17.972 b	18.141 b
K_2	18.313 a	18.547 a	18.856 a	18.944 a	19.1 a	18.941 a	19.126 a	19.38 a	19.639 a	19.879 a
K_3	17.583 ab	17.774 ab	18.098 ab	18.253 ab	18.24 ab	18.183 ab	18.314 ab	18.54 ab	18.846 ab	18.692 ab
CV (%)	11.937	12.661	13.341	12.687	14.498	13.572	15.469	14.123	13.312	15.419

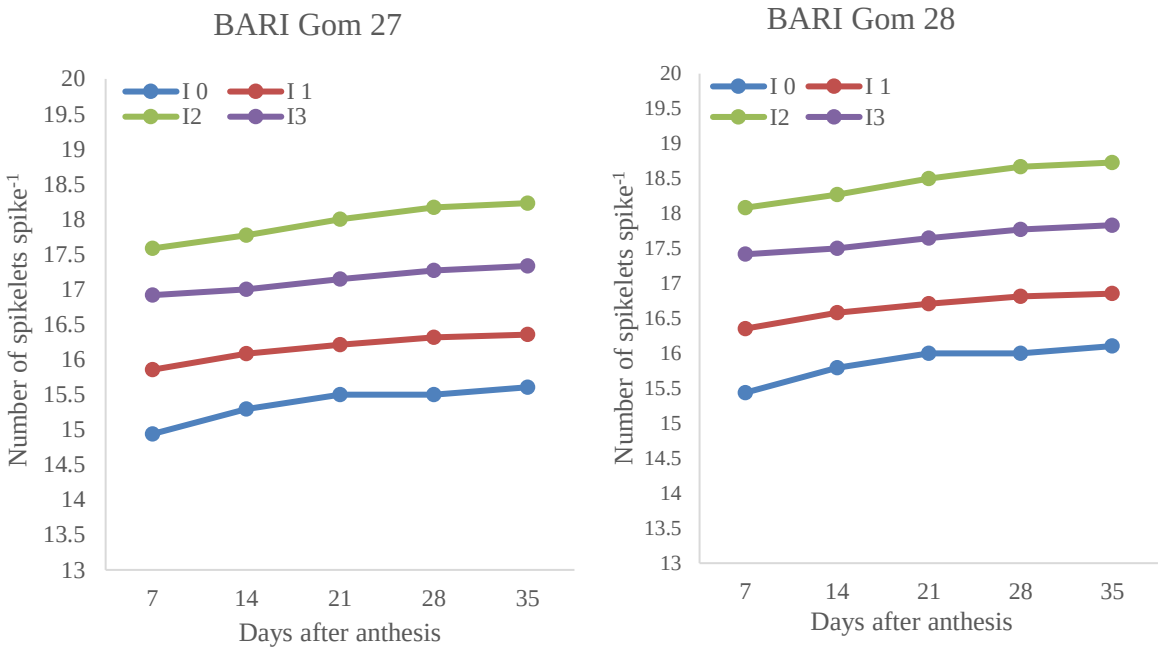
At specific days after anthesis, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 116: Interaction effect of irrigation and potassium on number of spikelets spike^{-1} of wheat at different day after anthesis (DAA) in 2015-2016 (left) and 2016-2017 (right)

Interaction (Irrigation Potassium)	A.Number of spikelets spike^{-1} (2015-2016)					B. Number of spikelets spike^{-1} (2016-2017)				
	7 DAA	14 DAA	21 DAA	28 DAA	35 DAA	7 DAA	14 DAA	21 DAA	28 DAA	35 DAA
I_0K_0	13.012 i	13.121 h	13.323 h	13.422 j	13.571 i	12.502 i	12.741 h	12.872 h	12.891 j	13.310 i
I_0K_1	15.689 fg	16.167 d-f	16.333 ef	16.333 f-h	16.417 e-g	15.250 fg	15.667 d-f	15.833 ef	15.833 f-h	15.917 e-g
I_0K_2	16.888 d-f	17.393 b-e	17.502 de	17.500 d-g	17.583 c-f	16.417 d-f	16.833 b-e	17.000 de	17.000 d-g	17.083 c-f
I_0K_3	16.123 e-g	16.466 c-f	16.750 d-f	16.750 e-h	16.917 d-g	15.583 e-g	15.917 c-f	16.250 d-f	16.250 e-h	16.417 d-g
I_1K_0	14.410 hi	14.083 gh	14.244 gh	14.333 ij	14.333 hi	13.500 hi	13.583 gh	13.750 gh	13.833 ij	13.833 hi
I_1K_1	16.566 d-g	16.862 c-f	16.917 d-f	17.090 d-g	17.083 d-g	16.083 d-g	16.333 c-f	16.417 d-f	16.500 d-g	16.583 d-g
I_1K_2	17.642 b-e	17.917 b-d	18.107 b-d	18.167 b-e	18.250 b-e	17.167 b-e	17.417 b-d	17.667 b-d	17.667 b-e	17.750 b-e
I_1K_3	17.211 c-f	17.521 b-e	17.540 de	17.751 c-f	17.750 b-e	16.667 c-f	17.000 b-e	17.000 de	17.250 c-f	17.250 b-e
I_2K_0	15.212 gh	15.083 f-h	15.557 f-h	15.167 h-j	15.167 g-i	14.583 gh	14.583 f-h	14.667 f-h	14.667 h-j	14.667 g-i
I_2K_1	17.509 b-e	17.503 b-d	17.660 c-e	17.834 c-f	18.000 b-e	17.000 b-e	17.083 b-d	17.167 c-e	17.333 c-f	17.500 b-e
I_2K_2	19.861 a	20.443 a	20.531 a	20.586 a	20.750 a	19.333 a	19.583 a	20.000 a	20.083 a	20.250 a
I_2K_3	18.225 b-d	18.250 a-c	18.417 b-d	18.577 b-d	18.667 b-d	17.583 b-d	17.750 a-c	17.917 b-d	18.083 b-d	18.167 b-d
I_3K_0	15.667 f-h	15.637 e-g	15.677 fg	15.750 g-i	15.750 f-h	15.167 f-h	15.167 e-g	15.167 fg	15.250 g-i	15.250 f-h
I_3K_1	18.009 b-d	18.330 a-c	18.350 b-d	18.673 b-d	18.750 b-d	17.500 b-d	17.750 a-c	18.833 a-c	18.167 b-d	18.250 b-d
I_3K_2	19.033 ab	19.088 ab	19.332 a-c	19.533 a-c	19.500 a-c	18.500 ab	18.583 ab	17.833 b-d	19.000 a-c	19.000 a-c
I_3K_3	18.555 a-c	19.152 ab	19.471 ab	19.559 ab	19.609 ab	18.513 a-c	18.567 ab	19.090 ab	19.337 ab	19.327 ab
CV (%)	11.937	12.661	13.341	12.687	14.498	13.572	15.469	14.123	13.312	15.419

At specific days after anthesis, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

A



B

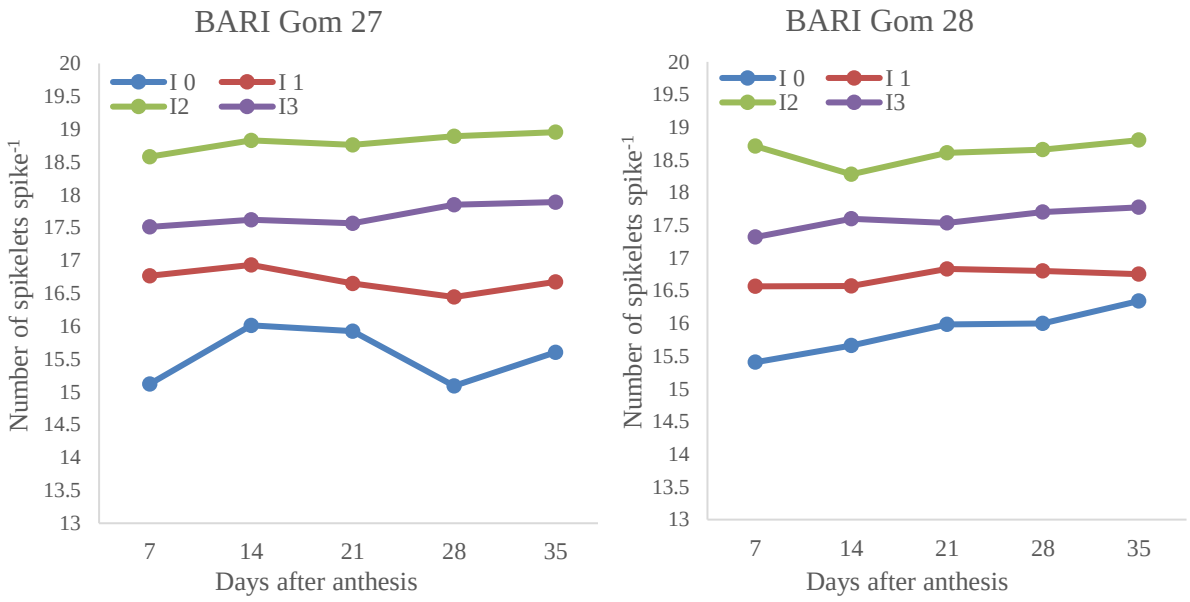
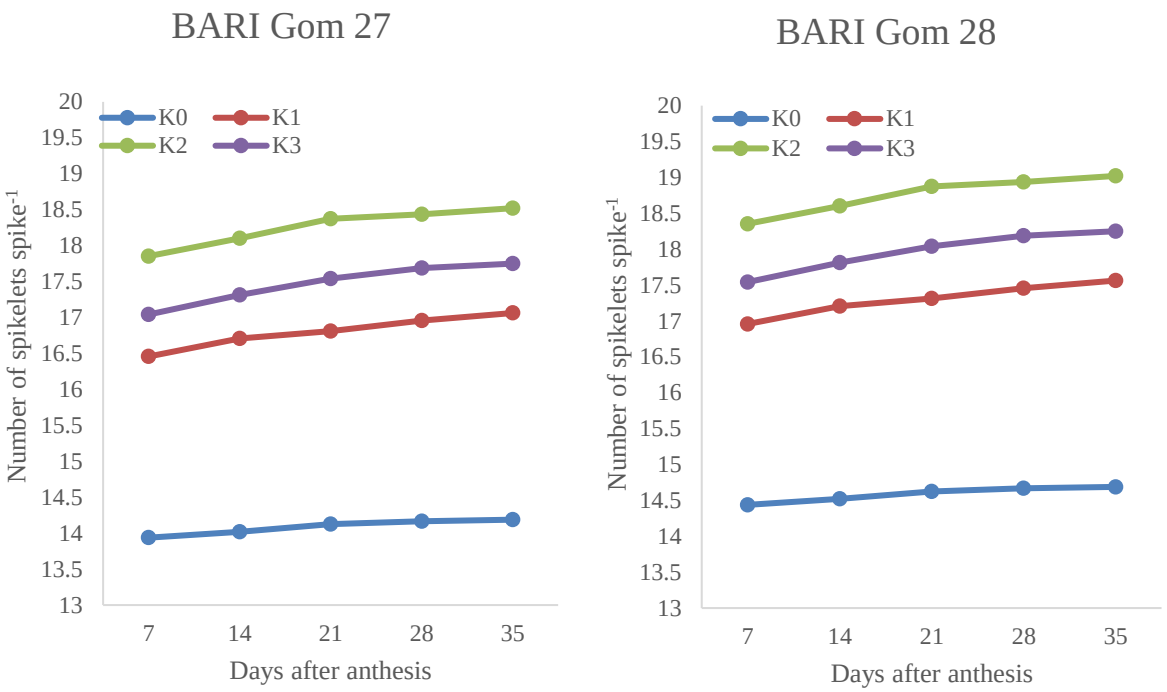


Fig. 25: Effect of irrigation on number of spikelets spike^{-1} at different days after anthesis (DAA) in 2015-2016 (A) and 2016-2017 (B)

A



B

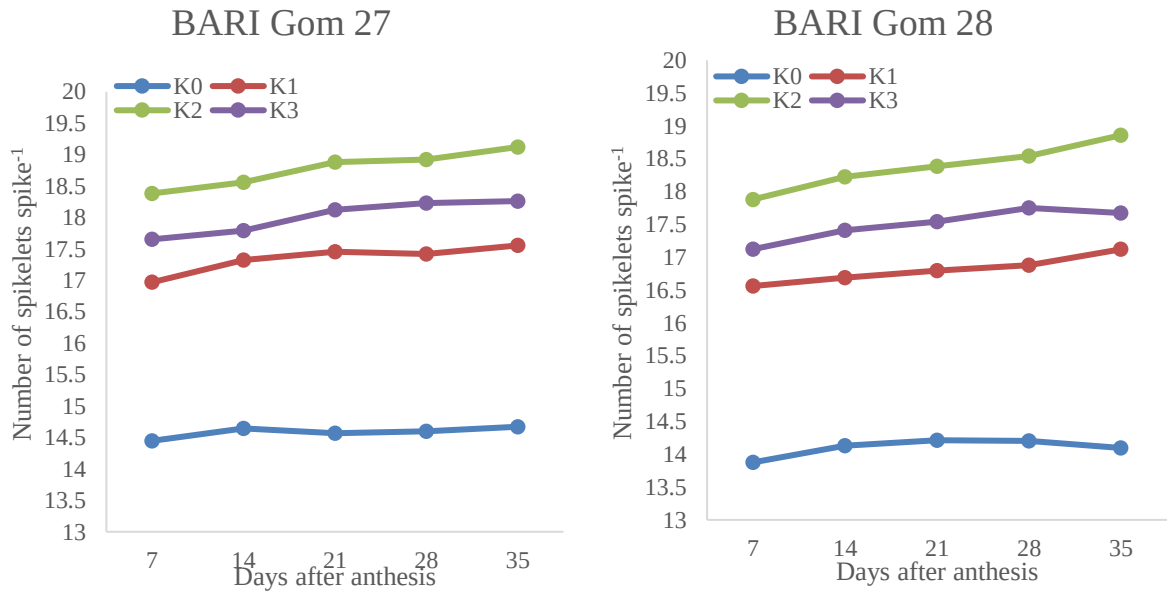


Fig. 26: Effect of potassium on number of spikelets spike^{-1} at different days after anthesis (DAA) in 2015-2016 (A) and 2016-2017 (B)

4.7.2. Number of grains spike^{-1}

The study results in relation to number of grains spike^{-1} of wheat as influenced by various irrigation treatments are shown in Table 117A and Fig. 27A for first year (2015-2016) and in Table 117B and Fig. 27B for second year (2016-2017) respectively. Irrigation had significant effect on number of grain spike^{-1} at all the days after anthesis (DAA) in both the years. The highest number of grain spike^{-1} was recorded in I_2 which was statistically similar with I_3 followed by I_1. The lowest value was obtained in I_0 at all the stages during the two successive growing seasons. Similar result were reported by separate researchers (Yadav *et al.*, 2001, Pandit *et al.,* 2001, Abdorrahmani *et al.,* 2005, Sana Ullah Baloch *et al.,* 2014 and Atikullah *et al.,* 2014) in wheat. Mandal *et al.* (2003) noticed that the highest grain yield was observed with an increase in water supply in every nutrient treatment, being highest in three irrigations. Mollah and Paul (2011) stated that higher frequency of irrigation produced the highest grain number per spike and the lowest was in the control in barley. This finding is also supported by the findings of Khan *et al.* (2007), Muhammad *et al.* (2012), Sarker *et al.* (2015) and Zaman *et al.* (2016), Mishra and Padmakar (2010), Rahman and Paul (1998), Rahman *et al.* (2001) and Ngwako and Mashiqa (2013) in wheat.

Number of grains spike^{-1} did not differ significantly due to variety at 14, 21, 28 and 35 DAA in both the years are given in Table 118A for first year (2015-2016) and in Table 118B for second year (2016-2017) respectively. Between the two varieties, BARI Gom 28 (V_2) produced the highest number of grains spike^{-1} in compare to BARI Gom 27 (V_1) during the two successive growing seasons.

The effects of foliar application of potassium was found significant in respect to number of grains spike^{-1} at all crop growth stages in both the seasons are shown in Table 119A and Fig. 28A for first year (2015-2016) and in Table 119B and Fig. 28B for second year (2016-2017) respectively. At 14 DAA, the crop received K_2 produced highest number of grains spike^{-1} which was at par with K_3 and K_1 in both the years. At 21 DAA, the highest number of grains spike^{-1} was produced in K_2 which were statistically similar with K_3 and K_1 in the both the years. At 28 and 35 DAA, the highest number of grains spike^{-1} was produced in K_2 which was at par with K_3 followed by K_1 in both the years. The lowest value was found in K_0 at all the days after anthesis during the two successive growing seasons. Desoky *et al.* (2017) reported similar findings that potassium can avoid the adverse effect of drought stress

on growth characters as well as yield and its components of wheat plants. Naveed *et al.* (2013) reported that the number of grains spike^{-1} increased with increase in the amount of potassium application. Aown *et al*. (2012) reported that foliar application of K at all three critical growth stages improved the drought tolerance of plants and improved the growth and yield components, however, grain filling stage was found more responsive.This results also supported the findings of Martre *et al.* (2003) who reported decreased grain numbers under potassium deficiency conditions. Singh *et al.* (1992) reported that potassium fertilization showed marked improvement in seeds spike^{-1}.

The interaction effects of irrigation and potassium had significant influence on number of grains spike^{-1} of wheat at different days after anthesis (DAA) in both the growing seasons are shown in Table 120A for first year (2015-2016) and in Table 120B for second year (2016-2017) respectively. The obtaining data revealed that I_2K_2 produced the highest number of grains spike^{-1} which was statistically identical with I_3K_3, I_3K_2 and I_3K_1 at all sampling dates in both the years. The lowest value was obtained in I_0K_0 in both the growing seasons.

Table 117: Effect of irrigation on number of grains spike^{-1} of wheat at different day after anthesis (DAA) in 2015-2016 (left) and 2016-2017 (right)

Irrigation	A. Number of grains spike^{-1} (2015-2016)				117. Number of grains spike^{-1} (2016-2017)			
	14 DAA	21 DAA	28 DAA	35 DAA	14 DAA	21 DAA	28 DAA	35 DAA
I_0	40.277 b	41.021 b	41.429 b	42.218 b	41.639 b	42.371 b	42.896 b	43.643 b
I_1	41.654 ab	45.291 ab	45.572 ab	46.208 ab	46.211 ab	46.409 ab	47.125 ab	47.778 ab
I_2	47.531 a	48.123 a	48.561 a	48.986 a	48.306 a	48.911 a	49.692 a	50.517 a
I_3	46.327 a	46.872 a	47.233 a	47.91 a	47.672 a	47.544 a	48.855 a	48.988 a
CV (%)	9.288	8.686	10.051	8.751	8.651	7.987	9.616	10.011

At specific days after anthesis, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 118: Effect of variety on number of grain spike^{-1} of wheat at different day after anthesis (DAA) in 2015-2016 (left) and 2016-2017 (right)

Variety	A. Number of grains spike^{-1} (2015-2016)				B. Number of grains spike^{-1} (2016-2017)			
	14 DAA	21 DAA	28 DAA	35 DAA	14 DAA	21 DAA	28 DAA	35 DAA
V_1	43.438 a	43.922 a	44.552 a	45.22 a	44.549 a	45.176 a	45.861 a	46.563 a
V_2	43.897 a	44.561 a	45.567 a	46.331 a	45.51 a	45.968 a	46.633 a	47.718 a
CV (%)	9.288	8.686	10.051	8.751	8.651	7.987	9.616	10.011

At specific days after anthesis, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 119: Effect of potassium on number of grains spike^{-1} of wheat at different day after anthesis (DAA) in 2015-2016 (left) and 2016-2017 (right)

Potassium	A. Number of grains spike^{-1} (2015-2016)				B. Number of grains spike^{-1} (2016-2017) C.			
	14 DAA	21 DAA	28 DAA	35 DAA	14 DAA	21 DAA	28 DAA	35 DAA
K_0	33.663 b	34.385 b	35.102 c	34.977 c	33.536 c	35.102 c	35.581 c	36.231 c
K_1	46.238a	46.917 a	47.391 b	47.881 b	46.271 a	47.391 b	47.31 b	47.673 b
K_2	48.293 a	48.981 a	49.71 a	51.105 a	48.698 a	49.71 a	49.723 a	51.012 a
K_3	47.324 a	47.908 a	48.411 ab	48.958 ab	47.341 a	48.411 ab	48.375 ab	48.843 ab
CV (%)	9.288	8.686	10.051	8.751	8.651	7.987	9.616	10.011

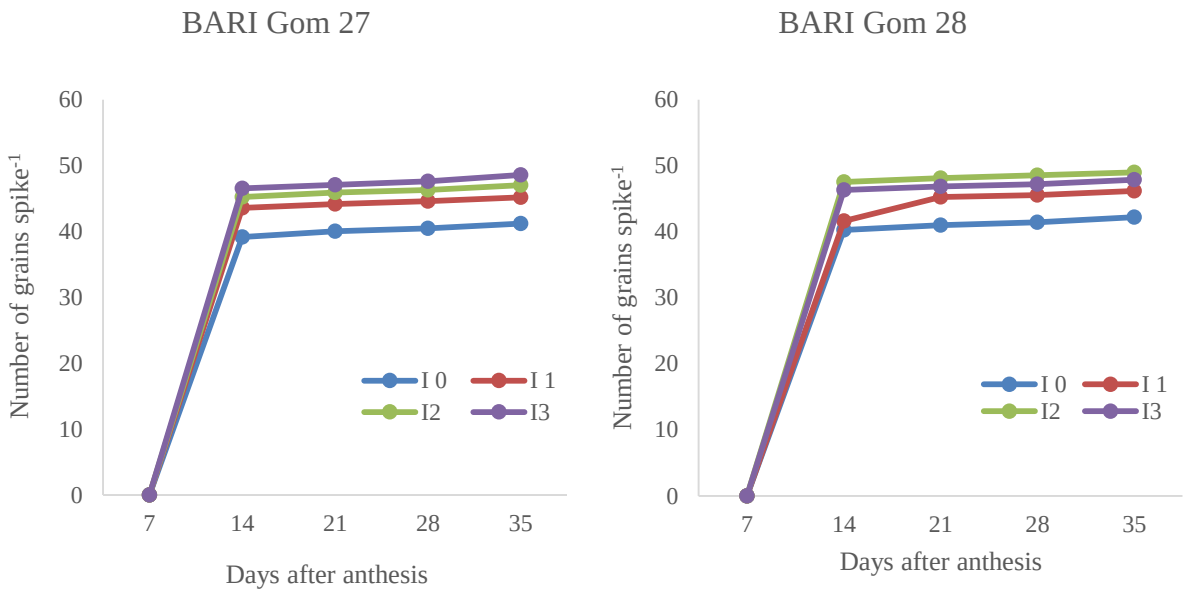
At specific days after anthesis, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 120: Interaction effect of irrigation and potassium on number of grains spike^{-1} of wheat at different day after anthesis (DAA) in 2015-2016 (left) and 2016-2017 (right)

Interaction (irrigation x potassium	A. Number of grains spike^{-1} (2015-2016)				B. Number of grains spike^{-1} (2016-2017)			
	14 DAA	.21 DAA	28 DAA	35 DAA	14 DAA	21 DAA	28 DAA	35 DAA
I_0 K_0	30.252 j	31.241 j	31.708 j	32.290 k	31.334 i	32.083 j	32.677 j	33.155 l
I_0 K_1	44.667 g	43.254 g	43.708 g	44.278 h	44.167 f	44.667 g	45.167 g	44.917 i
I_0 K_2	44.346 g	45.431 f	45.917 f	47.125 fg	45.917 f	46.756 f	47.660 ef	48.861 gh
I_0 K_3	43.416 g	44.167 fg	44.542 fg	45.177 gh	44.933f	45.500 fg	46.083 fg	46.567 hi
I_1 K_0	33.417 hi	34.041 i	34.167 i	34.542 j	34.500 h	34.845 i	35.333 i	35.750 k
I_1 K_1	47.011 f	47.690 e	47.958 e	48.443 ef	48.507 e	48.752 e	49.251 de	50.123 fg
I_1 K_2	49.416 c-e	50.042 b-d	50.750 b-d	52.083 bc	51.083 b-d	51.501 cd	52.750 bc	53.910 b-d
I_1 K_3	48.414 ef	49.219 de	49.458 de	49.779 de	49.907 de	50.422 de	51.167 cd	51.511 ef
I_2 K_0	34.919 hi	35.625 hi	35.875 hi	36.288 ij	36.083 gh	36.583 hi	37.090 hi	37.502 jk
I_2 K_1	48.915 d-f	49.654 cd	49.958 cd	50.750 cd	50.655 cd	50.854 d	51.522 c	52.333 de
I_2 K_2	52.022 a	52.750 a	53.583 a	55.329 a	53.927 a	54.501 a	55.667 a	57.511 a
I_2 K_3	50.123 b-e	50.741 b-d	51.083 b-d	51.564 b-d	51.666 b-d	52.022 b-d	52.750 bc	53.244 c-e
I_3 K_0	36.541 h	36.608 h	37.000 h	37.583 i	37.250 g	37.833 h	38.343 h	39.0211 j
I_3 K_1	50.521 a-d	51.331 a-c	51.500 bc	52.120 bc	52.123 a-c	52.252 b-d	53.083 bc	53.917 b-d
I_3 K_2	50.943 a-c	51.625 ab	52.208 ab	53.483 ab	52.583 a-c	53.123 a-c	54.107 ab	55.583 ab
I_3 K_3	51.423 ab	51.833 ab	52.417 ab	53.599 ab	52.927 ab	53.417 ab	54.183 ab	55.849 bc
CV (%)	9.288	8.686	10.051	8.751	8.651	7.987	9.616	10.011

At specific days after anthesis, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

A



B

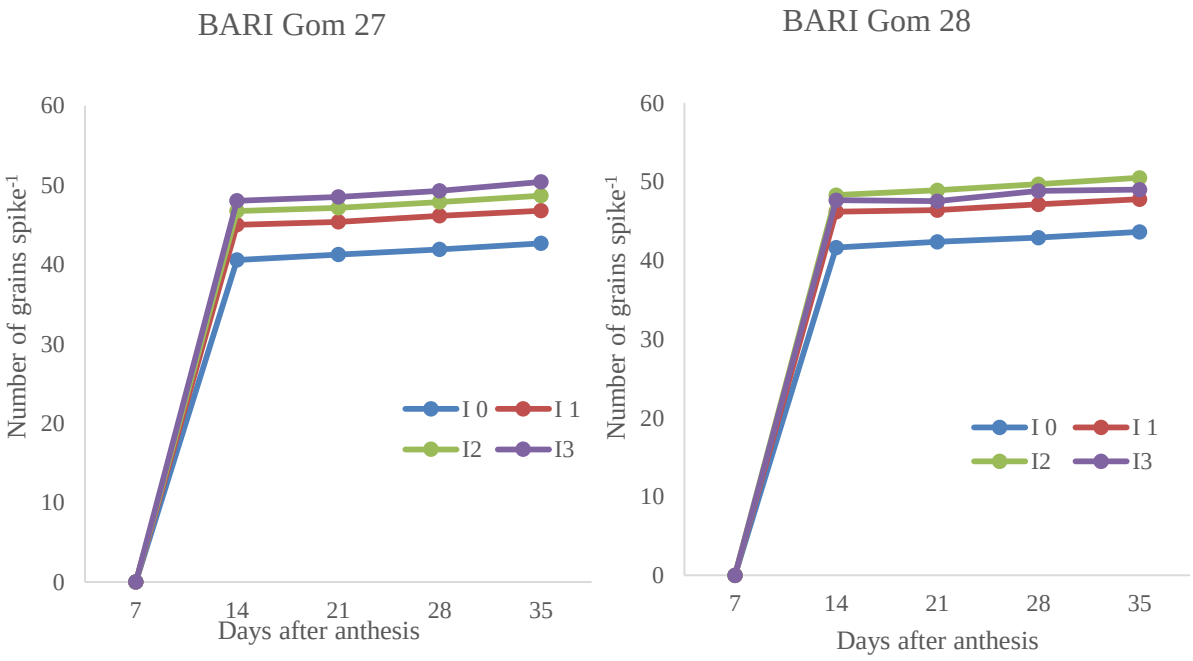
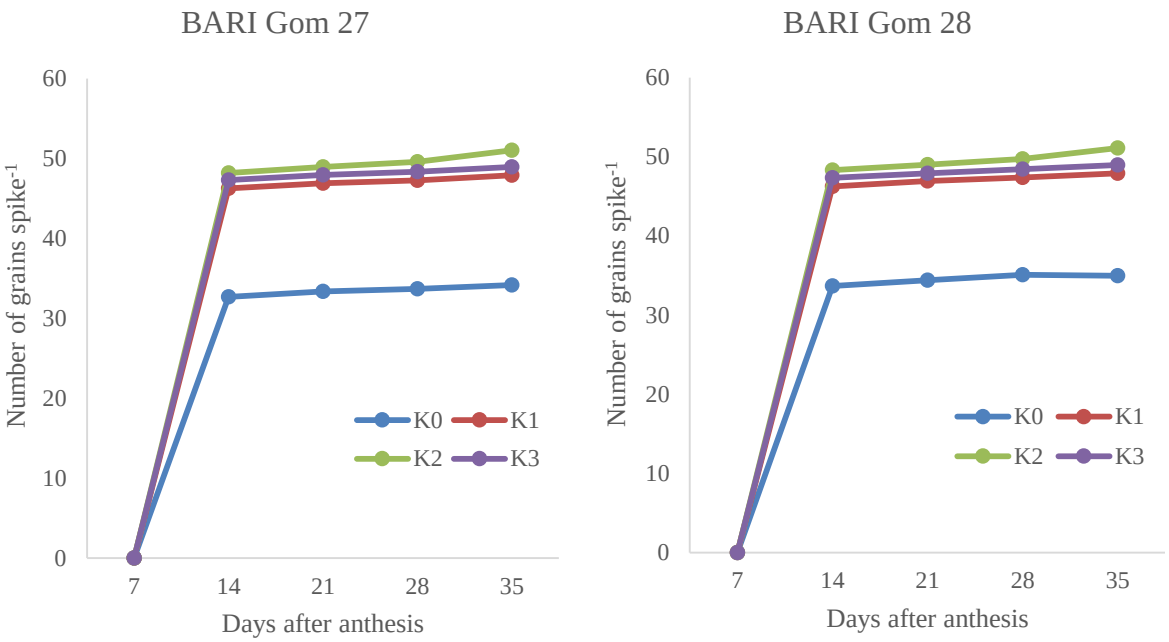


Fig. 27: Effect of irrigation on number of grains spike^{-1} at different days after anthesis (DAA) in 2015-2016 (A) and 2016-2017 (B)

A



B

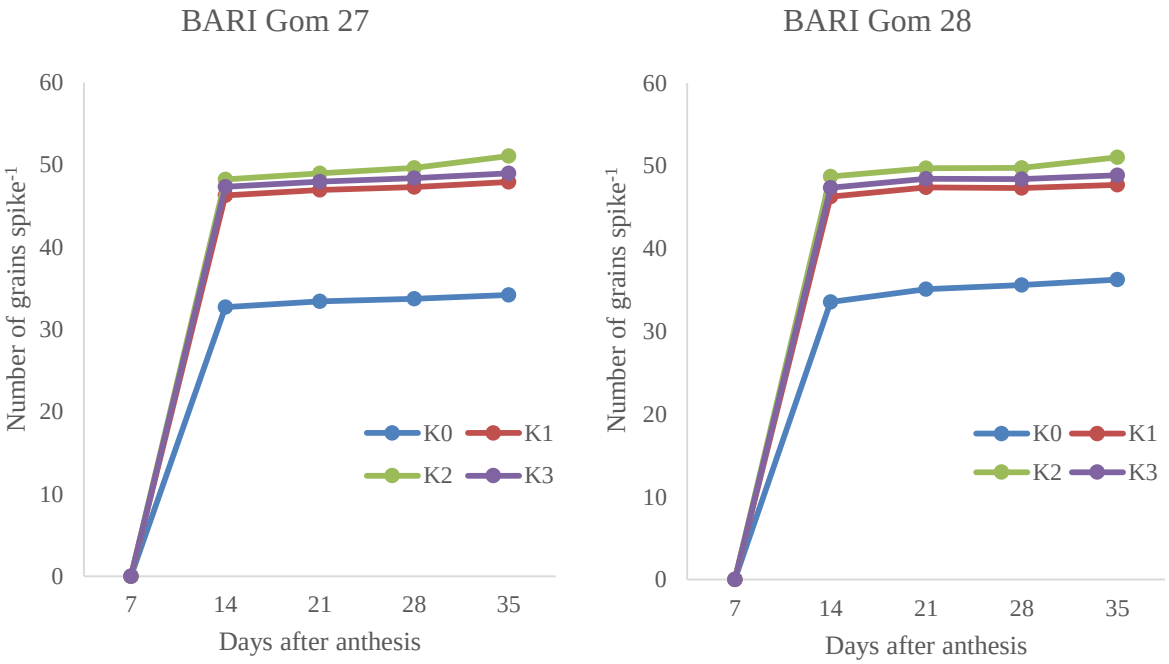


Fig. 28: Effect of potassium on number of grains spike^{-1} at different days after anthesis (DAA) in 2015-2016 (A) and 2016-2017 (B)

4.7.3. Dry weight spike^{-1}

There was a pronounced effect of different irrigations level on dry weight per spike at all the days after anthesis in both the growing seasons are presented in Table 121A and Fig. 29A for first year (2015-2016) and in Table 121B and Fig. 29B for second year (2016-2017) respectively. Spike growth is fully dependent on the anthesis and grain filling duration. The highest dry weight per spike was recorded in I_2 followed by I_3 and I_1 at all sampling dates in both the years. The lowest value was observed in I_0 at all sampling dates in both the years. Similar results were found by Rahman and Paul (1996) and Rahman (2004) in wheat and they stated that the irrigated wheat plants had higher spike weight than the rain-fed plants at all growth stages. This results is corroborated with the findings of Hasil *et al.* (2014), Atikullah *et al*. (2014) and Sarker *et al*. (2013) in wheat. This results also supported the findings of Ibrahim *et al.* (2010) where they reported that grain yield, harvest index, number of tillers and spikes per m^2, spike length and fertility, 1000-grain weight and grain weight per spike significantly increased in increasing irrigation up to three times in wheat plants.

Varieties had no significant effect on dry weight per spike at 7, 14, 21, 28 and 35 DAA in both the years are given in Table 122A for first year (2015-2016) and in Table 122B for second year (2016-2017) respectively. Between the two varieties, higher dry weight per spike was found in BARI Gom 28 (V_2) than BARI Gom 27 (V_1) at all sampling dates in both the years.

Dry weight per spike was significantly influenced by foliar applications of potassium at all stages in both the years are presented in Table 123A and Fig. 30A for first year (2015-2016) and in Table 123B and Fig. 30B for second year (2016-2017) respectively. At 7 DAA, the highest dry weight per spike was observed in K_2 which was at par with K_3 followed by K_1 during the two successive growing seasons. The lowest value was obtained in K_0 at all sampling dates in both the years. In the remaining sampling dates (at 14, 21, 28 and 35 DAA), K_2 produced highest dry weight per spike which was statistically identical to K_3 and K_1 and the lowest was produced in K_0 in both the years. Similar results were found by Rahman (2004) in wheat. Desoky *et al*. (2017) also reported that potassium can counter the adverse effect of drought stress on growth characters as well as yield and its components of wheat plants.

The interaction effect of irrigation and potassium had significant influence on dry weight per spike in both the years at all sampling dates and are given in Table 124A for first year (2015-2016) and in Table 124B for second year (2016-2017) respectively. At 7 DAA, the maximum

dry weight per spike was observed in I_2K_2 which was statistically similar with I_3K_2 and the minimum dry weight per spike was found in I_0K_0 during the two successive growing seasons. In case of 14, 21, 28 and 35 DAA, the highest dry weight per spike were observed in I_2K_2 followed by I_3K_3 and I_3K_2 in both the years. The lowest value was found in I_0K_0 at all the sampling dates during the two successive growing seasons.

Table 121: Effect of irrigation on dry weight per spike of wheat at different day after anthesis (DAA) in 2015-2016 (left) and 2016-2017 (right)

Irrigation	A. Dry weight of spike (g) (2015-2016)					B. Dry weight of spike (g) (2016-2017)				
	7 DAA	14 DAA	21 DAA	28 DAA	35 DAA	7 DAA	14 DAA	21 DAA	28 DAA	35 DAA
I_0	0.793 c	1.197 c	1.58 c	1.87 c	2.201 c	0.869 c	1.256 c	1.613 c	1.916 c	2.261 c
I_1	0.931 b	1.386 b	1.759 b	2.079 b	2.452 b	0.951 b	1.399 b	1.789 b	2.144 b	2.477 b
I_2	1.024 a	1.687 a	2.151 a	2.554 a	2.988 a	1.112 a	1.731 a	2.192 a	2.612 a	3.112 a
I_3	0.9417 b	1.493 b	1.885 b	2.261 b	2.633 b	0.963 b	1.468 b	1.935 b	2.253 b	2.693 b
CV (%)	2.328	2.673	2.530	2.872	2.260	1.998	2.201	2.443	2.412	2.887

At specific days after anthesis, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 122: Effect of variety on dry weight per spike of wheat at different day after anthesis (DAA) in 2015-2016 (left) and 2016-2017 (right)

Variety	A. Dry weight of spike (g) (2015-2016)					B. Dry weight of spike (g) (2016-2017)				
	7 DAA	14 DAA	21 DAA	28 DAA	35 DAA	7 DAA	14 DAA	21 DAA	28 DAA	35 DAA
V_1	0.897 a	1.432 a	1.828 a	2.201 a	2.556 a	0.953 a	1.459 a	1.848 a	2.231 a	2.601 a
V_2	0.901 a	1.465 a	1.858 a	2.268 a	2.593 a	0.967 a	1.489 a	1.897 a	2.273 a	2.647 a
CV (%)	2.732	2.297	2.284	2.315	2.298	2.542	1.987	2.563	2.762	2.349

At specific days after anthesis, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 123: Effect of potassium on dry weight per spike of wheat at different day after anthesis (DAA) in 2015-2016 (left) and 2016-2017 (right)

Potassium	A. Dry weight of spike (g) (2015-2016)					B. Dry weight of spike (g) (2016-2017)				
	7 DAA	14 DAA	21 DAA	28 DAA	35 DAA	7 DAA	14 DAA	21 DAA	28 DAA	35 DAA
K_0	0.813 b	1.175 b	1.489 b	1.771 b	2.101 b	0.813 b	0.817 b	1.197 b	1.501 b	1.813 b
K_1	0.971 b	1.521 a	1.946 a	2.332 a	2.709 a	0.971 b	0.977 a	1.567 a	1.983 a	2.361 a
K_2	1.033 a	1.565 a	1.977 a	2.367 a	2.762 a	1.033 a	1.051 a	1.591 a	2.022 a	2.389 a
K_3	0.991 ab	1.539 a	1.959 a	2.356 a	2.732 a	0.991 ab a	0.997 a	1.568 a	1.991 a	2.375 a
CV (%)	2.234	2.611	2.678	2.902	2.268	2.346	2.789	1.991	2.431	2.559

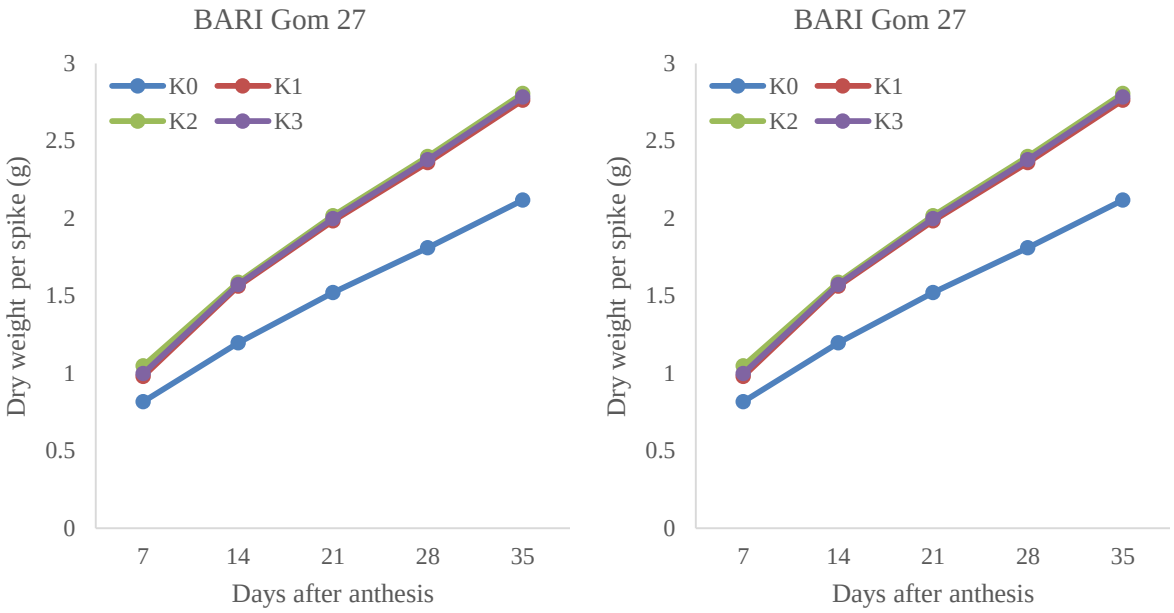
At specific days after anthesis, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

Table 124: Interaction effect of irrigation and potassium on dry weight per spike of wheat at different day after anthesis (DAA) in 2015-2016 (left) and 2016-2017 (right)

Interaction (Irrigation Potassium)	A. Dry weight of spike (g) (2015-2016)					B. Dry weight of spike (g) (2016-2017)				
	7 DAA	14 DAA	21 DAA	28 DAA	35 DAA	7 DAA	14 DAA	21 DAA	28 DAA	35 DAA
I_0K_0	0.651 j	1.034 f	1.289 f	1.544 f	1.819 f	0.661 j	1.045 f	1.332 f	1.577 f	1.851 f
I_0K_1	0.879 h	1.315 d	1.659 d	1.973 d	2.316 d	0.901 h	1.331 d	1.689 d	2.016 d	2.349 d
I_0K_2	0.941 g	1.341 d	1.688 d	2.009 d	2.353 d	0.943 g	1.356 d	1.721 d	2.049 d	2.391 d
I_0K_3	0.927 gh	1.320 d	1.682 d	1.989 d	2.333 d	0.930 gh	1.343 d	1.712 d	2.030 d	2.374 d
I_1K_0	0.759 i	1.216 e	1.529 e	1.820 e	2.125 e	0.770 i	1.224 e	1.545 e	1.850 e	2.170 e
I_1K_1	0.954 fg	1.438 c	1.823 c	2.171 c	2.540 c	0.964 fg	1.462 c	1.857 c	2.210 c	2.591 c
I_1K_2	1.060 bc	1.462 c	1.859 c	2.232 c	2.591 c	1.061 bc	1.494 c	1.894 c	2.254 c	2.642 c
I_1K_3	0.980 ef	1.453 c	1.838 c	2.182 c	2.557 c	0.988 ef	1.473 c	1.871 c	2.231 c	2.605 c
I_2K_0	0.879 h	1.222 e	1.556 e	1.853 e	2.170 e	0.890 h	1.248 e	1.583 e	1.886 e	2.215 e
I_2K_1	0.995 de	1.565 b	1.986 b	2.364 b	2.767 b	1.025 de	1.592 b	2.034 b	2.418 b	2.821 b
I_2K_2	1.091 a	1.855 a	2.341 a	2.789 a	3.273 a	1.122 a	1.885 a	2.393 a	2.849 a	3.341 a
I_2K_3	1.021 cd	1.579 b	2.016 b	2.392 b	2.789 b	1.036 cd	1.610 b	2.046 b	2.433 b	2.851 b
I_3K_0	0.942 g	1.249 e	1.583 e	1.893 e	2.212 e	0.949 g	1.275 e	1.619 e	1.933 e	2.249 e
I_3K_1	1.024 cd	1.560 b	2.022 b	2.394 b	2.816 b	1.032 cd	1.617 b	2.063 b	2.811 a	3.287 a
I_3K_2	1.061 ab	1.835 a	2.325 a	2.762 a	3.234 a	1.080 ab	1.864 a	2.362 a	2.819 a	3.305 a
I_3K_3	1.045 bc	1.844 a	2.332 a	2.773 a	3.241 a	1.060 bc	1.867 a	2.382 a	2.846 a	3.861 b
CV (%)	2.325	2.552	2.657	2.236	2.435	2.161	2.306	2.299	2.291	2.29

At specific days after anthesis, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

A



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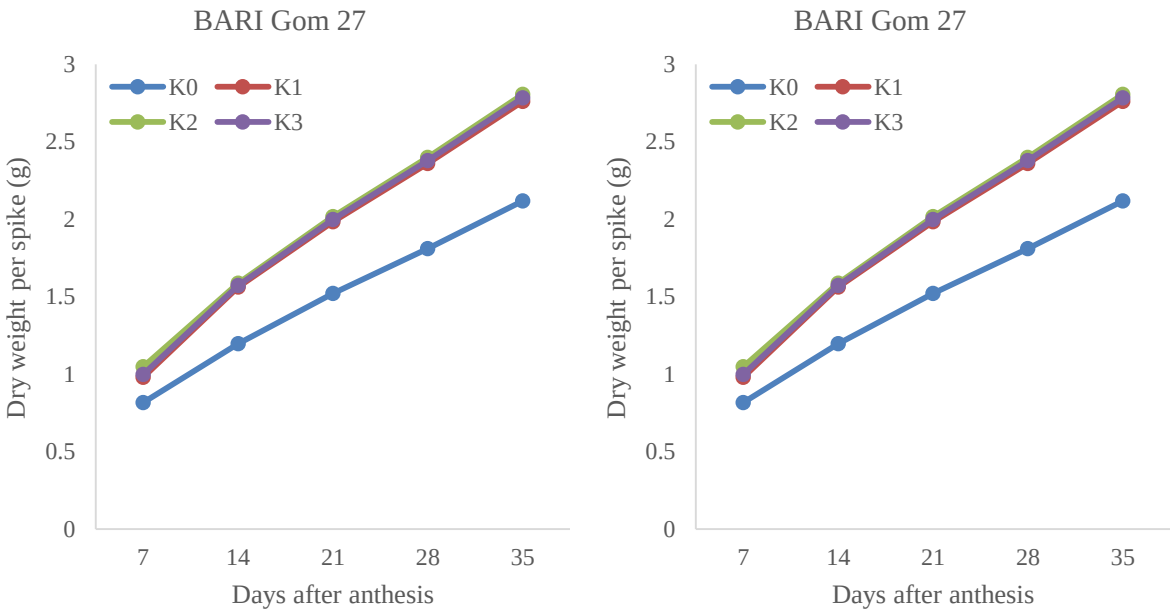
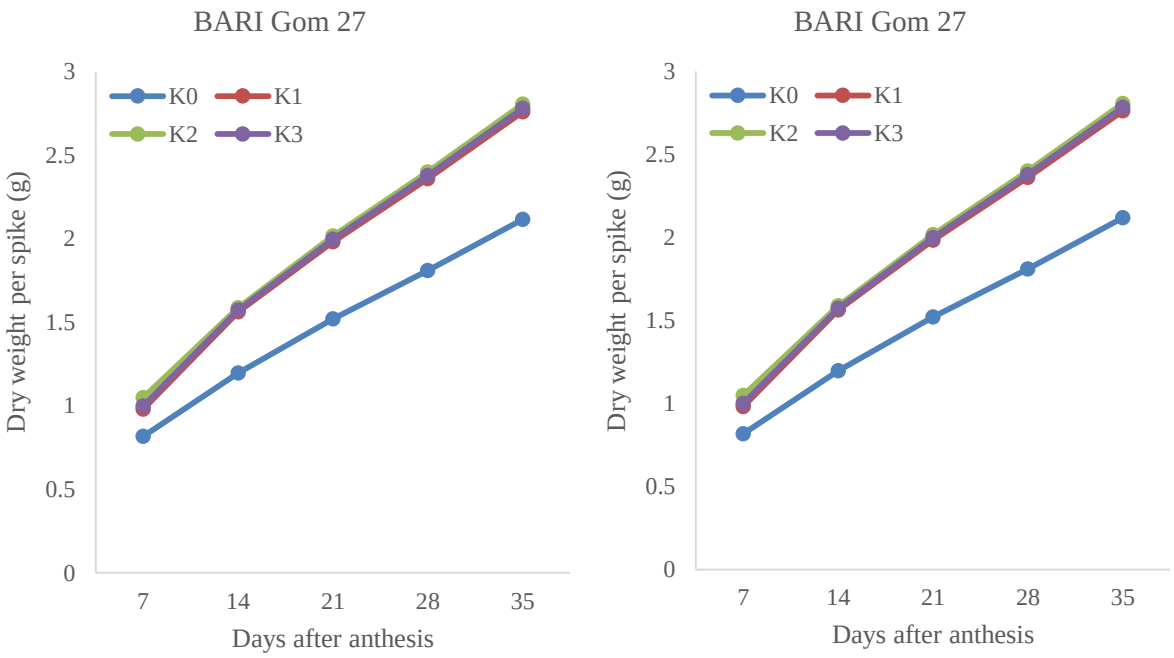


Fig. 29: Effect of irrigation on dry weight per spike at different days after anthesis (DAA) in 2015-2016 (A) and 2016-2017 (B)

A



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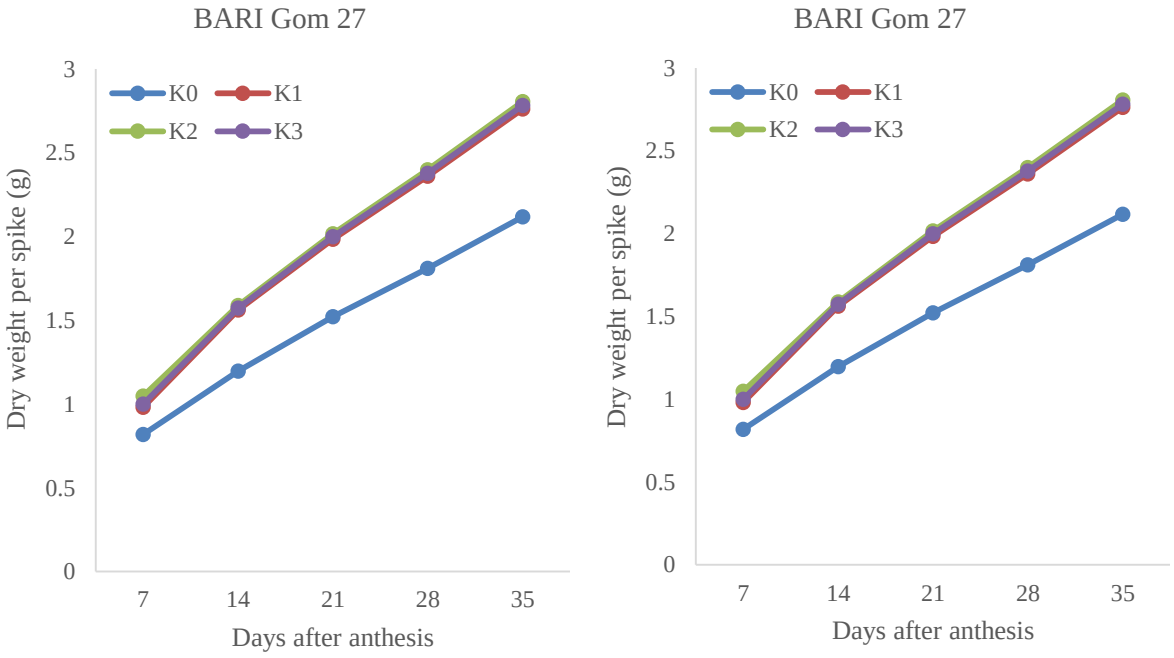


Fig. 30: Effect of potassium on dry weight per spike at different days after anthesis (DAA) in 2015-2016 (A) and 2016-2017 (B)

4.7.4. Dry weight grain^{-1}

Dry weight grain^{-1} of wheat was significantly affected by different irrigation regimes at all stages in both the growing seasons are presented in Table 125A and Fig. 31A for first year (2015-2016) and in Table 125B and Fig. 31B for second year (2016-2017) respectively. At 14 DAA, the highest dry weight grain^{-1} was found in I_2 which was statistically similar with I_3 and I_1 and the lowest was found in I_0 in both the years. At 21, 28 and 35 DAA, the highest dry weight grain^{-1} was obtained in I_2 which was statistically identical with I_3 in both the growing seasons. The lowest value was found in I_0 at all stages in both the years. Similar results were also stated by Machado and Paulsen (2001), Haider (2002) and Rahman (2004) in wheat and Bahadur (2008) in barley. Amin *et al.* (1995) reported that grain weight ear^{-1} is dependent on the number of grains and it size and shape. Rahman and Paul (1996) noticed that dry weight of grains was significantly affected by water stress in crops.

Dry weight grain^{-1} did not differ significantly due to variety at 14, 21, 28 and 35 DAA in both the years are shown in Table 126A for first year (2015-2016) and in Table 126B for second year (2016-2017) respectively. Between the two varieties, higher dry weight grain^{-1} was found in BARI Gom 28 (V_2) than BARI Gom 27 (V1) at all sampling dates in both the years.

Foliar applications of potassium had significant effect on dry weight grain^{-1} at all stages in both the growing seasons and are given in Table 127A and Fig. 32A for first year (2015-2016) and in Table 127B and Fig. 32B for second year (2016-2017) respectively. Significantly, the highest dry weight grain^{-1} at 14, 21, 28 and 35 DAA were recorded in K_2 which was statistically similar with K_3 and the lowest value at 14, 21, 28 and 35 DAA were found in K_0 in both the years. This results is corroborated with Rahman (2004) in wheat. Similar findings were reported by Desoky *et al*. (2017) that potassium can overcome the adverse effect of drought stress on growth characters of wheat plants. Similar findings were reported by Shah *et al*. (2017), Khan *et al*. (2013) and Amal *et al.* (2011) in wheat.

Dry weight grain^{-1} showed statistically significant variation at all stages by the interaction of irrigation and potassium in both the years are presented in Table 128A for first year (2015-2016) and in Table 128B for second year (2016-2017) respectively. From the table, it was observed that I_2K_2 produced the highest dry weight grain^{-1} than any other treatments at all sampling dates in both the growing seasons and the lowest value at 14, 21, 28 and 35 DAA were obtained in I_0K_0 during the two successive growing seasons.

Table 125: Effect of irrigation on dry weight grain^{-1} (mg) of wheat at different day after anthesis (DAA) in 2015-2016 (left) and 2016-2017 (right)

Irrigation	A. Dry weight grain^{-1} (mg) (2015-2016)				B. Dry weight grain^{-1} (mg) (2016-2017)			
	14 DAA	21 DAA	28 DAA	35 DAA	14 DAA	21 DAA	28 DAA	35 DAA
I_0	13.920 b	24.362 c	28.427 c	31.286 c	14.898 b	26.503 c	31.255 c	34.831 c
I_1	14.722 ab	26.319 b	31.129 bc	34.631 b	15.632 ab	28.442 b	34.118 bc	38.378 b
I_2	15.783 a	28.512 a	34.553 a	38.542 a	16.414 a	30.592 a	37.694 a	42.296 a
I_3	15.319 a	27.231 ab	33.122 ab	36.911 ab	16.082 a	29.411 ab	36.29 ab	40.496 ab
CV (%)	5.673	4.567	4.635	5.347	6.656	5.419	3.432	4.025

At specific days after anthesis, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 126: Effect of variety on dry weight grain^{-1} (mg) of wheat at different day after anthesis (DAA) in 2015-2016 (left) and 2016-2017 (right)

Variety	A. Dry weight grain^{-1} (mg) (2015-2016)				B. Dry weight grain^{-1} (mg) (2016-2017)			
	14 DAA	21 DAA	28 DAA	35 DAA	14 DAA	21 DAA	28 DAA	35 DAA
V_1	14.861 a	26.311 a	31.452 a	34.988 a	15.746 a	28.39 a	34.462 a	38.684 a
V_2	15.010 a	26.901 a	32.163 a	35.697 a	15.767 a	29.083 a	35.216 a	39.316 a
CV (%)	5.673	4.567	4.635	5.347	6.656	5.419	3.432	4.025

At specific days after anthesis, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 127: Effect of potassium on dry weight grain^{-1} (mg) of wheat at different day after anthesis (DAA) in 2015-2016 (left) and 2016-2017 (right)

Potassium	A. Dry weight grain^{-1} (mg) (2015-2016)				B. Dry weight grain^{-1} (mg) (2016-2017)			
	14 DAA	21 DAA	28 DAA	35 DAA	14 DAA	21 DAA	28 DAA	35 DAA
K_0	13.236 c	22.715 c	26.152 c	28.538 c	13.969 c	24.850 c	29.043 c	32.145 c
K_1	15.225 b	27.154 b	32.632 b	36.329 b	16.174 b	29.288 b	35.625 b	39.853 b
K_2	15.865 a	28.821 a	34.914 a	39.114 a	16.567 a	30.957 a	38.041 a	42.847 a
K_3	15.418 ab	27.733 ab	33.533 ab	37.392 ab	16.318 ab	29.85 ab	36.648 ab	41.156 ab
CV (%)	5.673	4.567	4.635	5.347	6.656	5.419	3.432	4.025

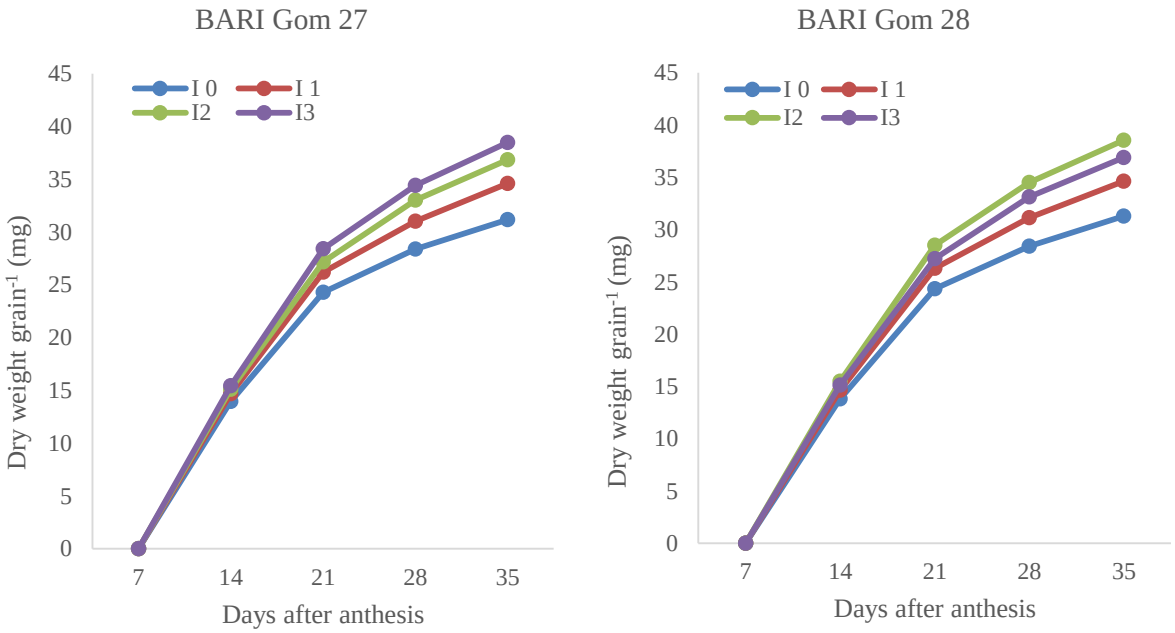
At specific days after anthesis, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 128: Interaction effect of irrigation and potassium on dry weight grain^{-1} (mg) of wheat at different day after anthesis (DAA) in 2015-2016 (left) and 2016-2017 (right)

Interaction (Irrigation x Potassium	A. Dry weight grain^{-1} (mg) (2015-2016)				B. Dry weight grain^{-1} (mg) (2016-2017)			
	14 DAA	21 DAA	28 DAA	35 DAA	14 DAA	21 DAA	28 DAA	35 DAA
I_0 K_0	12.512 m	21.712 j	24.293 l	25.971 j	12.654 m	21.911 j	24.561 l	26.652 j
I_0 K_1	14.567 i	24.873 fg	28.901 hi	31.555 g	14.666 i	25.282fg	29.422 hi	32.238 g
I_0 K_2	14.931 gh	25.734 ef	30.951 fg	34.558 e	14.881 gh	26.227 ef	31.490 fg	35.473 e
I_0 K_3	14.543 hi	25.432 f	29.644 gh	32.823 f	14.658 hi	25.372 f	30.456 gh	33.562 f
I_1 K_0	12.911 l	22.455 ij	25.578 k	28.231 i	13.329 l	22.734 ij	25.881 k	28.761 i
I_1 K_1	14.943 fg	26.561 e	31.872 ef	35.556 e	15.412 fg	26.891 e	32.381 ef	36.375 e
I_1 K_2	15.822 cd	28.619 cd	34.311 d	38.319 c	15.933 cd	28.951 cd	34.669 d	39.291 c
I_1 K_3	15.432 ef	27.623 d	32.876 e	36.576 d	15.682 ef	28.231 d	33.623 e	37.528 d
I_2 K_0	13.3783 k	23.348 hi	26.920 j	29.789 h	13.473 k	23.556 hi	27.522 j	30.355 h
I_2 K_1	15.643d e	27.741 d	34.279 d	38.321 c	15.734 de	28.329 d	34.653 d	38.709 c
I_2 K_2	16.423 a	30.912 a	37.792 a	42.481 a	16.631 a	31.391 a	38.462 a	43.453 a
I_2 K_3	15.670 c-e	27.993 d	34.692 cd	38.822 c	15.919 c-e	28.470 d	35.376 cd	39.782 c
I_3 K_0	13.654 j	23.891 gh	27.756 ij	30.647 gh	13.952 j	24.347 gh	28.367 ij	31.342 gh
I_3 K_1	15.897 bc	29.231 bc	35.621 bc	39.975 b	16.239 bc	29.685 bc	36.321 bc	40.908 b
I_3 K_2	16.732 ab	29.829 ab	36.723 b	40.971 b	16.562 ab	30.423 ab	37.467 b	41.877 b
I_3 K_3	15.922 bc	29.741 ab	36.712 ab	40.892 b	16.274 bc	30.492 ab	37.201 ab	41.874 b
CV (%)	5.673	4.567	4.635	5.347	6.656	5.419	3.432	4.025

At specific days after anthesis, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

A



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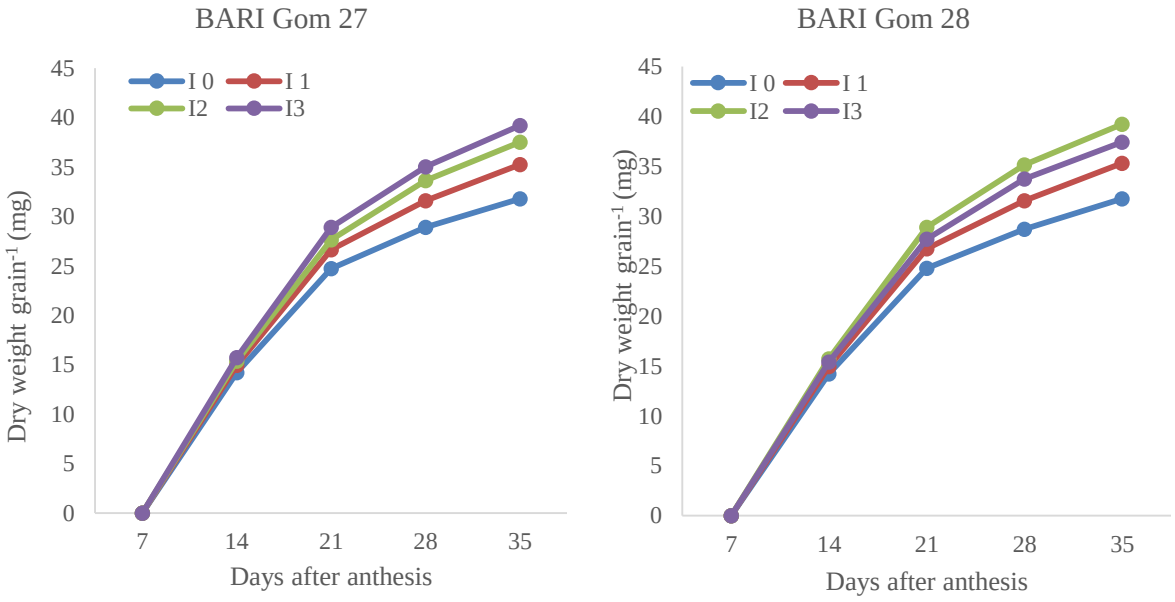
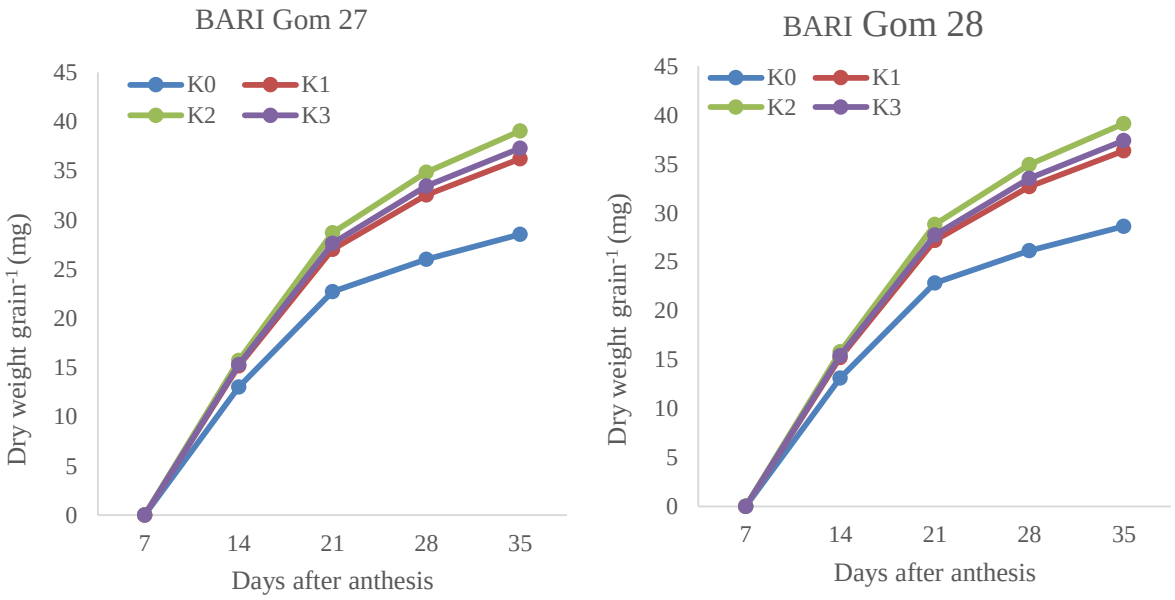


Fig. 31: Effect of irrigation on dry weight grain^{-1} (mg) at different days after anthesis (DAA) in 2015-2016 (A) and 2016-2017 (B)

A



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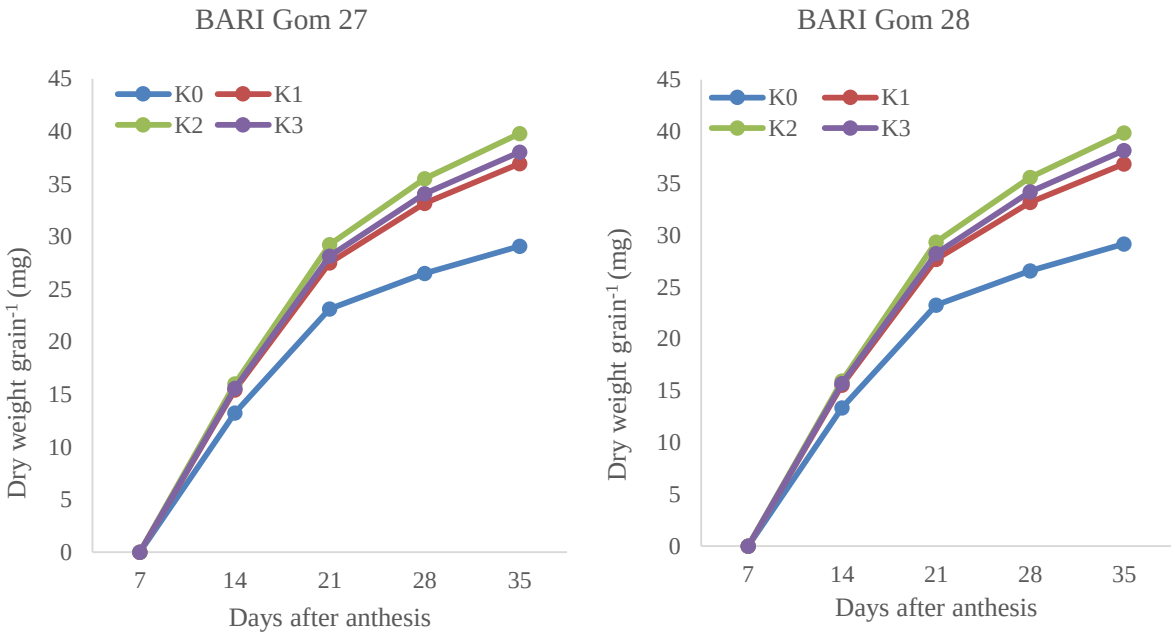


Fig. 32: Effect of potassium on dry weight grain^{-1} (mg) at different days after anthesis (DAA) in 2015-2016 (A) and 2016-2017 (B)

4.7.5. Grain growth rate

Grain growth rate varied significantly during the period of 7-14, 14-21, 21-28 and 28-35 DAA due to different irrigation treatments in both the years are presented in Table 129A and Fig. 33A for first year (2015-2016) and in Table 129B and Fig. 33B for second year (2016-2017) respectively. The plants with more irrigation exhibited higher grain growth rate than the less irrigated plants. During the period of 7-14, 14-21 and 21-28 DAA, the highest grain growth rate was observed in I_2 which was statistically similar with I_3 and the lowest was found in I_0 during the two successive growing seasons. During the period of 14-21 DAA, the highest grain growth rate was observed in I_2 which was at par with I_3 followed by I_1 in both the growing seasons. At 21-28 and 28-35 DAA, the highest grain growth rate was observed in I_2 which was statistically identical to I_3 and I_1 in both the growing seasons. In every cases the highest grain growth rate was observed at 7-14 DAA and soon after followed by a sharp decrease of grain growth rate. Similar findings were notice by Haider *et al.* (2007) who reported that irrigation regimes had significant effects on spike and grain growth, relative grain growth rate and yield of wheat plants. This results also corroborated with the findings of Savin and Nicolas (1996), Wardlaw (1994) and Gallagher (1976) in wheat plants.

During the total grain growth periods, varieties had no significant effect on grain growth rate in both the years are showed in Table 130A for first year (2015-2016) and in Table 130B for second year (2016-2017) respectively. Between the two varieties, higher grain growth rate was found in BARI Gom 28 (V_2) than BARI Gom 27 (V_1) during the two successive growing seasons.

During the period of 7-14, 14-21, 21-28 and 28-35 DAA, grain growth rate was significantly influenced by foliar applications of potassium in both the years are presented in Table 131A and Fig. 34A for first year (2015-2016) and in Table 131B and Fig. 34B for second year (2016-2017) respectively. The highest grain growth rate was observed in K_2 which was statistically similar with K_3 and the lowest was found in K_0 in all sampling dates in both the growing seasons. At 7-14, 14-21 and 28-35 DAA, the maximum grain growth rate was observed in K_2 which was statistically similar with K_3 followed by K_1 and the lowest was found in 28-35 DAA during the two successive growing seasons. At 21-28 DAA, the highest grain growth rate was observed in K_2 which was statistically similar with K_3 and K_1 treatments in both the growing seasons.

Interaction effect of irrigation and potassium had significant influence on grain growth rate during the period of 7-14, 14-21, 21-28 and 28-35 DAA in both the years are presented in Table 132A for first year (2015-2016) and in Table 132B for second year (2016-2017) respectively. During the period of 7-14, 14-21 and 21-28 DAA, the highest grain growth rate was recorded in I_2K_2 which was at par with I_3K_2 in 7-14 DAA and I_3K_3 and I_3K_2 for rest of the sampling dates in both the growing seasons. The lowest grain growth rate was found in I_0K_0.

Table 129: Effect of irrigation on grain growth rate of wheat at different day after anthesis (DAA) in 2015-2016 (left) and 2016-2017 (right)

Irrigation	Grain growth rate (mg grain^{-1} day^{-1}) (2015-2016)				Grain growth rate (mg grain^{-1} day^{-1}) (2016-2017)			
	7-14 DAA	14-21 DAA	21-28 DAA	28-35 DAA	7-14 DAA	14-21 DAA	21-28 DAA	28-35 DAA
I_0	1.906 b	1.484 c	0.563 b	0.426 a	2.035 c	1.664 c	0.706 b	0.475 b
I_1	2.106 ab	1.644 b	0.688 b	0.516 a	2.265 ab	1.814 b	0.815 b	0.586 a
I_2	2.238 a	1.842 a	0.897 a	0.58 a	2.364 a	2.036 a	0.985 a	0.658 a
I_3	2.189 a	1.723 ab	0.864 a	0.55 a	2.292 a	1.914 ab	0.966 a	0.619 a
CV (%)	6.148	4.984	9.236	3.567	8.610	5.453	3.459	5.009

At specific days after anthesis, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 130: Effect of variety on grain growth rate of wheat at different day after anthesis (DAA) in 2015-2016 (left) and 2016-2017 (right)

Variety	Grain growth rate (mg grain^{-1} day^{-1}) (2015-2016)				Grain growth rate (mg grain^{-1} day^{-1}) (2016-2017)			
	7-14 DAA	14-21 DAA	21-28 DAA	28-35 DAA	7-14 DAA	14-21 DAA	21-28 DAA	28-35 DAA
V_1	2.065 a	1.602 a	0.729 a	0.513 a	2.233 a	1.848 a	0.862 a	0.572 a
V_2	2.155 a	1.746 a	0.777 a	0.522 a	2.245 a	1.866 a	0.873 a	0.597 a
CV (%)	6.148	4.984	9.236	3.567	8.610	5.453	3.459	5.009

At specific days after anthesis, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 131: Effect of potassium on grain growth rate of wheat at different day after anthesis (DAA) in 2015-2016 (left) and 2016-2017 (right)

Potassium	Grain growth rate (mg grain^{-1} day^{-1}) (2015-2016)				Grain growth rate (mg grain^{-1} day^{-1}) (2016-2017)			
	7-14 DAA	14-21 DAA	21-28 DAA	28-35 DAA	7-14 DAA	14-21 DAA	21-28 DAA	28-35 DAA
K_0	1.854 c	1.352 c	0.474 b	0.355 c	1.983 c	1.579 c	0.564 b	0.425 c
K_1	2.171 b	1.684 b	0.802 a	0.527 b	2.309 b	1.902 b	0.970 a	0.595 b
K_2	2.241 a	1.889 a	0.882 a	0.621 a	2.359 a	2.032 a	0.983 a	0.700 a
K_3	2.174 ab	1.771 ab	0.853 a	0.567 ab	2.304 ab	1.913 ab	0.953 a	0.620 ab
CV (%)	6.148	4.984	9.236	3.567	8.610	5.453	3.459	5.009

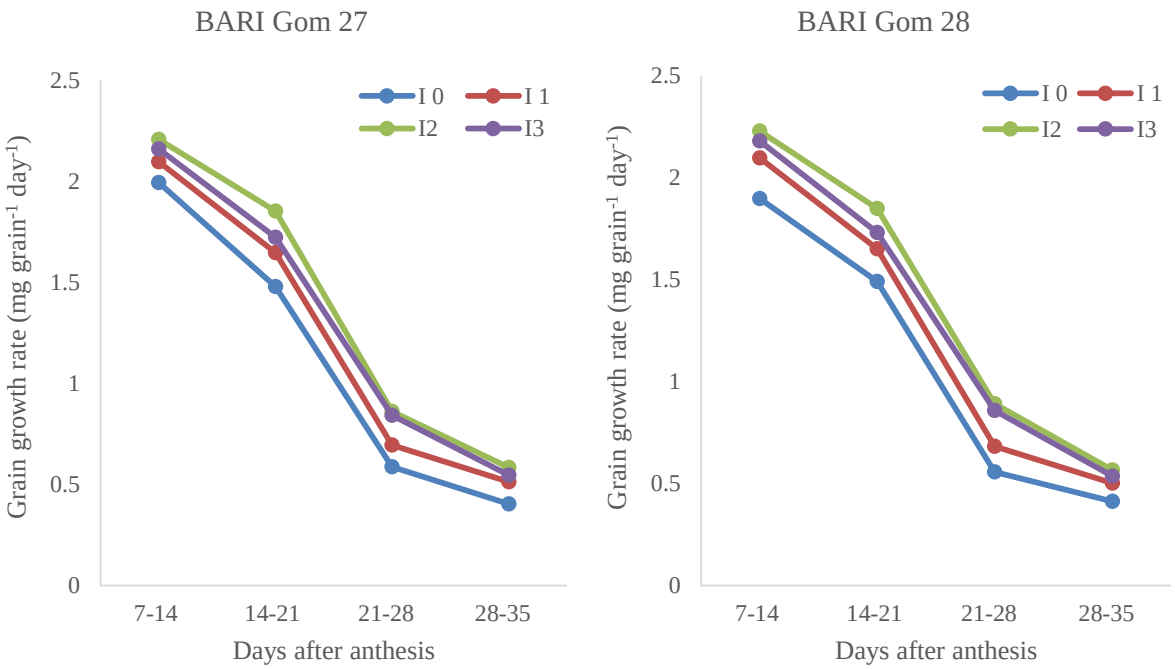
At specific days after anthesis, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 132: Interaction effect of irrigation and potassium on grain growth rate of wheat at different day after anthesis (DAA) in 2015-2016 (left) and 2016-2017 (right)

Interaction (Irrigation x Potassium	Grain growth rate (mg grain^{-1} day^{-1}) (2015-2016)				Grain growth rate (mg grain^{-1} day^{-1}) (2016-2017)			
	7-14 DAA	14-21 DAA	21-28 DAA	28-35 DAA	7-14 DAA	14-21 DAA	21-28 DAA	28-35 DAA
I_0 K_0	1.687 m	1.316 j	0.411 i	0.378 i	1.796 m	1.340 j	0.358 i	0.288 i
I_0 K_1	2.044 i	1.487 g-i	0.574 g	0.364 h	2.080 i	1.520 g-i	0.596 g	0.377 h
I_0 K_2	2.112 gh	1.557 fg	0.755 e	0.543 f	2.140 gh	1.607 fg	0.752 e	0.532 f
I_0 K_3	2.057 hi	1.553 f-h	0.683 f	0.439 g	2.094 hi	1.553 f-h	0.683 f	0.447 g
I_1 K_0	1.829 l	1.373 ij	0.435 h	0.384 h	1.862 l	1.398 ij	0.428 h	0.391 h
I_1 K_1	2.143 fg	1.721 ef	0.796 e	0.530 ef	2.176 fg	1.665 ef	0.784 e	0.540 ef
I_1 K_2	2.241 cd	1.819 cd	0.845 d	0.588 b-d	2.279 cd	1.853 cd	0.844 d	0.599 b-d
I_1 K_3	2.185 ef	1.781 de	0.756 e	0.545 d-f	2.220 ef	1.783 de	0.770 e	0.556 d-f
I_2 K_0	1.878 k	1.4 h-j	0.592 g	0.386 h	1.925 k	1.437 h-j	0.556 g	0.393 h
I_2 K_1	2.212 de	1.567 de	0.900 c	0.572 c-e	2.248 de	1.787 de	0.916 c	0.583 c-e
I_2 K_2	2.337 a	2.157 a	0.994 a	0.667 a	2.376 a	2.106 a	1.010 a	0.680 a
I_2 K_3	2.253 c-e	1.753 c-e	0.977 ab	0.590 bc	2.274 c-e	1.796 c-e	0.978 ab	0.602 bc
I_3 K_0	1.977 j	1.439 h-j	0.500 g	0.398 gh	1.988 j	1.466 h-j	0.589 g	0.406 gh
I_3 K_1	2.268 bc	1.893 bc	0.918 bc	0.637 a	2.311 bc	1.928 bc	0.935 bc	0.649 a
I_3 K_2	2.303 ab	1.957 ab	0.961 ab	0.631 ab	2.344 ab	1.992 ab	0.978 ab	0.643 ab
I_3 K_3	2.234 bc	2.004 ab	0.951 ab	0.629 ab	2.313 bc	2.041 ab	0.968 ab	0.641 ab
CV (%)	6.148	4.984	9.236	3.567	8.610	5.453	3.459	5.009

At specific days after anthesis, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

A



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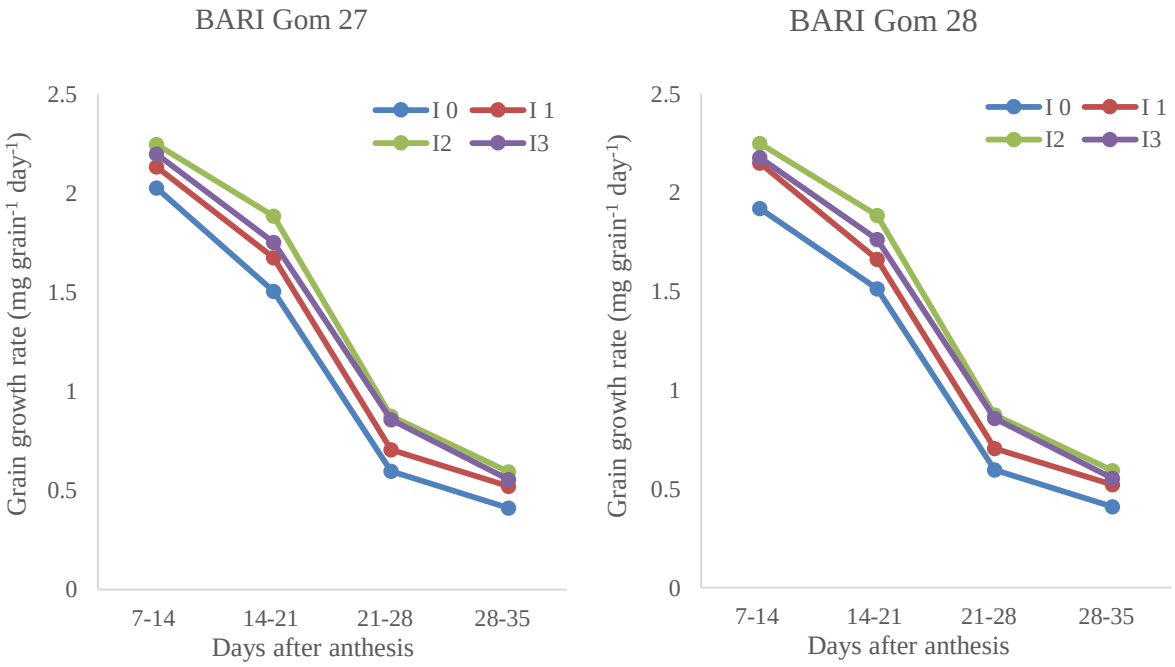
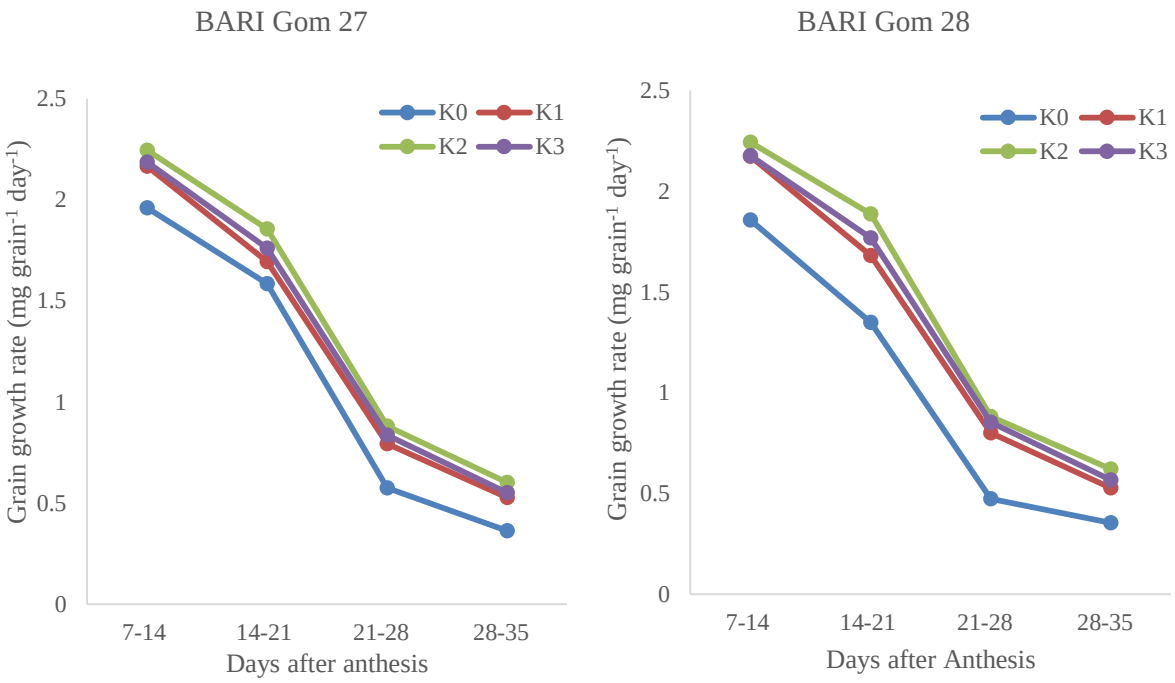


Fig. 33: Effect of irrigation on grain growth rate (mg grain^{-1} day^{-1}) at different days after anthesis (DAA) in 2015-2016 (A) and 2016-2017 (B)

A



B

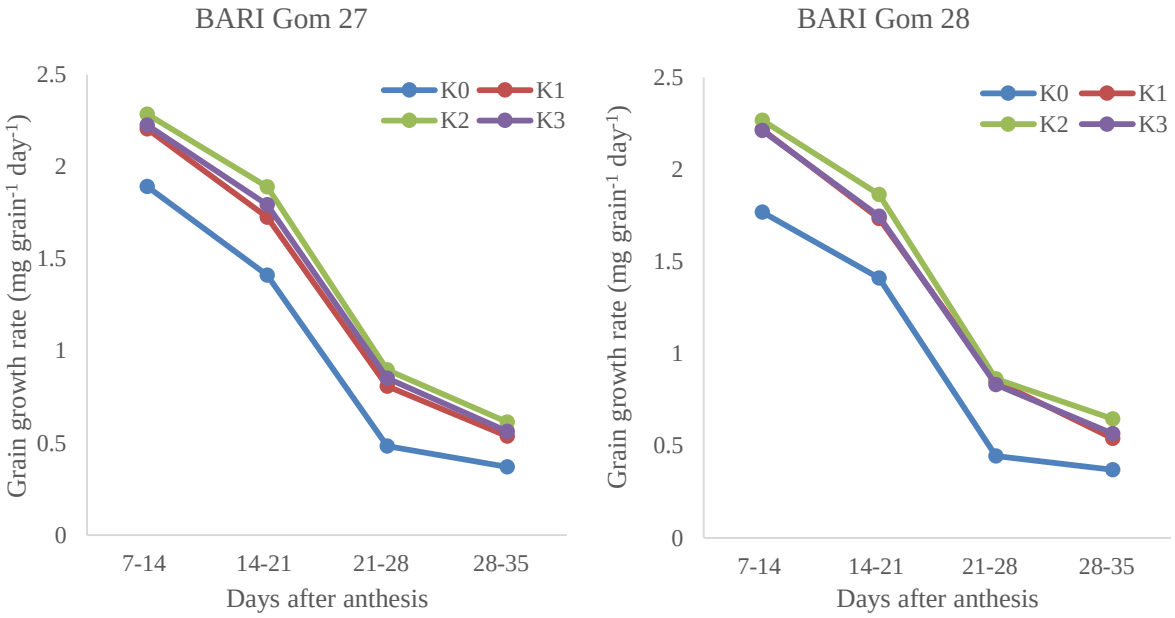


Fig. 34: Effect of potassium on grain growth rate (mg grain^{-1} day^{-1}) at different days after anthesis (DAA) in 2015-2016 (A) and 2016-2017 (B)

4.8 Yield and yield contributing characters

4.8.1 Plant height

Irrigation treatments had significant effect on plant height in both the years are presented in Table 133 for first year (2015-2016) and Table 134 for second year (2016-2017) respectively. Plant height is an important morphological character directly linked with the productive potential of plant in terms of grain yield. The tallest plant was produced by I_2 which was statistically similar with I_3 and the shortest plant height was obtained in I_0 in both the growing seasons. Plant height was decreased under water scarcity condition (Shah *et al.*, 2017). Plant height might be declined due to desiccation of protoplasm; reduction in relative turgidity related with turgor injury and declined cell extension and cell separation (Hussain *et al.*, 2008) and finally forcefully abridged plant height. In the presented study it was strongly evident that, supplemental irrigation at three growth stages reduced the effect of drought stress and thus plant height boost up in irrigated plot over the control one. These results were in line with those of Sarwar *et al.* (2010), Khan *et al.* (2001) and Thompson and Chase (1992) who reported that irrigation treatments significantly influenced plant height of wheat. Atikullah *et al.* (2014) stated that significant variation for plant height of wheat was due to different irrigation levels. This result is in good agreement with the result of Islam (1997) who reported that plant height increased with increasing number of irrigations.

Plant height did not show statistically significant variation due to variety in both the years are given in Table 135 for first year (2015-2016) and Table 136 for second year (2016-2017) respectively. Between the two varieties, higher plant height was observed in BARI Gom 28 (V_2) than BARI Gom 27 (V_1) during the two successive growing seasons.

Plant height was significantly influenced by foliar applications of potassium in both the years are shown in Table 137 for first year (2015-2016) and Table 138 for second year (2016-2017) respectively. The tallest plant was produced by K_2 which was statistically identical with K_3 followed by K_1 and the lowest value was found in control (K_0) in both the years. This result is in agreement with the findings of Brhane *et al.* (2017), Abbas *et al.* (2013), Zareian *et al.* (2013), Aown *et al.* (2012), Tahir *et al.* (2008), Ahmad *et al*. (2007), El-Sabbagh *et al.* (2002) and Abou El-Defan *et al.* (1999). It has been proposed that plants mineral nutrient especially K plays a key role in enhancing the resistance of plant to stress situations (Hasanuzzaman *et al.*, 2018, Wang *et al*., 2013, Yadov, 2006 and Yadav *et al*., 2004) and foliar application of K ameliorated this negative effect to a significant level. From the presented study, similar

outcome has been observed that foliar application of K to wheat plants under water deficit condition plays a mitigating role and for consequence enhanced crop growth and development. Mengel and Kirkby (2001) reported that, for many physiological processes such as activation of enzymes, photosynthesis, maintenance of turgescence, translocation of photosynthates, K is essential element.

Different treatments of irrigation and potassium had significant influence on plant height during the two successive growing seasons and are given in Table 139 for first year (2015-2016) and Table 140 for second year (2016-2017) respectively. Among thedifferent interactions, the highest plant height was recorded by I_2K_2 which was statistically similar with I_3K_2 and I_3K_3 and the lowest value was obtained in I_0K_0 during the two successive growing seasons.

4.8.2 Effective tillers plant^{-1}

Irrigation treatments significantly influenced the production of effective tillers plant^{-1} compared to the no irrigation (I_0) treatment in both the growing seasons are presented in Table 133 for first year (2015-2016) and Table 134 for second year (2016-2017) respectively. The highest number of tillers plant^{-1} was obtained from the crops received irrigation with 3800 m^3 ha^{-1} water (I_2) which was statistically similar with I_3 water (irrigation with 4200 m^3 ha^{-1}) and the lowest value was recorded from I_0 in both the years. Similar results were reported by Islam *et al.* (2018) who found that the maximum number of effective tillers hill^{-1} was obtained under three irrigation treatments whereas it was statistically different from other irrigations (one, two and four) and no irrigation. In contrast, no irrigation treatment produced the minimum number of effective tillers hill^{-1}. Similar study were also obtained by Ali and Amin (2007) who reported that significant effects was observed on number of effective tillers hill^{-1} where two irrigations were more effective. Irrigation had significant effect on number of effective tillers plant^{-1} in wheat (Sarker and Paul 1997, Rahman *et al.,* 2001 and Afzal *et al.,* 2006). The response of effective tillers plant^{-1} with increased irrigation frequencies was progressive in wheat (Rahman *et al.,* 2001 and Rafiq *et al.,* 2005).

Effect tillers plant^{-1} varied significantly due to variety in both the years are given in Table 135 for first year (2015-2016) and Table 136 for second year (2016-2017) respectively. Significantly higher number of effective tillers plant^{-1} was produced by BARI Gom 28 (V_2) than BARI Gom 27 (V_1) during the two successive growing seasons.

Number of effective tillers plant^{-1} was significantly influenced by the foliar applications of potassium in both the years are shown in Table 137 for first year (2015-2016) and Table 138 for second year (2016-2017) respectively. Effective tillers are the key component of grain yield in wheat crop. The highest number of tillers plant^{-1} were produced in K_2 which was at par with K_3 in both the growing years. The lowest value was found in control (K_0). The reason of increased number of productive tillers in plots receiving foliar application of potassium may be due to sufficient availability of potassium during tillering stage. On the contrary, plots with no foliar application of potassium resulted in less number of tillers due to less availability of potassium. Bulk potassium application at sowing may have resulted in losses in forming other complexes of nutrients that subsequently resulted less availability of K. Similar result was reported by Aown *et al*. (2012) where they concluded that foliar application of K at all three (tillering, flower initiation and milking stages) critical growth stages improved the drought tolerance of plants and improved the growth and yield components, however, grain filling stage was found more responsive.

Different treatments of irrigation and potassium had significant influence on effective tillers plant^{-1} in both the growing seasons are presented in Table 139 for first year (2015-2016) and Table 140 for second year (2016-2017) respectively. The highest number of effective tillers plant^{-1} was produced by I_2K_2 was statistically similar with I_3K_2 and I_3K_3 followed by I_3K_1 and the lowest value was obtained in I_0K_0 during the two successive growing seasons.

4.8.3 Spike length

Spike length was significantly influenced by different irrigation regimes in both the years are presented in Table 133 for first year (2015-2016) and Table 134 for second year (2016-2017) respectively. The highest value of spike length was produced by I_2 which was statistically similar with I_3 and followed by I_1 and the lowest value was found in control (I_0) in both the years. That is, the decrease in spike length due to no irrigation was noticed in the presented study. The result demonstrated that drought stress critically affected the spike length. Maximum spike length were documented from well-watered plots, whereas minimum spike length was documented when crop faced water stress throughout the growth period. Giunata *et al*. (1993) described that the spike length was badly affected by water shortage among stem elongation and spike establishment phase. The declined spike length was due to less number of nodes and fewer node to node distances on the rachis. Furthermore, it was also perceived by Yadav *et al.* (2004), who reported that spike length remains constant at under drought stress

situation. Small canopy was established when crop faced water stress earlier in grain filling or at flowering phase (Hammadeh *et al*., 2005) that can be enhanced by augmenting plant's stress tolerance by cell membrane stability (Daneshian *et al*., 2005). This was similar to that of Islam *et al.* (2018), Shah *et al.* (2017) and Aown *et al.* (2012). Similarly, Khokhar *et al*. (2010) also reported that application of five irrigations at different wheat growth stages resulted in higher spike length than without irrigation.

Variety had no significant effect on spike length during the two successive growing seasons and are given in Table 135 for first year (2015-2016) and Table 136 for second year (2016-2017) respectively. Between the two varieties, BARI Gom 28 (V_2) had higher spike length than BARI Gom 27 (V_1).

Potassium application method had significant effect on spike length in both the years are shown in Table 137 for first year (2015-2016) and Table 138 for second year (2016-2017) respectively. In the present study, the highest spike length was recorded in K_2 followed by K_3 and K_1 in both the growing season and the lowest value of spike length was found in control (K_0). Potassium nutrient took part in spike formation as well as spike elongation and for this reason spike length increased with the increase of K- fertilization. Similar findings was reported by Shah *et al*. (2017), who reported that foliar application of K at different growth phases positively affected plant height, spike length, number of spikelets per spike, number of grains per spike, 1000-grain weight, grain yield and nutrient uptake of the wheat plant. Aown *et al*. (2012) also reported similar findings.

Spike length showed statistically significant variation by the interaction of irrigation and potassium in both the years are given in Table 139 for first year (2015-2016) and Table 140 for second year (2016-2017) respectively. The highest spike length was produced by the I_2K_2 which was statistically similar with I_3K_2 and I_3K_3 and the lowest spike length was observed in I_0K_0 in both the growing seasons.

4.8.4 Extrusion length

Irrigation regimes showed significant effect on extrusion length of wheat in both the growing seasons are presented in Table 133 for first year (2015-2016) and Table 134 for second year (2016-2017) respectively. The crops grown with treatment I_2 gave the highest extrusion length which was statistically identical with I_3 and the lowest value was obtained in I_0 (no irrigation)

condition in both the years. This findings was supported by Mollah and Paul (2011) where they obtained the highest and the lowest extrusion length were in the I_2 (40 mm water as three times) and I_0 (no irrigation) treatments respectively in barley. Similar result was reported in barley by Bahadur (2008) in barley.

Extrusion length did not show statistically significant variation due to variety in both the years are given in Table 135 for first year (2015-2016) and Table 136 for second year (2016-2017) respectively. Between the two varieties, higher extrusion length was produced by the variety BARI Gom 28 (V_2) than BARI Gom 27 (V_1) in both the years.

The effects of foliar application of potassium on extrusion length was found significant in both the years are shown in Table 137 for first year (2015-2016) and Table 138 for second year (2016-2017) respectively. The highest extrusion length was observed in K_2 which was statistically similar with K_3 and K_1 and the lowest value of extrusion length was found in K_0 (control) during the two successive growing seasons.

The combine effects of irrigation regimes and foliar application of potassium on extrusion length had significant influence during the two successive growing seasons are shown in Table 139 for first year (2015-2016) and Table 140 for second year (2016-2017) respectively. The highest extrusion length was recorded in I_2K_2 which was at par with I_3K_3, I_3K_2 and I_3K_1 and the lowest value was obtained in I_0K_0 during the two successive growing seasons.

4.8.5 Fertile spikelets spike^{-1}

The number of fertile spikelets spike^{-1} of wheat was significantly influenced by different irrigation regimes for both the field investigations are presented in Table 133 for first year (2015-2016) and Table 134 for second year (2016-2017) respectively. The highest number of fertile spikelets spike^{-1} was produced in I_2 which was statistically similar with I_3 and lowest value was observed in I_0 in both the growing seasons. Islam *et al.* (2018) reported that the highest number of grains spike^{-1} at harvest was obtained with three irrigations which were followed by both two and four irrigations where two and four irrigations treatment were statistically identical. This results were also in line with those of Richards *et al.* (2001) who reported that the numbers of spikelets spike^{-1} were diminished badly under water stress condition. This findings were in agreement with that of Shah *et al.* (2017), Mubeen *et al.* (2013), Ngwako and Mashiqa (2013), El-Abady *et al.* (2009) and Gupta *et al.* (2001) found

that optimum irrigation throughout the growth stages recorded the more gains spike^{-1}. Similar results were also found by Mollah and Paul (2011) and Bahadur (2008), in barley and Rahman *et al.* (2001) and Rafiq *et al.* (2005) in wheat.

The effect of variety on fertile spikelets spike^{-1} was not statistically significant in both the years are given in Table 135 for first year (2015-2016) and Table 136 for second year (2016-2017) respectively. Between the two varieties, the higher fertile spikelets spike^{-1}was recorded in BARI Gom 28 (V_2) than BARI Gom 27 (V_1) in both the growing years.

There had a marked influence on the number of fertile spikelets spike^{-1} for foliar application of potassium in both the years are presented in Table 137 for first year (2015-2016) and Table 138 for second year (2016-2017) respectively. The highest fertile spikelets spike^{-1} was observed in K_2 which was at par with K_3 followed by K_1 and the lowest value was found in K_0 during the two successive growing seasons.

Fertile spikelets spike^{-1} showed statistically significant variation by the interaction of irrigation and foliar application of potassium in both the years are presented in Table 139 for first year (2015-2016) and Table 140 for second year (2016-2017) respectively. The highest fertile spikelets spike^{-1} was produced by I_2K_2 which was statistically identical to I_3K_3, I_3K_2, I_3K_1, and I_2K_3 and the lowest fertile spikelets spike^{-1} was observed in I_0K_0 during the two successive growing seasons.

4.8.6 Infertile spikelets spike^{-1}

Different irrigation regimes had significant influenced on the number of infertile spikelets spike^{-1} of wheat in both the years are presented in Table 133 for first year (2015-2016) and Table 134 for second year (2016-2017) respectively. The highest infertile spikelets spike^{-1} was obtained in I_0 followed by I_1 and I_2 and the lowest infertile spikelets spike^{-1} was obtained in I_3 in both the trails. This result was in agreement with Bahadur (2008) in barley.

Infertile spikelets spike^{-1} did not show statistically significant variation due to variety in both the years are given in Table 135 for first year (2015-2016) and Table 136 for second year (2016-2017) respectively. Between the two varieties, the higher infertile spikelets spike^{-1} was recorded in BARI Gom 27 (V_1) than BARI Gom 28 (V_2) in both the years.

Different potassium levels had significant influence on the number of infertile spikelets spike^{-1} of wheat for both the field experiment are presented in Table 137 for first year (2015-2016) and Table 138 for second year (2016-2017) respectively. The highest infertile spikelets spike^{-1} was recorded in control (K_0) followed by K_1 and K_3 and the lowest value was found in K_2 in both the years.

The interaction effect of irrigation and potassium exhibited a significant variation in infertile spikelets spike^{-1} in both the growing seasons are shown in Table 139 for first year (2015-2016) and Table 140 for second year (2016-2017) respectively. The highest infertile spikelets spike^{-1} was produced in I_0K_0 followed by I_1K_0 and the lowest number was produced in I_2K_2 in both the years.

4.8.7 1000-grain weight

Significant variation was observed in 1000-grain weight due to different irrigation regimes in both the years are presented in Table 133 for first year (2015-2016) and Table 134 for second year (2016-2017) respectively. The I_2 exibited the highest 1000-grain weight which was statistically similar with I_3 followed by I_1 and the lowest grain weight was found in I_0 in both the years. Similar findings were reported by Anjum *et al.* (2011). Nasri (2005) noticed that drought stress noticeably decreased grain yield and yield constituents in wheat, particularly 1000 grain weight. The results of this experiment was in conformity with that of Islam *et al.* (2018), Taipodia and Singh (2013), Aown *et al.* (2012), Sarwar *et al.* (2010), Ali and Amin (2007), Manivannan *et al*. (2007), Sankar *et al*. (2007) and Brisson and Casals (2005), who reported that 1000-grain weight was significantly affected by different irrigation levels.

The effect of variety on 1000-grain weight was not significant in both the years are given in Table 135 for first year (2015-2016) and Table 136 for second year (2016-2017) respectively. The higher 1000-grain weight was recorded in BARI Gom 28 (V_2) than Bari Gom 27 (V_1) during two successive growing seasons. This may be due to genetical variation between the two varieties.

The effects of potassium packages was found to be significant in respect to 1000-grain weight in both the growing seasons are presented in Table 137 for first year (2015-2016) and Table 138 for second year (2016-2017) respectively. The result of the experiment revealed that, the highest 1000- grain weight was recorded in K_2 which was statistically similar with K_3 and K_1 and the lowest value was found in K_0 in both the years. This findings was the good agreement

with El-Abady *et al.* (2009) who reported that, spraying wheat plants with 3% K_2O produced the highest values of 1000-grain weight followed by spraying plants with 1.5 % K_2O, while control treatment (without potassium foliar application) gave the lowest values of this character. Raza *et al.* (2013) also noticed that foliar application of potassium considerably enhanced the 1000-grain weight. Shah *et al.* (2017), Desoky *et al*. (2017) and Fusheng 2006, El-Sabbagh *et al.* (2002) also reported similar findings in different crops.

Interaction effect of irrigation and potassium on 1000-grain weight showed statistically significant variation in both the years are presented in Table 139 for first year (2015-2016) and Table 140 for second year (2016-2017) respectively. The highest 1000-grain weight was recorded in I_2K_2 which was statistically similar with I_3K_3, I_3K_1 and I_2K_3 followed by I_3K_2 and the lowest was produced in I_0K_0 in both the years.

4.8.8 Grain yield

The grain yield for the different irrigation schedules are shown in Table 133 for first year (2015-2016) and Table 134 for second year (2016-2017) respectively. Irrigation treatments had significant effect on grain yield in both the years. The highest grain yield was produced by I_2 which was statistically similar with I_3 followed by I_1 and the lowest grain yield was produced in I_0 in both the growing seasons. Higher grain yield in I_2 treatments might be due to higher number of tillers per plant, spike length, number of spikelets per spike, and 100-grain weight in I_2 plots. This results supported the findings of Ngwako and Mashiqa (2013) and Kabir *et al.* (2009) who noted similar effects of irrigation on grain yield while working on wheat. Similar results were also recorded by Sarker *et al.* (2015) in barley and Razi-us-Shams 2001, Rahman *et al.,* 2001, Rafiq *et al.,* 2005, Warraich *et al.,* 2007 and Alsohaibani 2007 in wheat.

Grain yield did not show significant variation due to variety in both the years are given in Table 135 for first year (2015-2016) and Table 136 for second year (2016-2017) respectively. Between the two varieties BARI Gom 28 (V_2) produced higher grain yield than BARI Gom 27 (V_1) during the two successive growing seasons. This was also due to higher number of fertile spikelets per spike and higher 1000-grain weight in BARI Gom 28.

Grain yield of wheat was significantly affected by foliar applications of potassium in both the years are presented in Table 137 for first year (2015-2016) and Table 138 for second year (2016-2017) respectively. In the study, the highest grain yield was produced in K_2 which was

statistically similar with K_3 followed by K_1 and the lowest grain yield was found in control (K_0) during the two successive growing seasons. Aown *et al*. (2012) reported that foliar application of K at all three critical growth stages improved the drought tolerance of plants and improved the growth and yield components, however, grain filling stage was found more responsive. Damon *et al*. (2007) also noted that low grain yield resulting from water deficit could be overcome by increasing K supply. In every cases the higher amount of K increased the production of wheat in a significant range though the amount of applied water was similar. From the present investigation, it was also exhibited that foliar application of K only at the rate of 1 and 2%; can be reduced soil application of K. Besides in some cases, foliar application of K also gave higher grain yield of wheat than 100% recommended dose of K, applied as basal dose. Similar results were also recorded by Mesbah (2009) who noted that foliar application of K significantly increase grain yield of wheat. Similar results were also reported by Kabir *et al*. (2009), Magdy *et al*. (2009) and Onyibe (2005).

Interaction effect of irrigation and potassium had significant influence on grain yield in both the growing seasons are presented in Table 139 for first year (2015-2016) and Table 140 for second year (2016-2017) respectively. The highest grain yield was produced by I_2K_2 followed by I_3K_2 and I_3K_3 and the lowest value was obtained in I_0K_0 in both the years.

4.8.9 Biological yield

The total dry matter produced by a crop is known as biological yield. The biological yield refers to the total dry matter accumulation of a plant system. Significant difference was observed in biological yield due to different irrigation regimes in both the growing seasons are presented in Table 133 for first year (2015-2016) and Table 134 for second year (2016-2017) respectively. The highest biological yield was obtained in I_2 (3800 m^3 ha^{-1} water) which was at par with I_3 (4400 m^3 ha^{-1} water) followed by I_1 (3200 m^3 ha^{-1} water) and the lowest biological yield was produced in I_0 (no irrigation) during the two successive growing seasons. This highest biological yield might be attributed to highest dry matter $plant^{-1}$, grain yield and straw yield. The results of the present study were in agreement with Taipodia and Singh (2013) who found significant variation among the irrigation treatments for biological yield of wheat. Islam *et al.* (2018) revealed that the highest biological yield (10.05t ha^{-1}) was found with three irrigations given at 25, 40 and 55 DAS which was statistically differed from other irrigation treatments. Alsohaibani (2007) noticed that higher biological yield of wheat with irrigated crops. Gupta *et*

al. (2001) reported that biological yield decreased to a greater extent when water stress was imposed at the anthesis stage. Finding of Pandit *et al.* (2001) were also similar to the findings of the presented study, where they found three times irrigation at crown root initiation, booting and early grain filling stages resulted in higher biological yield of wheat as against no irrigation.

A non-significant difference was observed in the biological yield of wheat due to varietal difference in both experiments are shown in Table 135 for first year (2015-2016) and Table 136 for second year (2016-2017) respectively. Between the two varieties, BARI Gom 28 (V_2) produced higher biological yield which was at par with BARI Gom 27 (V_1) in both the growing seasons. Findings of this experiment revealed that, varietal differences between wheat cultivars may be due to genetically differences between cultivars, as well as, the range of cultivar response towards nutrients. Abd El-Gawad *et al*. (1987) found that wheat cultivars differed in partitioning and migration of the total available photosynthate to economic yields. These results were in harmony with the results obtained by Amal *et al.* (2011), El-Habbasha *et al*. (2008), Ahmed *et al*. (2006), Sarhan and Abd El-Maksoud (2002), Hassanein *et al*. (2001) and Hassanein and Gomaa (2001).

There was statistically significant effect of foliar applications of potassium on biological yield in both the growing seasons are presented in Table 137 for first year (2015-2016) and Table 138 for second year (2016-2017) respectively. The highest biological yield was produced in K_2 which was a par with K_3 followed by K_1 and the lowest biological yield was found in K_0 in both the years. The increase in biological yield was obtained due to optimum utilization of potassium fertilizer that ensured maximum plant height, number of fertile spike plant^{-1} and number of spikes per plant. The results of the present study were in agreement with Dafan *et al*. (1999) where they reported that biological yield was increased with foliar spray of potassium. This findings were also in agreement with the findings of Brhane and Teka (2018), Maurya *et al.* (2014) and Wassie *et al.* (2013) and Aown *et al*. (2012) who reported that application of potassium had significant effect on the biological yield of wheat.

The combine effects of irrigation regimes and foliar application of potassium on biological yield were significant in both the growing seasons and are given in Table 139 for first year (2015-2016) and Table 140 for second year (2016-2017) respectively. The highest biological yield was produced by the treatments I_2K_2 which was statistically similar with I_3K_2 and the lowest value was obtained in I_0K_0 during the two successive growing seasons.

4.8.10 Harvest index

Harvest index is the proportion of commercial yield and biological yield. Harvest index of wheat was affected significantly due to different levels of irrigation in both year trials are shown in Table 133 for first year (2015-2016) and Table 134 for second year (2016-2017) respectively. The highest harvest index was observed in I_2 which was statistically identical with I_3 followed by I_1 and the lowest harvest index was found in I_0 in both growing seasons. The increase in harvest index was due to optimum use of water that ensured maximum yield. These results supported the findings of Taipodia and Singh (2013), Sarwar *et al*. (2010), Pannu *et al*. (1996) and Giunata *et al*. (1993) who found that harvest index was significantly influenced by irrigation. Similar results were observed by Rafiq *et al.* (2005), Baheri *et al.* (2005) and Xue *et al.* (2006), Warraich *et al*. (2007) and Sarker (2015). Ali and Amin (2007) showed that harvest index was significantly higher at two irrigations compared to the other treatments in wheat. Ngwako and Mashiqa (2013) stated that irrigation at all growth stages of crop plant increased harvest index over no irrigation treatment.

The difference in harvest index due to variety was not statistically significant in both the years are shown in Table 135 for first year (2015-2016) and Table 136 for second year (2016-2017) respectively. Between the two varieties, higher harvest index was found in BARI Gom 28 (V_2) compared to BARI Gom 27 (V_1) in both the growing seasons.

There had a marked influence on harvest index by different foliar application of potassium in both the years are presented in Table 137 for first year (2015-2016) and Table 138 for second year (2016-2017) respectively. Significantly highest harvest index was recorded in K_2 which was statistically identical to K_3 followed by K_1 and the lowest harvest index was found in K_0 in both the growing seasons. Similar findings were also observed by Khan *et al.* (2014) who reported that, the plots that received 10% and 15% of the total nutrients as foliar application produced higher harvest index, as compared with all nutrients were applied as basal.

Harvest index of wheat was affected significantly due to interaction of different levels of irrigation and potassium in both years are shown in Table 139 for first year (2015-2016) and Table 140 for second year (2016-2017) respectively. The highest harvest index was obtained in I_2K_2 which was at par with I_3K_1, I_3K_3 and I_3K_2 and the lowest harvest index was observed in I_0K_0 during the two successive growing seasons.

Table 133: Effect of irrigation on yield components and yield of wheat in 2015-2016

Irrigation	Plant height (cm)	Effective tillers plant^{-1}	Spike length (cm)	Extrusion length (cm)	Fertile spikelets spike^{-1}	Infertile spikelets spike^{-1}	1000-grain weight (g)	Grain yield (kg ha^{-1})	Biological yield (kgha^{-1})	Harvest index
I_0	86.031 b	1.950 c	11.602 c	31.837 b	13.655 c	3.968 a	43.588 c	2787.153 c	6375.020 c	43.720 b
I_1	89.651 b	2.537 bc	12.706 bc	33.500 b	14.68 bc	2.689 b	46.527 bc	3272.279 b	7489.515 b	43.691 ab
I_2	99.208 a	3.755 a	14.822 a	37.391 a	17.399 a	2.468 b	53.264 a	4238.018 a	9271.922 a	45.708 a
I_3	98.327 a	3.288 ab	14.012 ab	35.811 ab	16.38 ab	2.545 c	51.115 ab	3775.679 ab	9737.924 a	38.773 b
CV (%)	5.673	4.567	4.635	5.347	6.347	7.347	8.347	9.347	10.347	11.347

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 134: Effect of irrigation on yield components and yield of wheat in 2016-2017

Irrigation	Plant height (cm)	Effective tillers plant^{-1}	Spike length (cm)	Extrusion length (cm)	Fertile spikelets spike^{-1}	Infertile spikelets spike^{-1}	1000-grain weight (g)	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index
I_0	88.185 b	2.017 c	12.015 c	32.623 b	14.27 b	3.571 a	42.837 c	3023.743 c	7458.864 c	40.539 b
I_1	90.735 b	2.704 bc	13.417 bc	34.079 b	15.302 bc	2.544 b	50.017 b	3393.321 b	8166.702 b	41.551 b
I_2	102.494 a	3.75 a	14.702 a	38.088 a	18.115 a	2.104 b	52.203 a	4063.436 a	9074.422 a	44.779 a
I_3	99.411 a	3.517 ab	15.207 ab	35.813 ab	16.957 ab	2.219 b	50.638 b	3725.116 ab	8528.883 ab	43.676 ab
CV (%)	6.656	5.419	3.432	4.025	5.025	6.025	7.025	8.025	9.025	10.025

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 135: Effect of variety on yield components and yield of wheat in 2015-2016

Variety	Plant height (cm)	Effective tillers plant^{-1}	Spike length (cm)	Extrusion length (cm)	Fertile spikelets spike^{-1}	Infertile spikelets spike^{-1}	1000-grain weight (g)	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index
V_1	88.241 a	2.556 b	13.225 a	34.001 a	15.512 a	3.079 a	46.2 b	3463.431 a	8167.766 a	42.404 a
V_2	98.367 a	3.21 a	13.347 a	35.269 a	15.546 a	2.757 a	51.048 a	3573.129 a	8219.424 a	43.472 a
CV (%)	5.673	4.567	4.635	5.347	6.347	7.347	8.347	9.347	10.347	11.347

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 136: Effect of variety on yield components and yield of wheat in 2016-2017

Variety	Plant height (cm)	Effective tillers plant^{-1}	Spike length (cm)	Extrusion length (cm)	Fertile spikelets spike^{-1}	Infertile spikelets spike^{-1}	1000-grain weight (g)	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index
V_1	94.442 a	2.562 b	13.728 a	34.393 a	15.982 a	2.778 a	46.618 b	3523.205 a	8268.261 a	42.611 a
V_2	95.969 a	3.431 a	13.943 a	35.908 a	16.34 a	2.44 a	51.23 a	3579.603 a	8346.174 a	42.889 a
CV (%)	6.656	5.419	3.432	4.025	5.025	6.025	7.025	8.025	9.025	10.025

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 137: Effect of potassium on yield components and yield of wheat in 2015-2016

Potassium	Plant height (cm)	Effective tillers plant^{-1}	Spike length (cm)	Extrusion length (cm)	Fertile spikelets spike^{-1}	Infertile spikelets spike^{-1}	1000-grain weight (g)	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index
K_0	82.962 c	1.373 c	9.979 b	26.2143 b	9.777 c	4.415 a	41.812 c	3013.353 c	7184.248 c	41.944 c
K_1	94.2 b	3.261 ab	13.828 b	36.308 a	16.773 b	2.658 b	49.787 b	3353.230 c	8591.086 bc	39.032 b
K_2	99.01	3.744a	14.878 a	38.686 a	17.97 a	2.224 b	51.984 a	3990.312 a	8738.493 a	45.664 a
K_3	97.045	3.154 b	14.457 a	37.331 a	17.596 ab	2.374 b	50.911 ab	3716.223 ab	8260.554 ab	44.988 b
CV (%)	5.673	4.567	4.635	5.347	6.347	7.347	8.347	9.347	10.347	11.347

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 138: Effect of potassium on yield components and yield of wheat in 2016-2017.

Potassium	Plant height (cm)	Effective tillers plant^{-1}	Spike length (cm)	Extrusion length (cm)	Fertile spikelets spike^{-1}	Infertile spikelets spike^{-1}	1000-grain weight (g)	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index
K_0	84.589 c	1.454 c	10.191 b	26.858 b	10.246 c	3.882 a	41.842 c	3209.122 c	7614.152 c	42.147 c
K_1	96.366 b	3.308 ab	14.376 a	36.783 a	17.396 b	2.324 b	50.064 bc	3463.154 bc	8358.073 bc	41.435 b
K_2	101.132 a	3.775 a	15.488 a	38.948 a	18.697 a	2.022 b	52.173 a	3927.115 a	8930.717 a	43.973 a
K_3	98.735 ab	3.45 b	15.285 a	38.014 a	18.305 ab	2.208 b	51.617 ab	3606.207 ab	8325.931 ab	43.313 b
CV (%)	6.656	5.419	3.432	4.025	5.025	6.025	7.025	8.025	9.025	10.025

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 139: Interaction effect of irrigation and potassium on yield components and yield of wheat in 2015-2016

Interaction (Irrigation× Potassium)	Plant height (cm)	Effective tillers plant^{-1}	Spike length (cm)	Extrusion length (cm)	Fertile spikelets spike^{-1}	Infertile spikelets spike^{-1}	1000-grain weight (g)	Grain yield (kg ha^{-1})	Biological yield(kgha^{-1})	Harvest index
I_0K_0	77.421 n	1.137 i	8.753 l	25.127 g	9.153 h	4.987 a	36.303 g	1855.123 k	5453.706 h	34.016 h
I_0K_1	87.163 k	2.347 d-i	11.067 h	33.812 f	16.022 e	3.867 bc	45.583 d-f	2252.649 ij	7238.695 f	31.120 ij
I_0K_2	91.723 gh	2.433 d-h	12.766 f	34.387 ef	17.119 de	3.513 c-e	48.035 b-e	2412.655 i	7362.879 f	32.768 i
I_0K_3	89.671 ij	2.103 e-i	12.583 g	34.507 ef	16.826 de	3.390 cd	47.571 b-e	2435.448 hi	7264.348 f	33.526 hi
I_1K_0	80.123 m	1.427 hi	9.652 k	25.554 g	10.167 gh	4.667 ab	39.833 fg	2753.914 h	6159.941 g	44.407 d
I_1K_1	90.734 hi	3.090 b-f	13.349 e	35.232 d-f	17.412 de	1.803 f	49.607 e	3136.756 g	7646.567 e	41.022 e
I_1K_2	95.891 f	3.341 b-e	14.311 d	37.306 c-e	18.123 b-d	2.467 d-f	50.158 e	3294.815 f	8735.912 d	37.716 g
I_1K_3	92.733 g	2.693 c-g	13.697 e	36.123 c-f	17. 632c-e	2.073 f	49.742 e	3166.538 fg	7852.692 de	40.324 ef
I_2K_0	85.703 l	1.461 g-i	10.601 j	26.574 g	11.799 fg	4.267 a-c	44.258 ef	3936.654 e	6731.541 h	58.481 a
I_2K_1	97.781 de	3.597 a-d	14.599 c	37.412 c-e	18.456 b-d	2.067 ef	50.595 e	4210.228 d	10189.780 b	41.318 de
I_2K_2	105. 391 a	4.733 a	16.400 a	41.867 a	21.523 a	1.823 f	56.763 a	4779.911 a	10135.784 b	47.159 cd
I_2K_3	99.834 cd	3.408 a-e	15.456 b	38.875 b-d	19.455 a-c	1.967 f	51.651 a-b	4496.757 bc	9835.045 bc	45.722 c
I_3K_0	87.973 jk	1.760 f-i	11.432 i	27.977 g	12.763 f	3.267 cd	45.753 c-f	3876.336 k	7178.623 f	53.998 b
I_3K_1	102.345 b	4.291 ab	15.429 b	39.345 a-c	19.216 a-c	2.345 d-f	53.073 ab	4373.539 c	8527.678 b	51.286 bc
I_3K_2	104.398 a	4.133 ab	16.278 a	39.209 a-c	19.823 ab	1.933 f	54.812 b	4733.524 a	10787.897 a	43.878 d
I_3K_3	103.985 ab	4.173 a-c	16.199 a	40.855 ab	20.601 a	2.251 d-f	54.240 ab	4577.654 b	9996.439 b	45.793 b
CV (%)	5.673	4.567	4.635	5.347	6.347	7.347	8.347	9.347	10.347	11.347

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 140: Interaction effect of irrigation and potassium on yield components and yield of wheat in 2016-2017

Interaction (Irrigation× Potassium)	Plant height (cm)	Effective tillers plant^{-1}	Spike length (cm)	Extrusion length (cm)	Fertile spikelets spike^{-1}	Infertile spikelets spike^{-1}	1000-grain weight (g)	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index
I_0K_0	79.123 n	1.271 i	8.088 l	25.499 g	9.485 h	5.011 a	36.647 g	1798.321 n	5789.907 l	31.060 f
I_0K_1	89.753 k	2.521 d-i	12.625 h	34.143 f	16.780 e	3.533 a-c	45.879 d-f	2301.321 l	6446.031 jk	35.701 ef
I_0K_2	93.782 gh	2.613 d-h	13.601 f	35.501 ef	17.888 de	2.967 c-f	48.658 b-e	2412.514 j	6698.123 hi	36.018 d
I_0K_3	91.923 ij	2.167 e-i	13.127 g	34.783 ef	17.607 de	3.133 b-d	47.902 b-e	2319.264 k	6522.893 ij	35.556 ef
I_1K_0	82.441 m	1.465 hi	9.952 k	25.850 g	10.599 gh	4.267 ab	40.343 fg	2812.098 m	6267.047 k	44.871 b
I_1K_1	93.872 hi	3.067 b-f	14.046 e	35.776 d-f	18.201 de	1.733 g	49.761 a-e	3207.547 h	7485.441 fg	42.850 bc
I_1K_2	97.908 f	3.430 b-e	14.844 d	37.607 c-e	19.091 b-d	2.267 d-g	50.573 a-e	3343.876 f	7956.789 e	42.025 cd
I_1K_3	95.345 g	2.795 c-g	14.677 e	36.712 c-f	18.603 c-e	1.800 fg	50.487 a-e	3287.456 g	7696.457 f	42.714 c
I_2K_0	87.9237 l	1.529 g-i	11.023 j	27.115 g	12.419 fg	3.905 a-c	44.598 ef	4011.453 k	6829.765 h	58.735 a
I_2K_1	99.784 e	3.709 a-d	15.365 c	37.978 c-e	19.422 b-d	1.910 e-g	51.043 a-e	4389.554 e	10052.672 d	43.666 bc
I_2K_2	105.238 a	4.798 a	16.987 a	42.567 a	22.123 a	1.231 g	56.445 a	4722.234 a	10812.150 a	43.675 bc
I_2K_3	102.351 d	4.006 a-e	16.003 b	38.885 b-d	20.423 a-c	1.667 g	52.592 a-d	4423.567 d	10205.874 c	43.343 bc
I_3K_0	90.569 jk	1.833 f-i	11.758 i	28.511 g	13.546 f	3.090 c-e	46.147 c-f	3923.653 i	7277.986 g	53.911 ab
I_3K_1	103.519 c	4.267 ab	16.124 b	39.921 a-c	20.321 a-c	2.133 d-g	53.447 a-c	4567.325 d	10689.558 c	42.727 c
I_3K_2	104.834 a	4.344 ab	16.593 a	39.880 a-c	20.764 ab	1.631 g	53.655 a-c	4723.897 c	11119.445 ab	42.483 c
I_3K_3	104.930 ab	4.133 a-c	16.550 a	41.687 ab	21.629 a	1.467 g	54.610 ab	4578.345 b	11065.349 b	41.376 cd
CV (%)	6.656	5.419	3.432	4.025	5.025	6.025	7.025	8.025	9.025	10.025

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

4.9 Correlation coefficient between yield and yield components

4.9.1 Effect of irrigation

Simple correlation co-efficient between yield and yield components of wheat as influenced by different irrigation regimes are shown in Tables 141, 142, 143 and 144.

4.9.1.1 No irrigation

The analyzed data on simple correlation coefficient between yield and yield components of wheat varieties as influenced by I_0 (no irrigation) is presented in Table 141. In I_0, plants height was positively correlated with effective tillers plant^{-1}, spike length, extrusion length, fertile spikelets spike^{-1}, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Effective tiller plant^{-1} was positively related with spike length, extrusion length, fertile spikelets spike^{-1}, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Spike length was positively correlated with extrusion length, fertile spikelets spike^{-1}, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}in both the years. Extrusion length had positive association with fertile spikelets spike^{-1}, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Fertile spikelets spike^{-1}was positively correlated with 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Infertile spikelets spike^{-1} was negatively associated with 1000-grain weight, straw yield, harvest index and grain yield. 1000-grain weight had positive association with straw yield, harvest index and grain yield in both the years. Straw yield was positively correlated with harvest index and grain yield. Harvest index was positively associated with grain yield in both the years in I_0 condition.

4.9.1.2 Irrigation with 3200 m^3 ha^{-1} water

In Table 142, the simple correlation coefficient between yield and yield components of wheat cultivars as influenced by irrigation with 3200 m^3 ha^{-1} water (I_1) is presented. In I_1, plant height was positively correlated with effective tillers plant^{-1}, spike length, extrusion length, fertile spikelets spike^{-1}, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Effective tillers plant^{-1} was positively related with spike length, extrusion length, fertile spikelets spike^{-1}, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Spike length had positive association with extrusion length, fertile spikelets spike^{-1}, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets

spike^{-1}. Extrusion length was positively associated with fertile spikelets spike^{-1}, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Fertile spikelets spike^{-1} was positively associated with 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Infertile spikelets spike^{-1}was negatively associated with 1000-grain weight, straw yield, harvest index and grain yield. 1000-grain weight was positively correlated with straw yield, harvest index and grain yield. Straw yield was positively related with harvest index and grain yield in both the years. Harvest index was positively associated with grain yield in both the years in I_1.

4.9.1.3 Irrigation with 3800 m^3 ha^{-1} water

Simple correlation coefficient between yield and yield components of wheat varieties as influenced by irrigation with 3800 m^3 ha^{-1} (I_2) is presented in Table 143. In I_2, plants height was positively correlated with effective tillers plant^{-1}, spike length, extrusion length, fertile spikelets spike^{-1}, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Effective tillers plant^{-1} was positively related with spike length, extrusion length, fertile spikelets spike^{-1}, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Spike length had positive association with extrusion length, fertile spikelets spike^{-1}, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Extrusion length was positively associated with fertile spikelets spike^{-1}, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Fertile spikelets spike^{-1} was positively associated with 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Infertile spikelets spike^{-1} was negatively associated with 1000-grain weight, straw yield, harvest index and grain yield. 1000-grain weight was positively correlated with straw yield, harvest index and grain yield. Straw yield was positively related with harvest index and grain yield in both the years. Harvest index was positively associated with grain yield in both the years in I_2.

4.9.1.4 Irrigation with 4400 m^3 ha^{-1}

The analyzed data on simple correlation coefficient between yield and yield components of wheat cultivars as influenced by irrigation with 4400 m^3 ha^{-1} (I_3) is presented in Table 144. In I_3, plants height was positively correlated with effective tillers $plant^{-1}$, spike length, extrusion length, fertile spikelets $spike^{-1}$, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets $spike^{-1}$. Effective tillers $plant^{-1}$ was positively related with spike length, extrusion length, fertile spikelets $spike^{-1}$, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets $spike^{-1}$. Spike length had positive association with extrusion length, fertile spikelets $spike^{-1}$, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets $spike^{-1}$. Extrusion length was positively associated with fertile spikelets $spike^{-1}$, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets $spike^{-1}$. Fertile spikelets $spike^{-1}$ was positively associated with 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets $spike^{-1}$. Infertile spikelets $spike^{-1}$ was negatively associated with 1000-grain weight, straw yield, harvest index and grain yield. 1000-grain weight was positively correlated with straw yield, harvest index and grain yield. Straw yield was positively related with harvest index and grain yield in both the years. Harvest index was positively associated with grain yield in both the years in I_3 of wheat crops.

In the present study, simple correlation coefficient between grain yield and its components were calculated for four irrigation regimes (Tables 141, 142, 143 and 144). The results of the present study are in agreement with Mandic *et al.* (2014) who found that grain yield had very strong positive correlation with 1000-grain weight. They also noticed that plant height was positively correlated with number of spikelets $spike^{-1}$, 1000-grain weight, number of spike m^{-2} and grain yield. Islam (1977) found a significant positive correlation between grain yield $plant^{-1}$ and 1000-seed weight. Similar result was reported by Bingham (1966) in wheat. Labuschange and Van-Deventer (1992) reported that grain number and grain weight on both primary and secondary tillers were significantly correlated with yield at different moisture levels. Kheiralla *et al.* (1993) noticed the association between grain yield and harvest index only under non-stress condition. In the study, straw weight was positively correlated with grain yield in all irrigation regimes. This result is in agreement with Chai *et al.* (1993). They noticed that grain weight/plant was correlated highly and significantly with dry weight $plant^{-1}$ in wheat. Rahman (1997) reported that grain yield was positively associated with biomass, harvest index, grain production rate and 1000-grain weight of wheat plant. Destro *et al.* (2001) reported that main

stem grain yield responded positively and significantly to irrigation which was the main cause of increased yield in wheat. Bakhshandeh *et al.* (2004) observed a positive correlation between grain and biological yield in wheat, while the correlation between grain yield, 1000-grain weight and harvest index was not significant**.**

Table 141: Simple correlation coefficients between yield and yield components of wheat cultivars as influenced by no irrigation (I_0). Upper diagonal shows values in 2015-2016 and lower diagonal shows values in 2016-2017

	Plant height (cm)	Effective tillers plant^{-1}	Spike length (cm)	Extrusion length(cm)	Fertile spikelets spike^{-1}	Infertile spikelets spike^{-1}	1000-grain weight (g)	Straw yield (kg ha^{-1})	Harvest index	Grain yield (kg ha^{-1})
	1	2	3	4	5	6	7	8	9	10
1	-	.918**	.981**	.921**	.950**	-.954**	.906**	.950**	.967**	.968**
2	.927**	-	.931**	.916**	.901**	-.855**	.827**	.930**	.921**	.929**
3	.973**	.916**	-	.889**	.973**	-.955**	.938**	.933**	.963**	.956**
4	.928**	.915**	.909**	-	.865**	-.869**	.777*	.961**	.911**	.936**
5	.953**	.894**	.983**	.863**	-	-.939**	.951**	.916**	.946**	.936**
6	-.966**	-.876**	-.978**	-.879**	-.947**	-	-.934**	-.908**	-.951**	-.942**
7	.906**	.820**	.946**	.774*	.954**	-.921**	-	.828**	.910**	.882**
8	.951**	.928**	.947**	.962**	.913**	-.900**	.827**	-	.939**	.960**
9	.977**	.926**	.983**	.919**	.957**	-.955**	.923**	.952**	-	.969**
10	.976**	.930**	.974**	.942**	.948**	-.955**	.891**	.969**	.969**	-

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 142: Simple correlation coefficients between yield and yield components of wheat cultivars as influenced by Irrigation with 3200 m^3 ha^{-1} (I_1). Upper diagonal shows values in 2015-2016 and lower diagonal shows values in 2016-2017

	Plant height (cm)	Effective tillers $plant^{-1}$	Spike length (cm)	Extrusion length(cm)	Fertile spikelets $spike^{-1}$	Infertile spikelets $spike^{-1}$	1000-grain weight (g)	Straw yield (kg ha^{-1})	Harvest index	Grain yield (kg ha^{-1})
	1	2	3	4	5	6	7	8	9	10
1	-	.866**	.983**	.917**	.959**	-.765*	.783*	.971**	.959**	.967**
2	.877**	-	.896**	.941**	.843**	-.846**	.491	.908**	.882**	.895**
3	.975**	.879**	-	.924**	.973**	-.814**	.794*	.959**	.962**	.961**
4	.923**	.940**	.942**	-	.907**	-.878**	.581	.943**	.944**	.943**
5	.959**	.834**	.987**	.901**	-	-.801*	.835**	.939**	.953**	.944**
6	-.774*	-.846**	-.835**	-.883**	-.805*	-	-.494	-.777*	-.832**	-.801*
7	.780*	.485	.805*	.577	.835**	-.480	-	.710*	.728*	.716*
8	.971**	.901**	.972**	.936**	.938**	-.770*	.713*	-	.955**	.969**
9	.968**	.884**	.985**	.950**	.961**	-.834**	.739*	.966**	-	.968**
10	.975**	.896**	.981**	.946**	.953**	-.801*	.727*	.978**	.968**	-

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 143: Simple correlation coefficients between yield and yield components of wheat cultivars as influenced by Irrigation with 3280 m^3 ha^{-1} (I_2). Upper diagonal shows values in in 2015-2016 and lower diagonal shows values in 2016-2017

	Plant height (cm)	Effective tillers plant^{-1}	Spike length (cm)	Extrusion length(cm)	Fertile spikelets spike^{-1}	Infertile spikelets spike^{-1}	1000-grain weight (g)	Straw yield (kg ha^{-1})	Harvest index	Grain yield (kg ha^{-1})
	1	2	3	4	5	6	7	8	9	10
1	-	.783*	.982**	.935**	.966**	-.793*	.708*	.966**	.951**	.962**
2	.792*	-	.789*	.889**	.817**	-.938**	.193	.759*	.855**	.819**
3	.971**	.769*	-	.941**	.974**	-.791*	.716*	.977**	.956**	.969**
4	.941**	.887**	.956**	-	.965**	-.873**	.531	.955**	.964**	.958**
5	.966**	.808**	.986**	.959**	-	-.816**	.657	.976**	.963**	.970**
6	-.795*	-.940**	-.802*	-.870**	-.816**	-	-.236	-.804*	-.861**	-.826**
7	.705*	.186	.728*	.527	.659	-.212	-	.698*	.587	.654
8	.966**	.790*	.990**	.952**	.978**	-.784*	.701*	-	.958**	.970**
9	.961**	.857**	.977**	.969**	.973**	-.853**	.599	.969**	-	.969**
10	.967**	.819**	.988**	.961**	.978**	-.816**	.666	.978**	.970**	-

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 144: Simple correlation coefficients between yield and yield components of wheat cultivars as influenced by Irrigation with 4200 m^3 ha^{-1} (I_3). Upper diagonal shows values in 2015-2016 and lower diagonal shows values in 2016-2017

	Plant height (cm)	Effective tillers $plant^{-1}$	Spike length (cm)	Extrusion length(cm)	Fertile spikelets $spike^{-1}$	Infertile spikelets $spike^{-1}$	1000-grain weight (g)	Straw yield (kg ha^{-1})	Harvest index	Grain yield (kg ha^{-1})
	1	2	3	4	5	6	7	8	9	10
1	-	.692*	.980**	.847**	.940**	-.401*	.597*	.952**	.948**	.957**
2	.701*	-	.705*	.797**	.591**	-.551**	.193	.680*	.762**	.705**
3	.969**	.687*	-	.832**	.938**	-.493*	.598*	.962**	.959**	.963**
4	.850**	.793**	.847**	-	.749**	-.597**	.218	.815**	.866**	.934**
5	.938**	.576**	.950**	.738**	-	-.392**	.702	.912**	.919**	.920**
6	-.629*	-.867**	-.683*	-.796**	-.553**	-	-.231	-.487*	-.564**	-.490**
7	.596*	.173	.610*	.211	.709	-.121	-	.544*	.502	.532
8	.950**	.671*	.976**	.808**	.910**	-.615*	.548*	-	.932**	.970**
9	.954**	.764**	.978**	.868**	.924**	-.756**	.514	.937**	-	.951**
10	.964**	.705**	.984**	.835**	.925**	-.432**	.542	.979**	.946**	-

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

4.9.2 Effect of Potassium

Simple correlation co-efficient between yield and yield components of wheat as influenced by potassium are shown in Tables 145, 146, 147 and 148.

4.9.2.1 The recommended rate of potassium i.e. 50 kg K ha^{-1}

In the presented study, simple correlation coefficient between grain yield and its components were calculated for the recommended rate of K for the variety i.e. 50 kg K ha^{-1} (K_0) is presented in Table 145. In K_0, plant height was positively correlated with effective tillers $plant^{-1}$, spike length, extrusion length, fertile spikelets $spike^{-1}$, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets $spike^{-1}$. Effective tiller $plant^{-1}$ was positively related with spike length, extrusion length, fertile spikelets $spike^{-1}$, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets $spike^{-1}$. Spike length was positively correlated with extrusion length, fertile spikelets $spike^{-1}$, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets $spike^{-1}$ in both the years. Extrusion length had positive association with fertile spikelets $spike^{-1}$, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets $spike^{-1}$. Fertile spikelets $spike^{-1}$ was positively correlated with 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets $spike^{-1}$. Infertile spikelets $spike^{-1}$ was negatively associated with 1000-grain weight, straw yield, harvest index and grain yield. 1000-grain weight had positive association with straw yield, harvest index and grain yield in both the years. Straw yield was positively correlated with harvest index and grain yield. Harvest index was positively associated with grain yield in both the years in rain-fed condition (no irrigation).

4.9.2.2 50% of the recommended rate of K + Foliar spray with 1% K_2O

The analyzed data on simple correlation coefficient between yield and yield components of wheat varieties as influenced by K_1 (50% of the recommended rate for the variety + Foliar spray with 1% K_2O) is presented in Table 146. Under K_1 condition, plant height was positively correlated with effective tillers $plant^{-1}$, spike length, extrusion length, fertile spikelets $spike^{-1}$, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets $spike^{-1}$. Effective tillers $plant^{-1}$ was positively related with spike length, extrusion length, fertile spikelets $spike^{-1}$, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets $spike^{-1}$. Spike length had positive association with extrusion length, fertile spikelets $spike^{-1}$, 1000-grain weight, straw yield,

harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Extrusion length was positively associated with fertile spikelets spike^{-1}, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Fertile spikelets spike^{-1} was positively associated with 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Infertile spikelets spike^{-1}was negatively associated with 1000-grain weight, straw yield, harvest index and grain yield. 1000-grain weight was positively correlated with straw yield, harvest index and grain yield. Straw yield was positively related with harvest index and grain yield in both the years. Harvest index was positively associated with grain yield in both the years.

4.9.2.3 50% of the recommended rate of K + Foliar spray with 2% K_2O

Simple correlation co-efficient between yield and yield components of wheat as influenced by K_2 (50% of the recommended rate for the variety + Foliar spray with 2% K_2O) is shown in Table 147. In K_2, plant height was positively correlated with effective tillers plant^{-1}, spike length, extrusion length, fertile spikelets spike^{-1}, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Effective tillers plant^{-1} was positively related with spike length, extrusion length, fertile spikelets spike^{-1}, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Spike length had positive association with extrusion length, fertile spikelets spike^{-1}, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Extrusion length was positively associated with fertile spikelets spike^{-1}, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Fertile spikelets spike^{-1} was positively associated with 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Infertile spikelets spike^{-1} was negatively associated with 1000-grain weight, straw yield, harvest index and grain yield. 1000-grain weight was positively correlated with straw yield, harvest index and grain yield. Straw yield was positively related with harvest index and grain yield in both the years. Harvest index was positively associated with grain yield in both the years.

4.9.2.4 50% of the recommended rate of K + Foliar spray with 3% K_2O

In the present investigation, simple correlation coefficient between grain yield and its components were calculated for K_3 (50% of the recommended rate for the variety + Foliar spray with 3% K_2O) is presented in Table 148. In K_3, plant height was positively correlated with effective tillers plant^{-1}, spike length, extrusion length, fertile spikelets spike^{-1}, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Effective tillers plant^{-1} was positively related with spike length, extrusion length, fertile spikelets spike^{-1}, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Spike length had positive association with extrusion length, fertile spikelets spike^{-1}, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Extrusion length was positively associated with fertile spikelets spike^{-1}, 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Fertile spikelets spike^{-1} was positively associated with 1000-grain weight, straw yield, harvest index and grain yield and negatively associated with infertile spikelets spike^{-1}. Infertile spikelets spike^{-1} was negatively associated with 1000-grain weight, straw yield, harvest index and grain yield. 1000-grain weight was positively correlated with straw yield, harvest index and grain yield. Straw yield was positively related with harvest index and grain yield in both the years.

Table 145: Simple correlation coefficients between yield and yield components of wheat cultivars as influenced by recommended rate of K i.e. 50 kg K ha^{1} (K_0). Upper diagonal shows values in 2015-2016 and lower diagonal shows values in 2016-2017

	Plant height (cm)	Effective tillers $plant^{-1}$	Spike length (cm)	Extrusion length(cm)	Fertile spikelets $spike^{-1}$	Infertile spikelets $spike^{-1}$	1000-grain weight (g)	Straw yield (kg ha^{-1})	Harvest index	Grain yield (kg ha^{-1})
	1	2	3	4	5	6	7	8	9	10
1	-	.748*	.991**	.753*	.982**	-.923**	.894**	.968**	.990**	.983**
2	.749*	-	.719*	.898**	.753*	-.654	.432	.825*	.785*	.812*
3	.993**	.721*	-	.711*	.977**	-.951**	.926**	.972**	.990**	.984**
4	.750*	.896**	.708*	-	.767*	-.655	.421	.804*	.799*	.810*
5	.984**	.749*	.979**	.761*	-	-.909**	.889**	.952**	.978**	.969**
6	-.921**	-.652	-.949**	-.650	-.910**	-	-.878**	-.895**	-.936**	-.923**
7	.895**	.431	.927**	.417	.894**	-.877**	-	.838**	.872**	.853**
8	.967**	.826*	.973**	.801*	.953**	-.889**	.836**	-	.987**	.996**
9	.988**	.788*	.995**	.796*	.979**	-.934**	.871**	.988**	-	.998**
10	.981**	.813*	.983**	.808*	.971**	-.919**	.852**	.998**	.999**	-

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 146: Simple correlation coefficients between yield and yield components of wheat cultivars as influenced by 50% of the recommended rate of K + Foliar spray with 1% K_2O (K_1). Upper diagonal shows values in 2015-2016 and lower diagonal shows values in 2016-2017

	Plant height (cm)	Effective tillers plant^{-1}	Spike length (cm)	Extrusion length(cm)	Fertile spikelets spike^{-1}	Infertile spikelets spike^{-1}	1000-grain weight (g)	Straw yield (kg ha^{-1})	Harvest index	Grain yield (kg ha^{-1})
	1	2	3	4	5	6	7	8	9	10
1	-	.695	.982**	.848**	.940**	-.466	.642	.972**	.986**	.986**
2	.697	-	.664	.850**	.594	-.452	-.036	.671	.771*	.706
3	.983**	.665	-	.802*	.971**	-.562	.691	.952**	.974**	.963**
4	.847**	.853**	.800*	-	.657	-.582	.235	.819*	.905**	.851**
5	.942**	.597	.975**	.658	-	-.459	.739*	.911**	.912**	.918**
6	-.487	-.480	-.580	-.601	-.468	-	-.194	-.490	-.568	-.495
7	.643	-.034	.695	.233	.742*	-.193	-	.593	.556	.584
8	.971**	.670	.951**	.817*	.910**	-.510	.595	-	.958**	.996**
9	.984**	.773*	.975**	.904**	.914**	-.596	.557	.955**	-	.978**
10	.988**	.708	.964**	.850**	.919**	-.518	.585	.998**	.976**	-

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table147: Simple correlation coefficients between yield and yield components of wheat cultivars as influenced by 50% of the recommended rate of K + Foliar spray with 2% K_2O (K_2). Upper diagonal shows values in 2015-2016 and lower diagonal shows values in 2016-2017

	Plant height (cm)	Effective tillers plant^{-1}	Spike length (cm)	Extrusion length(cm)	Fertile spikelets spike^{-1}	Infertile spikelets spike^{-1}	1000-grain weight (g)	Straw yield (kg ha^{-1})	Harvest index	Grain yield (kg ha^{-1})
	1	2	3	4	5	6	7	8	9	10
1	-	.742*	.979**	.923**	.967**	-.661	.669	.972**	.992**	.984**
2	.744*	-	.722*	.834*	.663	-.730*	.099	.711*	.804*	.740*
3	.980**	.725*	-	.870**	.970**	-.687	.708*	.970**	.983**	.977**
4	.925**	.837*	.869**	-	.827*	-.679	.375	.872**	.931**	.893**
5	.966**	.658	.971**	.826*	-	-.683	.749*	.934**	.960**	.949**
6	-.660	-.725*	-.684	-.672	-.682	-	-.141	-.707*	-.728*	-.711*
7	.671	.102	.709*	.374	.751*	-.140	-	.640	.606	.635
8	.973**	.713*	.973**	.871**	.936**	-.710*	.639	-	.972**	.997**
9	.991**	.805*	.984**	.932**	.959**	-.726*	.605	.970**	-	.985**
10	.985**	.742*	.978**	.895**	.950**	-.714*	.637	.998**	.984**	-

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 148: Simple correlation coefficients between yield and yield components of wheat cultivars as influenced by 50% of the recommended rate of K + Foliar spray with 3% K_2O (K_3). Upper diagonal shows values in 2015-2016 and lower diagonal shows values in 2016-2017

	Plant height (cm)	Effective tillers plant^{-1}	Spike length (cm)	Extrusion length(cm)	Fertile spikelets spike^{-1}	Infertile spikelets spike^{-1}	1000-grain weight (g)	Straw yield (kg ha^{-1})	Harvest index	Grain yield (kg ha^{-1})
	1	2	3	4	5	6	7	8	9	10
1	-	.720*	.989**	.872**	.960**	-.430	.616	.972**	.977**	.984**
2	.722*	-	.714*	.822*	.611	-.580	-.037	.700	.791*	.732*
3	.990**	.715*	-	.857**	.958**	-.522	.617	.982**	.988**	.990**
4	.871**	.821*	.856**	-	.769*	-.626	.237	.835**	.895**	.861**
5	.959**	.604	.959**	.763*	-	-.421	.721*	.932**	.948**	.947**
6	-.650	-.895**	-.692	-.821*	-.573	-	.068	-.507	-.593	-.517
7	.617	-.036	.619	.236	.729*	.027	-	.564	.531	.559
8	.971**	.699	.985**	.833*	.930**	-.644	.567	-	.961**	.997**
9	.975**	.792*	.987**	.893**	.944**	-.785*	.533	.957**	-	.978**
10	.985**	.733*	.993**	.860**	.945**	-.679	.561	.999**	.975**	-

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

4.10 Water Use

4.10.1 Consumptive use of water

The irrigation regimes exhibited significant influence on consumptive use of water (CUW) in both the growing seasons are presented in Table 149. The highest consumptive use of water (CUW) was recorded in I_2 followed by I_3 and I_1 and the lowest consumptive use of water (CUW) was recorded in I_0 by wheat crops in both the growing seasons. Similar results were reported by Pal *et al.,* 1996, Ju-Hui *et al.,* 2000 and Mollah 2007. Jana and Mitra (2004) noticed that water use increased and water use efficiency decreased with increasing amount of irrigations. Soni and Lehria (1999) also observed that total water use was highest with two irrigations, whereas water use efficiency was highest in the crops growing without irrigation. Ju-Hui *et al.* (2000) noticed that the total water consumption was decreased with decreasing amount of water, but the use of water stored in the soil was increased, particularly from deeper soil layers. Mollah and Paul (2011) stated that irrigated plants had higher CUW than the rain-fed plants in barley.

There was no significant effect on consumptive use of water (CUW) in two wheat varieties in both the years are shown in Table 150. Between the two varieties, BARI Gom 28 had higher consumptive use of water (CUW) than BARI Gom 27 during the two successive growing seasons. The effects of potassium on consumptive use of water in both the years are presented in Table 151. Among the treatments, the highest consumptive use of water was found in K_2 followed by K_3 and K_1 and the lowest CUW was recorded in K_0 both the growing seasons. Witold *et. at.,* (2013) stated that plants water use efficiency increased with the increase of potassium fertilizer level.

Interaction effects of irrigation and potassium had significant influence on consumptive use of water (CUW) during the two successive growing seasons are shown in Table 152. The highest consumptive use of water (CUW) was recorded in I_2K_2 which was statistically similar with I_3K_1, I_3K_3 and I_3K_2 in both the growing seasons. The lowest value was found in I_0K_0 which was statistically similar with I_0K_1, I_0K_2 and I_0K_3 in both the growing seasons. This findings is similar with Shabbir *et al*. (2015) who reported that supplemental foliar fertilization of potassium significantly increase consumptive use of water. The foliar spray of NPK in combination was effective in improving wheat growth under both well-watered and water-deficit conditions.

4.10.2 Water use efficienc

Different irrigation regimes had significant influence on water use efficiency of wheat and are given in Table 149 for both the growing seasons. In the present study, the highest water use efficiency (WUE) was observed in I_0 followed by I_1 and I_2 and the lowest WUE was found in I_3 the two successive growing seasons. Similar results were reported by Soni and Lehria 1999, Ju-Hui *et al.,* 2000, Kang *et al.,* 2002, Mahmood and Ahmad, 2005, Hari *et al.,* 2013, Abdelraouf *et al.,* 2013 and Mhamed *et al.,* 2015 in wheat, Begum and Paul 1993 in mustard. Mollah (2007) and Bahadur (2008) also found similar result with barley. Maurya and Singh (2008) also reported a decrease in WUE with an increase irrigation levels due to proportionately less increase in biomass with increase in water consumption. Similarly, Li *et al.* (2005) reported that WUE decreased with increasing in irrigation and because grain yield did not increase linearly with irrigation, excessive irrigation even decreased grain production. Wang *et al.* (2012) stated that the low crop water-use, related to high irrigation treatments, was most likely due to saturation over the root layer and high evapo-transpiration. Khan *et al.* (2007) stated that WUE was increased when the irrigation intervals increased. Mandal *et al.* (2003) reported that WUE of wheat decreased with increase in irrigation levels. Mollah and Paul (2011) stated that the highest WUE was in no irrigation treatment followed by different irrigation treatment in barley. Similar findings were also reported in wheat by Rahman and Islam (1991).

Variety had no significant effect on water use efficiency (WUE) in both the years are given in Table 150. Between the two varieties, BARI Gom 28 had higher water use efficiency than BARI Gom 27 in both the growing seasons.

Foliar applications of potassium had significant effect on water use efficiency (WUE) in both the years are presented in Table 151. Among K treatments, the highest water use efficiency was recorded in K_2 which was at par with K_3 and K_1 and the lowest value was recorded in K_0 in both the growing seasons. Elsa *et. al.* (2017) reported that water use efficiency increased with increased potassium fertilizer in water deficit condition. Similat results were also reported by Mesba (2009) who reported that wheat plants under water stressed condition sprayed with 2% potassium increased the water use efficiency, yield components and grain yield/fed.

Water use efficiency (WUE) was significantly influenced by the interaction of irrigation and potassium in both the years are shown in Table 152. The highest water use efficiency (WUE) was obtained in I_0K_0 followed by I_0K_3, I_0K_2 and the lowest value was found in I_2K_2 in both the growing seasons.

Table 149: Effect of irrigation on consumptive use of water and water use efficiency of wheat

Irrigation	Consumptive use of water (mm)		Water use efficiency (kg ha^{-1} mm^{-1})	
	2015-2016	2016-2017	2015-2016	2016-2017
I_0	195.143 d	222.228 d	11.244 a	10.427 a
I_1	328.301 c	368.496 c	8.059 b	8.343 b
I_2	604.895 a	629.348 a	7.81 b	8.335 b
I_3	555.526 b	566.371 b	6.726 c	7.027 c
CV (%)	1.434	1.221	4.452	4.033

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 150: Effect of variety on consumptive use of water and water use efficiency of wheat

Variety	Consumptive use of water (mm)		Water use efficiency (kg ha^{-1} mm^{-1})	
	2015-2016	2016-2017	2015-2016	2016-2017
V_1	399.173 a	455.567 a	8.620 a	8.800 a
V_2	442.759 a	437.654 a	8.299 a	8.266 a
CV (%)	1.434	1.221	4.452	4.033

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 151: Effect of potassium on consumptive use of water and water use efficiency of wheat

Potassium	Consumptive use of water (mm)		Water use efficiency (kg ha^{-1} mm^{-1})	
	2015-2016	2016-2017	2015-2016	2016-2017
K_0	416.481 a	446.121 a	6.190 b	6.214 b
K_1	419.123 a	443.528 a	8.874 a	8.894 a
K_2	426.031 a	449.067 a	9.559 a	9.577 a
K_3	422.231 a	447.727 a	9.215 a	9.236 a
CV (%)	1.434	1.221	4.452	4.033

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 152: Interaction effect of irrigation and potassium on consumptive use of water and water use efficiency of wheat

Interaction (irrigation x potassium)	Consumptive use of water (mm)		Water use efficiency (kg ha^{-1} mm^{-1})	
	2015-2016	2016-2017	2015-2016	2016-2017
$I_0 K_0$	221.022 d	233.072 d	12.136 a	13.369 a
$I_0 K_1$	220.989 d	238.405 d	9.024 ef	9.435 fg
$I_0 K_2$	223.659 d	233.393 d	10.408 c	10.120 c
$I_0 K_3$	220.876 d	243.100 d	11.726 b	11.471 b
$I_1 K_0$	345.989 c	382.187 c	6.319 k	6.315 k
$I_1 K_1$	361.121 c	382.869 c	8.306 h	8.237 h
$I_1 K_2$	359.451 c	384.304 c	9.053 ef	8.986 ef
$I_1 K_3$	356.784 c	385.421 c	8.666 g	8.662 g
$I_2 K_0$	490.679 b	513.976 b	5.225 l	5.242 l
$I_2 K_1$	481.533 b	513.139 b	8.783 fg	8.768 fg
$I_2 K_2$	621.933 a	653.094 a	4.443 m	4.478 m
$I_2 K_3$	479.987 b	514.865 b	9.548 d	9.579 d
$I_3 K_0$	490.012 b	514.110 b	9.146 e	9.108 e
$I_3 K_1$	620.674 a	652.185 a	7.250 j	7.307 j
$I_3 K_2$	619.644 a	650.410 a	7.751 i	7.812 i
$I_3 K_3$	621.110 a	651.235 a	7.574 i	7.634 i
CV (%)	1.434	1.221	4.452	4.033

In a column, means followed by different letter(s) differed significantly by Tukey's test at $P \leq 5\%$ level of probability.

4.11 Potassium content

4.11.1 Potassium content in grain

Irrigation regimes significantly influenced the potassium content (%) in grain in both the growing seasons are presented in Table 153A for first year (2015-2016) and in Table 153B for second year (2016-2017) respectively. The highest potassium content (%) in grain was recorded in I_2 followed by I_3 and I_1 and the lowest value was found in I_0 (control) in both the years. Similar result was observed in wheat by Shah *et al*. 2017.

All the treatments received foliar spraying showed better performance on potassium content (%) in grain than control (K_0) during the two successive growing seasons are presented in Table 154A for first year (2015-2016) and in Table 154B for second year (2016-2017) respectively. In the presented study, significantly highest potassium content (%) in grain was recorded in K_2 followed by K_3 and K_1 and the lowest potassium content (%) was found in control (K_0) in both the years. Similar results were also reported by Shah *et al*., 2017 who noticed that foliar feeding of 2% potassium (K) at three various growth phases was effective in increasing potassium content of wheat.

Potassium content (%) in grain was not significant due to variety in both the years are given in Table 155A for first year (2015-2016) and in Table 155B for second year (2016-2017) respectively. Between the two varieties, BARI Gom 28 exibited higher potassium content (%) than BARI Gom 27 in grain in both the growing seasons.

The interaction effect of irrigation and potassium was significant for potassium content (%) in grain in both the years are given in Table 156A for first year (2015-2016) and in Table 156B for second year (2016-2017) respectively. The highest potassium content (%) was recorded in I_3K_2 which was statistically identical to I_3K_3 and the lowest value was found in I_0K_0 in both the growing seasons.

4.11.2 Potassium content in straw

The irrigation regimes exhibited significant influence on potassium content (%) in straw during the two successive growing seasons are presented in Table 153A for first year (2015-2016) and in

Table 153B for second year (2016-2017) respectively. The highest amount of potassium content (%) in straw was recorded in I_2 which was statistically similar with I_3 and the lowest value was observed in I_0 in both the years.

There was no significant effect on potassium content (%) in straw in wheat varieties in both the years are shown in Table 154A for first year (2015-2016) and in Table 154B for second year (2016-2017) respectively. Between the two varieties, BARI Gom 28 had higher potassium content (%) than BARI Gom 27 in straw in both the growing seasons.

Potassium content (%) in wheat straw was significantly influenced by foliar applications of potassium in both the years are presented in Table 155A for first year (2015-2016) and in Table 155B for second year (2016-2017) respectively. The highest potassium percentage in straw was observed in K_2 which was statistically similar with K_3 and K_1 and the lowest value was found in control (K_0) in both the years.

Interaction effect of irrigation and potassium had significant influence on potassium content (%) in straw in both the growing seasons and are given in Table156A for first year (2015-2016) and in Table 156B for second year (2016-2017) respectively. The highest potassium content (%) in straw was recorded in I_2K_2 during the two successive growing seasons which was at par with I_2K_3 in the first year of experiment and the lowest value was found in I_0K_0 in both the growing seasons.

Table 153: Effect of irrigation regimes on potassium content on grain and straw of wheat

Irrigation	A. 2015-2016		B. 2016-2017	
	Potassium content in grain (%)	Potassium content in straw (%)	Potassium content in grain (%)	Potassium content in straw (%)
I_0	0.3643 d	1.861 d	0.3729 d	1.780 d
I_1	0.5096 c	2.205 c	0.5392 c	2.205 c
I_2	0.6913 a	2.380 a	0.7367 a	2.404 a
I_3	0.6017 b	2.318 b	0.5708 b	2.299 b
CV (%)	5.83	2.50	1.80	2.91

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 154: Effect of potassium treatments on potassium content on grain and straw of wheat

Potassium	A. 2015-2016		B. 2016-2017	
	Potassium content in grain (%)	Potassium content in straw (%)	Potassium content in grain (%)	Potassium content in straw (%)
K_0	0.4693 d	2.049 d	0.4767 d	1.997 d
K_1	0.5175 c	2.140 c	0.5275 c	2.106 c
K_2	0.6108 a	2.339 a	0.6371 a	2.368 a
K_3	0.5692 b	2.236 b	0.5783 b	2.218 b
CV (%)	5.83	2.50	1.80	2.91

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 155: Effect of variety on potassium content on grain and straw of wheat

Variety	A. 2015-2016		B. 2016-2017	
	Potassium content in grain (%)	Potassium content in straw (%)	Potassium content in grain (%)	Potassium content in straw (%)
V_1	0.538 b	2.190 a	0.550 b	2.170 a
V_2	0.546 a	2.191 a	0.560 a	2.180 a
CV (%)	5.83	2.50	1.80	2.91

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

Table 156: Interaction effect of irrigation and potassium on grain and straw of wheat

Interaction (irrigation x potassium)	A. 2015-2016		B. 2016-2017	
	Potassium content in grain (%)	Potassium content in straw (%)	Potassium content in grain (%)	Potassium content in straw (%)
$I_0 K_0$	0.2505 j	1.705 k	0.2750 l	1.497 l
$I_0 K_1$	0.318 i	1.72 k	0.3417 k	1.648 k
$I_0 K_2$	0.4583 gh	2.127 h	0.4517 i	2.155 h
$I_0 K_3$	0.4300 h	1.885 j	0.4233 j	1.822 j
$I_1 K_0$	0.4400 h	2.008 i	0.4533 i	2.008 i
$I_1 K_1$	0.4883 fg	2.192 gh	0.5067 h	2.157 h
$I_1 K_2$	0.5983 d	2.345 cd	0.6550 e	2.363 d
$I_1 K_3$	0.5117 ef	2.283 def	0.5417 g	2.292 ef
$I_2 K_0$	0.6433 bc	2.272 ef	0.6767 d	2.283 ef
$I_2 K_1$	0.6700 b	2.478 a	0.7300 c	2.370 cd
$I_2 K_2$	0.7433 a	2.345 cd	0.7867 a	2.523 a
$I_2 K_3$	0.7083 a	2.427 ab	0.7533 b	2.440 b
$I_3 K_0$	0.5433 e	2.222 fg	0.5017 h	2.198 gh
$I_3 K_1$	0.5933 d	2.297 de	0.5317 g	2.248 fg
$I_3 K_2$	0.6433 bc	2.407 bc	0.6550 e	2.432 bc
$I_3 K_3$	0.6267 cd	2.348 cd	0.5950 f	2.319 de
CV (%)	5.83	2.50	1.80	2.91

In a column, means followed by different letter(s) differed significantly by Tukey's test at P ≤ 5% level of probability.

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was conducted at the research farm and laboratory of Crop Physiology and Ecology Department, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh in 2015 - 2016 and 2016 - 2017 to study the morpho-physiological parameters, phenological stages, water relations, chlorophyll content, proline accumulation, growth parameters, potassium content, yield and yield contributing characters of wheat. Four levels of irrigations (i) I_0 - No irrigation (control) (ii) I_1 - Irrigation with 3200 $m^3 ha^{-1}$ water (iii) I_2 - Irrigation with 3800 $m^3 ha^{-1}$ water and (iv) I_3 - Irrigation with 4400 $m^3 ha^{-1}$ water and four levels of potassium were (i) K_0- The recommended rate for the variety i.e. 50 kg K ha^1 in the form of muriate of potash (control) (ii) K_1-50% of the recommended rate for the variety i.e. 25 kg K ha^1 in the form of muriate of potash + Foliar spray with 1% K_2O using K_2SO_4 (iii) K_2-50% of the recommended rate for the variety i.e. 25 kg K ha^1 in the form of muriate of potash + Foliar spray with 2% K_2O using K_2SO_4 and (iv) K_3-50% of the recommended rate for the variety i.e. 25 kg K ha^1 in the form of muriate of potash + Foliar spray with 3% K_2O using K_2SO_4. Two wheat varieties, namely, BARI Gom 27 and BARI Gom 28 were tested for the above mentioned parameters. The experiment was laid out in a split-split plot design with 3 replications.

Irrigation treatments had significant effect on all growth parameters in both the years. Irrigation with 3800 $m^3 ha^{-1}$ produced the highest plant height, tillers $plant^{-1}$, total dry matter, leaf area index, crop growth rate, net assimilation rate, relative leaf growth rate and leaf weight ratio which was statistically similar with 4400 $m^3 ha^{-1}$ in most of the growth parameters and the lowest values was observed in rain-fed condition in both the growing seasons. Relative growth rate fluctuated due to irrigations. At every stages of plant growth, the highest leaf area ratio and specific leaf area were observed in rain-fed crop. With some exceptions, varieties had no significant effect on all growth parameters in both the years. Growth parameters were significantly influenced by foliar applications of potassium in both the growing seasons. Among the potassium treatments, K_2 (50% of the recommended rate for the variety i.e. 25 kg K ha^1 in the form of muriate of potash + Foliar spray with 2% K_2O using K_2SO_4) gave the highest plant height, tillers $plant^{-1}$, TDM, LAI, CGR, NAR and RLGR in both the years which was statistically similar with K_3 (50% of the

recommended rate for the variety i.e. 25 kg K ha^1 in the form of muriate of potash + Foliar spray with 3% K_2O using K_2SO_4 in many cases. The highest LWR were observed in control. RGR, LAR and SLA fluctuated due to foliar applications of potassium. In every case plants growing with foliar application of potassium produced higher LAR and SLA than control.

Amount of irrigations showed significant effect on days needed to reach different phenological stages in both the years. The plants grown with 3800 $m^3 ha^{-1}$ irrigation needed the highest days for booting, heading, anthesis and physiological maturity which was statistically similar with 3800 m^3 ha^{-1} in both the years. The rain-fed plants needed the lowest days for attaining different phenological stages. Varieties had no significant effects on days needed for different phenological stages. Days needed for different phenological stages were significant due to foliar applications of potassium in both the years. In every casees, the number of days required for attaining different phenological stages was higher for foliar application of potassium than over the control. The more days were required for different phenological stages in K_2 condition followed by K_3 and less days were required in rain fed condition (no irrigation).

During booting, heading, anthesis and at physiological maturity, the highest plant height, leaf dry weight, stem dry weight, spike dry weight, total dry weight and leaf area were observed when plants were irrigated with 3800 $m^3 ha^{-1}$ which was statistically at par with 4400 $m^3 ha^{-1}$ and the lowest values were found in rain-fed condition. With a few exceptions, plant height, leaf dry weight, stem dry weight, spike dry weight, total dry weight and leaf area were not significant due to varieties in both the years but BARI Gom 28 had higher values than BARI Gom 27. Potassium treatments had significant effect on plant height, leaf dry weight, stem dry weight, spike dry weight, total dry weight and leaf area in both the growing seasons. Among the treatments, K_2 produced the highest plant height, leaf dry weight, stem dry weight, spike dry weight, total dry weight and leaf area which was statistically similar with K_3 followed by K_1 and K_0 (control) produced the lowest values.

The highest moisture retention capacity and relative leaf water content of the flag leaf were recorded when plants were irrigated with 3800 $m^3 ha^{-1}$ followed by 4400 $m^3 ha^{-1}$ and 3200 $m^3 ha^{-1}$ and the lowest was observed in rain-fed condition. Moisture retention capacity and relative leaf

water content did not differ significantly due to varieties in both the years. The highest moisture retention capacity and relative leaf water content were recorded in K_2 which was statistically similar with K_3 and the lowest was in K_0 (control).

Irrigation treatments had significant effect on chlorophyll content and proline accumulation in both the years. The plants irrigated with 4400 m^3 ha^{-1} contained the highest chlorophyll a, chlorophyll b and total chlorophyll which were statistically similar with 4400 m^3 ha^{-1} in both the years. The highest proline accumulation was observed in rain-fed condition and the least amount of proline was accumulated in the plants irrigated with 3800 m^3 ha^{-1}. BARI Gom 28 contained higher chlorophyll and proline than BARI Gom 27. Chlorophyll and proline content varied significantly due to foliar applications of potassium in both the growing seasons. The highest chlorophyll was found in K_2 which was statistically similar with K_3 in both the years. On the other hand highest proline accumulation was recorded in control and the least amount of proline was accumulated in K_2. Chlorophyll a : b did not differ due to irrigation and potassium treatments.

The highest number of spikelets $spike^{-1}$, number of grains $spike^{-1}$, dry weight of spike, dry weight $grain^{-1}$ and grain growth rate were observed in case of plants irrigated with 3800 m^3 ha^{-1} water at different days after anthesis which was statistically identical with 4400 m^3 ha^{-1} and followed 3200 m^3 ha^{-1}. The lowest values were found in rain-fed condition. Between the two varieties, BARI Gom 28 produced higher number of spikelets $spike^{-1}$, number of grains $spike^{-1}$, dry weight of spike, dry weight $grain^{-1}$ and grain growth rate than BARI Gom 27 at different day after anthesis. In case of foliar spray of potassium, K_2 produced the highest number of splikelets $spike^{-1}$, number of grains $spike^{-1}$, dry weight of spike, dry weight of grains and grain growth rate which was statistically similar with K_3 and the control produced the lowest values.

All the yield components i.e., plant height, effective tillers $plant^{-1}$, spike length, extrusion length, fertile spikelets, 1000-grain weight, grain yield, straw yield, biological yield and harvest index were significantly influenced by different irrigations, varieties and different foliar spray of potassium. Plants irrigated with 3800 m^3 ha^{-1} water produced the highest yield parameters and also grain and straw yield which was statistically similar with 4400 m^3 ha^{-1} and the lowest values were found in rain-fed condition. BARI Gom 28 produced higher effective tillers $plant^{-1}$, yield and yield

components than BARI Gom 27 in both the growing seasons. The highest plant height, effective tillers plant^{-1}, spike length, extrusion length, fertile spikelets, 1000-grain weight, grain yield, straw yield, biological yield and harvest index were observed in K_2 which was statistically similar with K_3 in both the years. The lowest values were found in K_0 (control). Treatment combination of I_0K_1 and I_0K_2 gave higher yield contributing characters and yield of wheat than I_0K_0. Similar results were also observed in all other irrigation treatments. For this findings it was observed that faliar spray of K alleviated the averse effects of water shortage for wheat cultivation. Increasing rate of K application (K_0 to K_3) successively decreased the yield reduction due to water shortage (I_0 and I_1).

Grain yield was positively correlated with plant height, effective tillers plant^{-1}, spike length, extrusion length, fertile spikelets, 1000-grain weight, straw yield, biological yield and harvest index in both the years for irrigation and potassium treatments. On the other hand, grain yield was negatively correlated with infertile spikelets spike^{-1}.

The highest consumptive use of water was recorded in plants irrigated with 3800 m^3 ha^{-1} water and the lowest value was obtained in rain-fed condition while the highest water use efficiency was recorded in rain-fed plants followed by the plants irrigated with 3200 m^3 ha^{-1} and 3800 m^3 ha^{-1} of water. Consumptive use of water and water use efficiency did not differ significantly due to varieties in both the years. The consumptive use of water did not vary significantly due to foliar application of potassium but a little bit higher consumptive use of water was recorded in K_2 (50% of the recommended rate for the variety i.e. 25 kg K ha^1 in the form of muriate of potash + Foliar spray with 2% K_2O using K_2SO_4. The highest water use efficiency was observed in K_2 which was statistically similar with K_3 and K_1 and the lowest was recorded in control.

Irrigation had significant effect on potassium content (%) in grain and straw in both the growing seasons. The highest potassium content in grain and straw were recorded in plants irrigated with 3800 m^3 ha^{-1} water which followed by 4400 m^3 ha^{-1} and 3200 m^3 ha^{-1} and the lowest results were found in rain-fed condition. Potassium content in grain and straw did not differ significantly due to varieties in both the years. Between the two varieties, BARI Gom 28 showed superiority over BARI Gom 27. The highest potassium content in grain and straw were observed in K_2 followed by K_3 and K_1 and basal applications of potassium showed lowest values in both the growing seasons.

The interaction effect of irrigation and foliar application of potassium showed significant in most of the parameter studied with some exception. The highest value was observed in I_2K_2 and lowest value was observed in I_0K_0 in both the growing seasons. Other interactions showed moderate result.

Based on the findings of the experiments the following conclusions may be made:

1. Almost all of the growth, phenology, yield and yield contributing characters were affected by different irrigation levels and foliar applications of potassium.

2. Among the irrigation treatments, I_2 (Irrigation with 3800 m^3 ha^{-1} at tillering, booting, heading stages) was the best irrigation schedule for achieving best performance of wheat.

3. Among the different potassium applications, K_2 (50% of the recommended dose of potassium i.e. 25 kg K ha^{-1} in the form of KCl + Foliar spray with 2% K_2O using K_2SO_4) was the best method of applying K nutrient for wheat cultivation.

4. Foliar application of 2% K_2O along with 50% of recommended dose of KCl significantly reduced yield loss of wheat due to shortage of water. This package reduces the soil application of K up to 50% of its recommended dose without any yield loss of wheat.

5. Optimum irrigation amounts and foliar applications of potassium were found to be responsive to leaf biochemical characters, potassium uptake by grain and straw and water use and water use efficiency of wheat.

CHAPTER 6

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CHAPTER 7

APPENDICES

Appendix I: Characteristics of soil of the experimental site

General characters		**Description**
Location		Research field of Crop Physiology and Ecology, HSTU, Dinajpur.
AEZ		Old Himalayan Piedmont Plain (AEZ-1)
General Soil type		Non-Calcareous Brown Floodplain Soil
Parent material		Piedmont alluvium
Soil series		Ranishankail
Drainage		Moderately well drained
Flood level		Above flood level
Topography		High land
Physical characteristics		**Value**
Bulk density (g cm-3)		0.86-1.07
Sand (2-0.02mm)		60.0
Silt (0.02-0.002mm)		27.0
Clay (< 0.002mm)		13.0
Textural class		Sandy loam
pH	5.40-5.50	Moderately acidic
Organic carbon (%)	0.69	Low
Organic matter (%)	1.19	Low
Chemical characteristics	**Content**	**Interpretation**
CEC (meq/100g soil)	5.60	Low
Total N (%)	0.07	Very low
Available P (ppm)	16.75	Medium
Exchangeable K (meq/100g soil)	0.17	Medium low

Source: Analysis of initial soil samples was done in SRDI, Dinajpur, Bangladesh.

Appendix II: Monthly record of air temperature, rainfall, humidity and sunshine hour during the period from November 2015 to April 2016 and November 2016 to April 2017

(2015-2016)

Month	Air temperature monthly mean (°C)			Monthly total rainfall (mm)	Average monthly humidity (%)	Sunshine in hour day
	Maximum	Minimum	Average			
November	29.95	15.55	22.75	0	82	9.7
December	24.53	10.93	17.73	0	84	6.5
January	23.45	9.15	16.3	10	84	7.6
February	28.03	12.85	20.44	0	79	7.4
March	32.05	17.45	24.75	68	74	8.6
April	34.15	21.55	27.85	4	75	8.4
Average			21.64	Total=82	79.63	6.03

(2016-2017)

Month	Air temperature monthly mean (°C)			Monthly total rainfall(mm)	Average monthly humidity (%)	Sunshine in hour day
	Maximum	Minimum	Average			
November	30.59	16.03	23.31	0	80.83	9.3
December	26.35	12.08	19.22	7	85.10	6.4
January	24.97	9.66	17.32	4	80.90	7.4
February	28.09	12.51	20.30	0	76.71	7.8
March	28.68	15.12	21.9	97	78.16	8.5
April	31.39	19.53	25.46	107	83.20	8.6
Average			21.64	Total=215	80.82	8.0

Source: Bangladesh Wheat and Maize Research Institute, Nashipur, Dinajpur, Bangladesh.

Appendix-IIIa: Mean squire value from ANOVA for different parameters in 2015-2016

Source of variation	df	Plant height (20 DAS)	Plant height (35 DAS)	Plant height (50 DAS)	Plant height (65 DAS)	Plant height (80 DAS)	Number of leaf plant^{-1} (20 DAS)	Number of leaf plant^{-1} (35 DAS)	Number of leaf plant^{-1} (50 DAS)	Number of leaf plant^{-1} (65 DAS)	Number of leaf plant^{-1} (80 DAS)
Block	2	3.65	12.65	23.38	68.20	337.70	4.84	5.39	15.45	9.11	7.55
Irrigation (A)	3	35.34*	332.30**	2002.83**	520.06*	586.34**	25.61*	113.67**	165.62**	65.62**	32.76**
Error-1	6	3.52	2.01	24.01	28.43	12.05	3.52	2.73	38.63	5.73	7.88
Potassium (B)	3	23.36*	191.20**	1236.10**	723.49**	502.02**	18.51*	31.00**	453.32**	42.00**	45.11**
AxB	9	11.66*	1.70**	24.55*	6.92**	18.94**	11.66*	3.53**	41.72*	2.30**	0.44**
Error-2	24	4.91	10.05	19.50	33.40	47.73	5.56	2.82	17.55	0.89	3.03
Variety (C)	1	58.08*	33.41^{NS}	208.51*	114.04^{NS}	79.72^{NS}	43.08*	3.90*	158.57*	5.90*	8.22*
AxC	3	7.63^{NS}	0.21^{NS}	7.42^{NS}	2.60^{NS}	4.36^{NS}	6.63^{NS}	3.06^{NS}	5.89^{NS}	1.06^{NS}	1.09^{NS}
BxC	3	8.62^{NS}	0.03^{NS}	7.46^{NS}	0.79^{NS}	0.30^{NS}	8.62^{NS}	0.06^{NS}	9.36^{NS}	0.66^{NS}	6.33^{NS}
AxBxC	9	6.72^{NS}	0.82^{NS}	3.55^{NS}	0.82^{NS}	0.63^{NS}	5.83^{NS}	0.01^{NS}	4.61^{NS}	4.01^{NS}	41.26^{NS}
Error-3	32	7.62	9.37	17.37	32.140	43.09	4.40	2.73	9.68^{NS}	4.96	5.56

Appendix-IIIb: Mean squire value from ANOVA for different parameters in 2015-2016

Source of variation	df	Number of tillers plant^{-1} 20 DAS	Number of tillers plant^{-1} 35 DAS	Number of tillers plant^{-1} 50 DAS	Number of tillers plant^{-1} 65 DAS	Number of tillers plant^{-1} 80 DAS	Total dry matter 20 DAS	Total dry matter 35 DAS	Total dry matter 50 DAS	Total dry matter 65 DAS	Total dry matter 80 DAS
Block	2	143.22	327.32	8.87	11.45	4.17	71.02	23.77	12.08	261.01	21.60
Irrigation (A)	3	12.21**	42.39*	5.74*	534.74**	29.76**	320.89**	5.52*	236.05**	15.42*	8.02**
Error-1	6	27.21	17.01	5.22	32.04	7.34	6.77	35.81	21.44	1.29	5.98
Potassium (B)	3	0.61**	144.57*	3.83*	103.88**	27.11**	239.91**	2.20**	112.56**	3.66*	4.89**
AxB	9	10.23*	8.55*	7.99*	3.20**	0.89**	1.44**	23.67**	3.94*	16.37	8.13
Error-2	24	9.25	15.01	7.55	11.84	5.03	6.22	4.91	0.67	43.11	7.77
Variety (C)	1	2.18**	4.61**	32.76**	29.70^{NS}	6.22*	56.61*	8.03**	23.70**	4.45**	2.95**
AxC	3	0.66^{NS}	16.77^{NS}	7.88^{NS}	23.55^{NS}	0.79^{NS}	0.85^{NS}	8.34^{NS}	0.45^{NS}	15.03^{NS}	7.22^{NS}
BxC	3	45.38^{NS}	23.23^{NS}	45.11^{NS}	12.15^{NS}	5.33^{NS}	8.17^{NS}	1.92^{NS}	4.56^{NS}	11.75^{NS}	4.17^{NS}
AxBxC	9	13.06^{NS}	6.34^{NS}	9.23^{NS}	0.99^{NS}	39.66^{NS}	1.08^{NS}	21.56^{NS}	6.08^{NS}	169.31^{NS}	5.54^{NS}
Error-3	32	6.85	8.66	3.55	8.67	3.95	5.91	17.03	7.85	7.99	21.14

Appendix-IIIc: Mean squire value from ANOVA for different parameters in 2015-2016

Source of variation	df	Leaf area Index 20 DAS	Leaf area Index 35 DAS	Leaf area Index 50 DAS	Leaf area Index 65 DAS	Leaf area Index 80 DAS	CGR 20-35 DAS	CGR 35-50 DAS	CGR 50-65 DAS	CGR 65-80 DAS	RGR 20-35 DAS
Block	2	18.23	32.34	18.89	13.56	9.84	24.34	32.05	26.37	36.65	32.44
Irrigation (A)	3	13.54**	138.45**	163.77**	6.78*	5.34*	151.30**	7.88**	32.04*	189.30**	457.16**
Error-1	6	5.67	22.88	6.56	5.97	7.53	12.01	8.34	5.65	2.41	61.16
Potassium (B)	3	14.34**	194.10**	27.55**	39.22**	4.65**	158.23**	13.32**	34.65*	267.20**	8.61**
AxB	9	23.32*	34.30*	9.05**	8.78*	16.33**	18.70**	12.63**	238.30**	11.70**	0.74**
Error-2	24	6.65	18.56	15.74	23.01	122.11	11.05	21.03	16.85	32.05	5.19
Variety (C)	1	159.54**	144.09*	7.22*	20.84**	4.78**	22.67^{NS}	4.77*	51.20**	23.33^{NS}	22.36**
AxC	3	2.09^{NS}	9.78^{NS}	14.43^{NS}	5.45^{NS}	6.23^{NS}	13.67^{NS}	0.89^{NS}	22.35^{NS}	8.89^{NS}	55.31^{NS}
BxC	3	21.76^{NS}	10.54^{NS}	17.30^{NS}	21.72^{NS}	5.51^{NS}	0.67^{NS}	2.03^{NS}	21.30^{NS}	0.45^{NS}	2.45^{NS}
AxBxC	9	6.67^{NS}	7.73^{NS}	5.91^{NS}	11.55^{NS}	10.32^{NS}	14.34^{NS}	38.27^{NS}	0.79^{NS}	23.70^{NS}	30.15^{NS}
Error-3	32	6.77	43.31	12.32	6.78	6.02	5.91	9.80	3.83	9.65	0.06

Appendix-IIId: Mean squire value from ANOVA for different parameters in 2015-2016.

Source of variation	df	RGR 35-50 DAS	RGR 50-65 DAS	RGR 65-80 DAS	NAR 20-35 DAS	NAR 35-50 DAS	NAR 50-65 DAS	NAR 65-80 DAS	Leaf area ratio 20-35 DAS	Leaf area ratio 35-50 DAS	Leaf area ratio 50-65 DAS
Block	2	18.42	12.04	22.98	11.65	43.22	21.94	4.17	8.01	23.78	7.55
Irrigation (A)	3	149.45**	169.90**	281.92**	377.78**	61.02**	10.78	29.76**	6.92**	3.64*	32.76**
Error-1	6	23.78	1.44	3.44	12.51	5.84	11.34	7.34	33.40	42.23	7.88
Potassium (B)	3	956.56**	203.31**	193.35**	230.34**	150.11**	0.89**	27.11**	4.45**	2.52**	45.11**
AxB	9	24.61*	3.96*	3.56*	7.70**	7.77**	1.71**	0.89**	2.73*	38.63*	5.73*
Error-2	24	67.50	6.55	6.44	22.05	7.34	0.58	5.03	31.00	453.32	42.00
Variety (C)	1	198.51*	16.60**	23.67**	19.33^{NS}	41.04*	8.66*	6.22*	5.53**	41.72*	2.30**
AxC	3	5.42	8.61^{NS}	4.91^{NS}	0.77^{NS}	2.78^{NS}	0.29^{NS}	0.79^{NS}	2.82^{NS}	17.55^{NS}	089^{NS}
BxC	3	0.96^{NS}	5.98^{NS}	8.03^{NS}	0.83^{NS}	5.67^{NS}	5.03^{NS}	5.33^{NS}	7.90^{NS}	158.57^{NS}	5.90^{NS}
AxBxC	9	3.99^{NS}	0.88^{NS}	5.767^{NS}	0372^{NS}	0.82^{NS}	6.22^{NS}	39.66^{NS}	22.84^{NS}	3.03^{NS}	25.34^{NS}
Error-3	32	8.68	7.21	17.08	6.52	4.29	15.82	3.95	14.65	10.23	6.68

Appendix-IIIe: Mean squire value from ANOVA for different parameters in 2015-2016

Source of variation	df	Leaf area ratio 65-80 DAS	Relative Leaf growth rate 20-35 DAS	Relative Leaf growth rate 35-50 DAS	Relative Leaf growth rate 50-65 DAS	Relative Leaf growth rate 65-80 DAS	Specific Leaf Area 20-35 DAS	Specific Leaf Area 35-50 DAS	Specific Leaf Area 50-65 DAS	Specific Leaf Area 65-80 DAS	Leaf weight ratio 20-35 DAS
Block	2	6.12	7.88	11.12	14.02	3.56	0.89	0.97	23.09	22.98	3.09
Irrigation (A)	3	6.53*	5.44**	231.77**	4.34*	6.78*	5.03*	55.43**	18.45	168.92**	74.45**
Error-1	6	2.22	0.01	6.73	15.11	5.42	4.89	3.11	34.03	3.59	0.89
Potassium (B)	3	6.33**	18.25**	23.32**	3.71**	4.67**	5.02*	0.53**	24.55*	201.35**	43.00**
AxB	9	187.43**	161.77**	8.53**	5.73*	3.67**	4.92**	198.51	5.74*	3.82*	0.53**
Error-2	24	32.01	6.56	5.74	5.22	9.23	2.01	23.78	33.09	7.44	3.65
Variety (C)	1	12.65*	15.55**	5.78*	150.32*	193.35**	11.66*	8.70**	25.89*	19.67**	5.90*
AxC	3	312.30 NS	2.17 NS	1.23 NS	4.55 NS	3.64 NS	5.56 NS	12.11 NS	8.01 NS	4.45 NS	9.56 NS
BxC	3	6.01 NS	5.00 NS	7.65 NS	8.87 NS	42.23 NS	5.90 NS	8.22 NS	6.92 NS	8.77 NS	4.22 NS
AxBxC	9	73.20 NS	8.14 NS	1.91 NS	5.74 NS	2.52 NS	1.06 NS	1.09 NS	33.40 NS	5.77 NS	11.43 NS
Error-3	32	4.89	10.11	8.46	5.22	4.07	9.22	11.90	4.45	14.11	45.04

Appendix-IIIf: Mean squire value from ANOVA for different parameters in 2015-2016

Source of variation	df	Leaf weight ratio 35-50 DAS	Leaf weight ratio 50-65 DAS	Leaf weight ratio 65-80 DAS	Moisture retention capacity 8:30	Moisture retention capacity 9:30	Moisture retention capacity 10:30	Moisture retention capacity 11:30	Moisture retention capacity 01:00	Moisture retention capacity 3:30	Moisture retention capacity 5:30
Block	2	23.33	7.23	15.03	5.62	423.32	11.20	4.17	10.02	9.03	23.70
Irrigation (A)	3	172.51*	4.55**	8.78*	56.33**	42.55*	0.89**	29.76**	4.75**	19.44**	171.77**
Error-1	6	11.42	3.88	15.50	4.56	29.01	3.81	7.34	7.72	7.34	6.56
Potassium (B)	3	8.23*	20.43*	4.77*	17.22**	165.57*	11.32*	27.11**	2.60**	44.11**	19.32**
AxB	9	117.56**	1639.22**	576.33**	8.20**	8.55*	674.22**	0.89**	5.05**	0.77**	8.87**
Error-2	24	6.73	23.78	4.56	17.80	11.01	78.78	5.03	5.02	5.90	5.74
Variety (C)	1	54.32**	1155.56**	189.22**	30.34NS	2.61**	905.56**	6.22*	4.92**	6.22*	5.22*
AxC	3	0.53 NS	24.55 NS	2.20 NS	8.01 NS	17.53 NS	71.55 NS	0.79 NS	2.01 NS	3.79 NS	4.23 NS
BxC	3	198.51 NS	5.74 NS	23.67 NS	6.92 NS	31.04 NS	6.02 NS	5.33 NS	0.01 NS	5.78 NS	7.55 NS
AxBxC	9	5.42 NS	61.02 NS	4.91 NS	33.40 NS	2.78 NS	62.11 NS	39.66 NS	9.11 NS	28.48 NS	3.91 NS
Error-3	32	0.96	5.84	8.03	4.45	5.67	7.83	3.95	7.33	3.51	9.32

Appendix-IIIg: Mean squire value from ANOVA for different parameters in 2015-2016

Source of variation	df	Relative leaf water content of leaf (8:00)	Relative leaf water content of leaf (12:0)	Relative leaf water content of leaf 4:30)	Chlorophyll a (mg g^{-1})	Chlorophyll b (mg g^{-1})	Proline accumulation (µg g^{-1} fresh wt.)	Number of spikelets $spike^{-1}$ 7 DAA	Number of spikelets $spike^{-1}$ 14 DAA	Number of spikelets $spike^{-1}$ 21 DAA	Number of spikelets $spike^{-1}$ 28 DAA
Block	2	6.87	18.39	24.55	0.01	0.001	0.001	58.02	8.23	20.43	4.77
Irrigation (A)	3	98.76**	3.44*	43.50*	0.77**	0.795**	0.357**	53.77**	17.56**	19.22**	576.33**
Error-1	6	0.73	193.35	198.51	0.001	0.002	0.000	8.15	6.73	23.78	4.56
Potassium (B)	3	38.00**	0.53**	24.55*	0.61**	0.615**	0.102**	188.91**	54.32**	15.56**	189.22**
AxB	9	0.53**	198.51	5.74*	0.007*	0.035**	0.001*	1.77**	0.53**	24.55*	2.20**
Error-2	24	0.74	4.67	7.84	0.005	0.002	0.000	6.39	5.74	43.50	7.89
Variety (C)	1	5.90*	18.32*	54.78*	0.09**	0.047**	0.017**	38.61*	5.90*	198.51	33.46^{NS}
AxC	3	0.86^{NS}	6.42^{NS}	43.73^{NS}	0.002^{NS}	0.001^{NS}	0.002^{NS}	2.33^{NS}	1.06^{NS}	5.42^{NS}	4.11^{NS}
BxC	3	0.36^{NS}	3.56^{NS}	0.89^{NS}	0.001^{NS}	0.001^{NS}	0.001^{NS}	3.17^{NS}	7.65^{NS}	0.96^{NS}	5.72^{NS}
AxBxC	9	0.91^{NS}	6.78^{NS}	5.03^{NS}	0.000^{NS}	0.000^{NS}	0.001^{NS}	0.67^{NS}	0.91^{NS}	3.99^{NS}	6.41^{NS}
Error-3	32	4.96	7.79	11.02	0.005	0.002	0.001	2.55	3.66	15.23	9.66

Appendix-IIIh: Mean squire value from ANOVA for different parameters in 2015-2016

Source of variation	df	Number of spikelets $spike^{-1}$ 35 DAA	Number of grains $spike^{-1}$ 14 DAA	Number of grains $spike^{-1}$ 21 DAA	Number of grains $spike^{-1}$ 28 DAA	Number of grains $spike^{-1}$ 35 DAA	Dry weight of spike 14 DAA	Dry weight of spike 21 DAA	Dry weight of spike 28 DAA	Dry weight of spike 35 DAA	Dry weight $grain^{-1}$ 14 DAA
Block	2	34.71	22.98	4.17	43.02	11.74	5.20	13.34	1.44	15.42	18.49
Irrigation (A)	3	164.63**	234.92**	29.76**	341.89**	187.87**	4.34**	424.23**	112.35**	8.87**	275.30**
Error-1	6	24.01	3.44	7.34	6.92	45.01	4.67	44.01	0.94	5.74	11.78
Potassium (B)	3	542.45**	213.35**	27.11**	193.78**	291.62**	18.32*	543.32**	0.78	5.22*	67.20**
AxB	9	65.55*	3.56*	0.89**	4.67**	4.70**	784.22**	32.67*	17.70**	0.97*	7.84**
Error-2	24	56.80	6.78	5.03	3.64	9.11	23.78	20.45	210.19	9.25	54.78
Variety (C)	1	201.44*	23.67**	6.22*	42.23*	31.66^{NS}	1005.56**	188.57*	6.20**	2.09**	9.51^{NS}
AxC	3	5.99^{NS}	4.67^{NS}	0.79^{NS}	2.52^{NS}	7.78^{NS}	34.55^{NS}	8.67^{NS}	17.67^{NS}	0.72^{NS}	6.38^{NS}
BxC	3	8.09^{NS}	5.03^{NS}	5.33^{NS}	4.09^{NS}	0.87^{NS}	5.89^{NS}	4.91^{NS}	167.66^{NS}	94.77^{NS}	45.83^{NS}
AxBxC	9	4.71^{NS}	5.78^{NS}	39.66^{NS}	2.67^{NS}	5.33^{NS}	54.02^{NS}	8.77^{NS}	17.56^{NS}	6.56^{NS}	7.02^{NS}
Error-3	32	56.20	21.56	3.95	4.67	35.61	9.28	11.56	5.67	9.34	4.22

Appendix-IIIi: Mean squire value from ANOVA for different parameters in 2015-2016

Source of variation	df	Dry weight grain^{-1} 21 DAA	Dry weight grain^{-1} 28 DAA	Dry weight grain^{-1} 35 DAA	Grain growth rate 7-14 DAA	Grain growth rate 14-21 DAA	Grain growth rate 21-28 DAA	Grain growth rate 28-35 DAA	Effective tillers plant^{-1}	Spike length (cm)	Extrusion length (cm)
Block	2	9.71	12.65	8.23	43.01	5.62	9.03	8.44	0.30	6.87	58.02
Irrigation (A)	3	4.75**	312.30**	117.56**	2.77**	456.33**	7.24*	6.34*	12.16**	120.94**	410.89**
Error-1	6	7.72	6.01	6.73	7.01	4.56	0.53	24.55	0.16	0.73	6.15
Potassium (B)	3	2.60**	73.20**	54.32**	2.61**	171.22**	198.51	5.74*	13.67**	38.00**	259.91**
AxB	9	5.05**	9.70**	0.53**	0.97*	8.20**	11.70**	26.11*	0.78**	0.53**	1.67**
Error-2	24	5.02	10.78	5.74	9.25	17.80	44.01	0.94	0.11	0.74	4.64
Variety (C)	1	4.92**	56.88^{NS}	5.90*	2.09**	30.34^{NS}	18.39*	12.65*	3.36**	5.90*	48.61*
AxC	3	2.01^{NS}	4.78^{NS}	1.06^{NS}	0.72^{NS}	8.01^{NS}	3.44^{NS}	323.30^{NS}	0.31^{NS}	0.06^{NS}	0.05^{NS}
BxC	3	0.01^{NS}	1.83^{NS}	7.65^{NS}	33.71^{NS}	5.72^{NS}	193.35^{NS}	12.33^{NS}	0.39^{NS}	0.06^{NS}	0.17^{NS}
AxBxC	9	9.11^{NS}	0.82^{NS}	0.91^{NS}	3.66^{NS}	6.41^{NS}	0.53^{NS}	301.20^{NS}	0.11^{NS}	0.01^{NS}	0.37^{NS}
Error-3	32	4.02	7.45	3.66	2.85	6.49	3.55	6.54	0.06	0.96	3.80

Appendix-IIIj: Mean squire value from ANOVA for different parameters in 2015-2016

Source of variation	df	Fertile spikelets spike^{-1}	Infertile spikelets spike^{-1}	1000-grain weight (g)	Grain yield (kg ha^{-1})	Biological yield (kgha^{-1})	Harvest index	Consumptive use of water	Water use efficiency	Potassium content in grain (%)	Potassium content in straw (%)
Block	2	18.98	0.17	1.63	0.01	0.97	2.92	9.74	19.67	0.53	5.99
Irrigation (A)	3	307.92**	41.76**	677.89**	19.67**	73.43**	28.45*	266.31**	564.23**	7.74*	8.09**
Error-1	6	1.44	0.12	8.75	0.17	0.11	3.52	2.01	24.01	12.90	4.71
Potassium (B)	3	112.35**	13.34**	207.30**	5.80**	29.49**	18.51*	230.74**	623.32**	2.06**	5.01*
AxB	9	0.94*	0.36**	2.20**	0.14*	0.34**	11.66*	8.70**	32.55*	14.11	63.20**
Error-2	24	0.78	0.03	8.84	0.11	0.46	5.56	12.11	20.01	216.30	9.45
Variety (C)	1	17.70**	1.22*	30.66^{NS}	0.81**	3.80**	43.08*	29.45^{NS}	197.57*	13.01*	12.78*
AxC	3	0.11^{NS}	0.06^{NS}	0.15^{NS}	0.022^{NS}	0.07^{NS}	6.63^{NS}	0.65^{NS}	8.47^{NS}	33.20^{NS}	3.64^{NS}
BxC	3	0.22^{NS}	0.03^{NS}	0.05^{NS}	0.004^{NS}	0.03^{NS}	8.62^{NS}	0.03^{NS}	7.91^{NS}	8.70^{NS}	42.23^{NS}
AxBxC	9	0.08^{NS}	0.03^{NS}	0.41^{NS}	0.009^{NS}	0.03^{NS}	5.83^{NS}	0.72^{NS}	4.61^{NS}	12.78^{NS}	2.52^{NS}
Error-3	32	0.85	0.10	10.40	0.06	0.21	6.55	8.86	13.53	22.07	8.84

Appendix-IVa: Mean squire value from ANOVA for different parameters in 2016-2017

Source of variation	df	Plant height (20 DAS)	Plant height (35 DAS)	Plant height (50 DAS)	Plant height (65 DAS)	Plant height (80 DAS)	Number of leaf plant^{-1} (20 DAS)	Number of leaf plant^{-1} (35 DAS)	Number of leaf plant^{-1} (50 DAS)	Number of leaf plant^{-1} (65 DAS)	Number of leaf plant^{-1} (80 DAS)
Block	2	3.95	24.02	60.12	92.37	112.52	5.12	11.49	12.40	11.09	4.62
Irrigation (A)	3	38.87*	549.53**	2024.49**	841.58*	1962.26*	33.23*	183.19**	159.63**	46.34**	43.55**
Error-1	6	3.96	7.96	39.35	56.29	55.37	4.11	12.67	21.52	7.82	10.91
Potassium (B)	3	24.97*	298.83**	1303.58**	941.29**	774.79**	15.50*	21.08**	328.51**	63.10**	60.11**
AxB	9	11.74*	5.33**	31.01*	4.98**	10.76**	9.29*	4.67**	5.49*	10.63**	1.56**
Error-2	24	4.78	16.78	22.29	39.53	55.94	7.02	5.56	23.89	0.99	3.98
Variety (C)	1	59.95*	65.94*	240.22*	163.80^{NS}	122.67^{NS}	64.44*	34.81*	138.67	7.78*	7.84*
AxC	3	6.65^{NS}	0.88^{NS}	7.23^{NS}	0.29^{NS}	1.02^{NS}	0.97^{NS}	21.32^{NS}	6.65^{NS}	11.06^{NS}	11.09^{NS}
BxC	3	8.03^{NS}	0.52^{NS}	3.27^{NS}	0.03^{NS}	1.50^{NS}	16.45^{NS}	6.05^{NS}	6.22^{NS}	3.45^{NS}	6.78^{NS}
AxBxC	9	6.69^{NS}	1.29^{NS}	2.95^{NS}	2.17^{NS}	1.34^{NS}	6.34^{NS}	0.95^{NS}	12.61^{NS}	8.72^{NS}	5.85^{NS}
Error-3	32	6.44	8.73	28.42	41.34	65.11	6.74	4.66	7.08	6.03	7.02

Appendix-IVb: Mean squire value from ANOVA for different parameters in 2016-2017

Source of variation	df	Number of tillers plant^{-1} 20 DAS	Number of tillers plant^{-1} 35 DAS	Number of tillers plant^{-1} 50 DAS	Number of tillers plant^{-1} 65 DAS	Number of tillers plant^{-1} 80 DAS	Total dry matter 20 DAS	Total dry matter 35 DAS	Total dry matter 50 DAS	Total dry matter 65 DAS	Total dry matter 80 DAS
Block	2	34.85	110.82	107.01	18.80	67.74	89.00	43.67	44.05	85.33	56.67
Irrigation (A)	3	112.67**	17.56*	29.43*	328.51**	42.46**	281.42**	19.89*	288.11**	23.45*	19.56*
Error-1	6	34.73	4.92	6.20	45.04	5.56	4.49	23.53	21.66	1.99	9.02
Potassium (B)	3	0.45**	95.35*	3.95*	211.57**	34.14**	156.98**	2.56**	102.02**	13.62*	14.56**
AxB	9	9.56*	9.83*	3.78*	7.22**	0.67**	11.44**	23.45**	3.74*	32.04	7.87
Error-2	24	4.89	21.68	7.50	45.67	5.78	8.78	14.56	10.05	32.45	14.70
Variety (C)	1	2.88**	7.43**	43.71**	34.71^{NS}	16.92*	44.61*	6.44**	13.85**	14.00**	43.04**
AxC	3	0.56^{NS}	13.50^{NS}	3.99^{NS}	34.29^{NS}	0.45^{NS}	10.65^{NS}	16.34^{NS}	0.88^{NS}	21.89^{NS}	5.71^{NS}
BxC	3	34.22^{NS}	33.32^{NS}	63.56^{NS}	27.15^{NS}	9.05^{NS}	5.34^{NS}	1.78^{NS}	14.34^{NS}	11.01^{NS}	14.94^{NS}
AxBxC	9	10.01^{NS}	7.72^{NS}	21.07^{NS}	0.73^{NS}	32.45^{NS}	0.98^{NS}	32.72^{NS}	6.78^{NS}	17.78^{NS}	7.34^{NS}
Error-3	32	5.07	6.45	3.55	7.88	9.49	9.76	7.54	11.02	7.564	15.12

Appendix-IVc: Mean squire value from ANOVA for different parameters in 2016-2017

Source of variation	df	Leaf area Index 20 DAS	Leaf area Index 35 DAS	Leaf area Index 50 DAS	Leaf area Index 65 DAS	Leaf area Index 80 DAS	CGR 20-35 DAS	CGR 35-50 DAS	CGR 50-65 DAS	CGR 65-80 DAS	RGR 20-35 DAS
Block	2	8.49	29.71	29.70	3.56	0.89	34.65	43.05	45.21	9.65	32.30
Irrigation (A)	3	3.02**	194.66**	161.77**	6.78*	5.03*	195.30**	14.76**	14.04*	198.30**	435.16**
Error-1	6	5.67	32.01	6.56	0.97	6.53	2.01	6.34	5.52	12.01	74.16
Potassium (B)	3	4.34**	923.10**	22.32**	50.22**	4.22**	239.87**	17.32**	17.65	121.20**	18.61**
AxB	9	3.09*	56.55*	8.87**	8.31*	6.33**	8.70**	2.63**	239.30**	11.70**	4.74**
Error-2	24	7.43	20.80	5.74	28.56	145.11	10.05	15.03	15.01	9.21	11.19
Variety (C)	1	161.29**	194.67*	5.22*	0.84**	4.54**	33.67^{NS}	6.77*	32.33**	39.38^{NS}	13.36**
AxC	3	2.09^{NS}	9.42^{NS}	4.56^{NS}	5.78^{NS}	9.23^{NS}	3.21^{NS}	0.09^{NS}	23.15^{NS}	5.21^{NS}	39.31^{NS}
BxC	3	32.23^{NS}	8.67^{NS}	7.55^{NS}	13.72^{NS}	5.66^{NS}	4.67^{NS}	2.33^{NS}	16.28^{NS}	2.67^{NS}	0.45^{NS}
AxBxC	9	2.32^{NS}	4.71^{NS}	5.91^{NS}	11.01^{NS}	9.63^{NS}	4.82^{NS}	28.66^{NS}	0.89^{NS}	21.23^{NS}	22.15^{NS}
Error-3	32	7.82	56.20	8.32	6.93	4.02	7.91	7.80	2.83	10.01	6.06

Appendix-IVd: Mean squire value from ANOVA for different parameters in 2016-2017

Source of variation	df	RGR 35-50 DAS	RGR 50-65 DAS	RGR 65-80 DAS	NAR 20-35 DAS	NAR 35-50 DAS	NAR 50-65 DAS	NAR 65-80 DAS	Leaf area ratio 20-35 DAS	Leaf area ratio 35-50 DAS	Leaf area ratio 50-65 DAS
Block	2	23.67	6.22	42.23	31.66	1005.56	188.57	6.20	2.09	9.51	201.44
Irrigation (A)	3	213.35**	27.11**	193.78**	291.62**	18.32*	543.32**	0.78*	5.22*	67.20**	542.45**
Error-1	6	3.44	7.34	6.92	45.01	4.67	44.01	0.94	5.74	11.78	24.01
Potassium (B)	3	5.03**	5.33**	4.09**	0.87**	5.89*	4.91**	167.66**	94.77**	45.83**	8.09**
AxB	9	3.56*	0.89**	4.67**	4.70**	784.22**	32.67*	17.70**	0.97*	7.84**	65.55*
Error-2	24	22.98	4.17	43.02	11.74	5.20	13.34	1.44	15.42	18.49	34.71
Variety (C)	1	234.92**	29.76**	341.89**	187.87**	4.34**	424.23**	112.35**	8.87**	275.30**	164.63**
AxC	3	4.67^{NS}	0.79^{NS}	2.52^{NS}	7.78^{NS}	34.55^{NS}	8.67^{NS}	17.67^{NS}	0.72^{NS}	6.38^{NS}	5.99^{NS}
BxC	3	6.78^{NS}	5.03^{NS}	3.64^{NS}	9.11^{NS}	23.78^{NS}	20.45^{NS}	210.19^{NS}	9.25^{NS}	54.78^{NS}	56.80^{NS}
AxBxC	9	5.78^{NS}	39.66^{NS}	2.67^{NS}	5.33^{NS}	54.02^{NS}	8.77^{NS}	17.56^{NS}	6.56^{NS}	7.02^{NS}	4.71^{NS}
Error-3	32	21.56	3.95	4.67	35.61	9.28	11.56	5.67	9.34	4.22	56.20

Appendix-IVe: Mean squire value from ANOVA for different parameters in 2016-2017

Source of variation	df	Leaf area ratio 65-80 DAS	Relative Leaf growth rate 20-35 DAS	Relative Leaf growth rate 35-50 DAS	Relative Leaf growth rate 50-65 DAS	Relative Leaf growth rate 65-80 DAS	Specific Leaf Area 20-35 DAS	Specific Leaf Area 35-50 DAS	Specific Leaf Area 50-65 DAS	Specific Leaf Area 65-80 DAS	Leaf weight ratio 20-35 DAS
Block	2	12.60	73.20	54.32	32.61	202.22	175.51	5.74	20.59	47.66	296.64
Irrigation (A)	3	4.75**	312.30**	117.56**	2.77**	277.33**	7.24*	6.34*	20.62**	210.15**	327.44**
Error-1	6	2.01	4.78	1.06	0.72	8.01	3.44	103.30	0.27	0.17	0.30
Potassium (B)	3	0.01*	1.83**	7.65**	33.71**	5.72**	201.35**	12.33	0.39*	0.20**	0.64**
AxB	9	9.11**	0.82**	0.91**	3.66**	6.41**	0.53**	239.20**	0.05**	0.06**	0.27**
Error-2	24	5.05	9.70	0.53	0.97	8.20	11.70	26.11	0.58	0.40	3.60
Variety (C)	1	5.02*	10.78*	5.74*	9.25*	17.80*	44.01*	0.94*	0.12*	0.73*	4.98*
AxC	3	7.72 NS	6.01 NS	6.73 NS	7.01 NS	4.56 NS	0.53 NS	24.55 NS	0.17 NS	1.29 NS	8.52 NS
BxC	3	4.02 NS	7.45 NS	3.66 NS	2.85 NS	6.49 NS	3.55 NS	6.88 NS	0.14 NS	1.38 NS	5.15 NS
AxBxC	9	4.63 NS	56.67NS	5.90 NS	2.09 NS	30.56NS	18.39 NS	12.65 NS	4.91 NS	9.95 NS	41.41 NS
Error-3	32	9.71	12.65	8.23	43.01	5.62	9.03	8.44	0.27	8.54	40.36

Appendix-IVf: Mean squire value from ANOVA for different parameters in 2016-2017

Source of variation	df	Leaf weight ratio 35-50 DAS	Leaf weight ratio 50-65 DAS	Leaf weight ratio 65-80 DAS	Moisture retention capacity 8:30	Moisture retention capacity 9:30	Moisture retention capacity 10:30	Moisture retention capacity11:30	Moisture retention capacity 01:00	Moisture retention capacity 3:30	Moisture retention capacity 5:30
Block	2	77.69	65.94	240.22	163.80	122.67	64.44	34.81	138.67	7.78	7.84
Irrigation (A)	3	14.87*	173.83**	967.58**	563.29**	321.79**	15.50*	21.08**	311.51**	63.10**	60.11**
Error-1	6	6.44	8.73	28.42	41.34	65.11	6.74	4.66	7.08	6.03	7.02
Potassium (B)	3	8.03*	0.52**	3.27**	0.03**	1.50**	16.45*	6.05**	6.22**	3.45**	6.78**
AxB	9	6.69*	1.29**	2.95**	2.17**	1.34**	6.34*	0.95**	12.61**	8.72**	5.85
Error-2	24	4.78	16.78	22.29	39.53	55.94	7.02	5.56	23.89	0.99	3.98
Variety (C)	1	6.65*	0.88**	7.23**	0.29**	1.02**	0.97*	21.32**	6.65*	11.06**	11.09**
AxC	3	38.87 NS	723.53 NS	104.49 NS	541.58 NS	138.26 NS	33.23 NS	183.19 NS	209.63 NS	46.34 NS	43.55 NS
BxC	3	11.74 NS	5.33 NS	31.01 NS	4.98 NS	10.76 NS	9.29 NS	4.67 NS	5.49 NS	10.63 NS	1.56 NS
AxBxC	9	3.96 NS	7.96 NS	39.35 NS	56.29 NS	55.37 NS	4.11 NS	12.67 NS	21.52 NS	7.82 NS	10.91 NS
Error-3	32	7.95	21.02	4.12	29.37	30.52	5.12	11.49	6.40	11.09	5.62

Appendix-IVg: Mean squire value from ANOVA for different parameters in 2016-2017

Source of variation	df	Relative leaf water content of leaf (8:00)	Relative leaf water content of leaf (12:0)	Relative leaf water content of leaf 4:30)	Chlorophyll a (mg g^{-1})	Chlorophyll b (mg g^{-1})	Proline accumulation (µg g^{-1} fresh wt.)	Number of spikelets $spike^{-1}$ 7 DAA	Number of spikelets $spike^{-1}$ 14 DAA	Number of spikelets $spike^{-1}$ 21 DAA	Number of spikelets $spike^{-1}$ 28 DAA
Block	2	16.04	18.39	23.55	0.01	0.001	0.002	58.02	8.23	20.43	4.77
Irrigation (A)	3	65.76**	3.44*	32.99*	1.09**	1.10**	0.543**	43.77**	99.56**	682.22**	553.33**
Error-1	6	20.73	231.78	205.51	0.003	0.001	0.002	8.15	6.73	23.78	4.56
Potassium (B)	3	26.55**	6.53**	24.59*	0.64**	0.538**	0.144**	156.91**	54.32**	731.56**	220.56**
AxB	9	3.53**	204.51*	15.74*	0.008*	0.014**	0.003*	1.77**	0.53**	24.55*	2.20**
Error-2	24	0.89	4.88	7.04	0.004	0.002	0.001	6.39	5.74	43.50	7.89
Variety (C)	1	15.95*	14.32*	37.78 *	0.12**	0.095**	0.018**	38.61*	5.90*	281.51*	64.46^{NS}
AxC	3	5.86^{NS}	6.90^{NS}	43.73^{NS}	0.06^{NS}	0.003^{NS}	0.001^{NS}	2.33^{NS}	1.06^{NS}	15.42^{NS}	24.11^{NS}
BxC	3	0.06^{NS}	3.02^{NS}	0.39^{NS}	0.001^{NS}	0.001^{NS}	0.078^{NS}	3.17^{NS}	7.65^{NS}	0.96^{NS}	4.72^{NS}
AxBxC	9	1.66^{NS}	3.78^{NS}	6.66^{NS}	0.001^{NS}	0.001^{NS}	0.09^{NS}	0.67^{NS}	0.91^{NS}	3.99^{NS}	6.41^{NS}
Error-3	32	3.08	5.32	9.02	0.003	0.002	0.001	2.55	3.66	7.23	4.66

Appendix-IVh: Mean squire value from ANOVA for different parameters in 2016-2017

Source of variation	df	Number of spikelets $spike^{-1}$ 35 DAA	Number of grains $spike^{-1}$ 14 DAA	Number of grains $spike^{-1}$ 21 DAA	Number of grains $spike^{-1}$ 28 DAA	Number of grains $spike^{-1}$ 35 DAA	Dry weight of spike 14 DAA	Dry weight of spike 21 DAA	Dry weight of spike 28 DAA	Dry weight of spike 35 DAA	Dry weight $grain^{-1}$ 14 DAA
Block	2	34.71	22.98	4.17	43.02	11.74	5.20	13.34	1.44	15.42	18.49
Irrigation (A)	3	164.63**	234.92**	29.76**	341.89**	187.87**	4.34**	424.23**	112.35**	8.87**	275.30**
Error-1	6	24.01	3.44	7.34	6.92	45.01	4.67	44.01	0.94^{NS}	5.74*	11.78*
Potassium (B)	3	542.45**	213.35**	27.11**	193.78**	291.62**	18.32	543.32**	0.78	5.22*	67.20**
AxB	9	65.55*	3.56*	0.89**	4.67**	4.70**	784.22**	32.67*	17.70**	0.97*	7.84**
Error-2	24	56.80	6.78	5.03	3.64	9.11	23.78	20.45	210.19	9.25	54.78
Variety (C)	1	201.44*	23.67**	6.22*	42.23*	31.66^{NS}	1005.56**	188.57*	6.20**	2.09**	9.51^{NS}
AxC	3	5.99^{NS}	4.67^{NS}	0.79^{NS}	2.52^{NS}	7.78^{NS}	34.55^{NS}	8.67^{NS}	17.67^{NS}	0.72^{NS}	6.38^{NS}
BxC	3	8.09^{NS}	5.03^{NS}	5.33^{NS}	4.09^{NS}	0.87^{NS}	5.89^{NS}	4.91^{NS}	167.66^{NS}	94.77^{NS}	45.83^{NS}
AxBxC	9	4.71^{NS}	5.78^{NS}	39.66^{NS}	2.67^{NS}	5.33^{NS}	54.02^{NS}	8.77^{NS}	17.56^{NS}	6.56^{NS}	7.02^{NS}
Error-3	32	56.20	21.56	3.95	4.67	35.61	9.28	11.56	5.67	9.34	4.22

Appendix-IVi: Mean squire value from ANOVA for different parameters in 2016-2017

Source of variation	df	Dry weight grain^{-1} 21 DAA	Dry weight grain^{-1} 28 DAA	Dry weight grain^{-1} 35 DAA	Grain growth rate 7-14 DAA	Grain growth rate 14-21 DAA	Grain growth rate 21-28 DAA	Grain growth rate 28-35 DAA	Effective tillers plant^{-1}	Spike length (cm)	Extrusion length (cm)
Block	2	7.78	73.20	31.66	12.40	15.67	34.85	11.44	0.27	8.54	40.36
Irrigation (A)	3	63.10**	312.30**	291.62**	159.63**	231.33**	112.67**	6.34*	20.62**	133.15**	439.44**
Error-1	6	6.03	4.78	45.01	21.52	24.56	34.73	32.55	0.17	1.29	8.52
Potassium (B)	3	3.45**	1.83**	0.87**	328.51**	241.22**	0.45**	15.74*	20.59**	47.66**	296.64**
AxB	9	8.72**	0.82**	4.70**	5.49*	5.20**	9.56*	16.11*	0.58*	0.40**	3.60**
Error-2	24	0.99	9.70	11.74	23.89	14.80	4.89	10.94	0.12	0.73	4.98
Variety (C)	1	11.06**	10.78*	187.87**	138.67*	28.55^{NS}	2.88**	12.65*	4.91**	9.95*	41.41*
AxC	3	46.34^{NS}	6.01^{NS}	7.78^{NS}	6.65^{NS}	8.81^{NS}	0.56^{NS}	272.30^{NS}	0.27^{NS}	0.17^{NS}	0.30^{NS}
BxC	3	10.63^{NS}	7.45^{NS}	9.11^{NS}	6.22^{NS}	15.72^{NS}	34.22^{NS}	9.33^{NS}	0.39^{NS}	0.20^{NS}	0.64^{NS}
AxBxC	9	7.82^{NS}	56.67$^{NS\ NS}$	5.33^{NS}	12.61^{NS}	5.41^{NS}	10.01^{NS}	299.20^{NS}	0.05^{NS}	0.06^{NS}	0.27^{NS}
Error-3	32	11.09	12.65	35.61	7.08	9.49	5.07	8.54	0.14	1.38	5.15

Appendix-IVj: Mean squire value from ANOVA for different parameters in 2016-2017

Source of variation	df	Fertile spikelets spike^{-1}	Infertile spikelets spike^{-1}	1000-grain weight (g)	Grain yield (kg ha^{-1})	Biological yield (kgha^{-1})	Harvest index	Consumptive use of water	Water use efficiency	Potassium content in grain (%)	Potassium content in straw (%)
Block	2	28.33	0.07	0.85	0.08	2.39	11.66	8.70	25.89	19.67	5.90
Irrigation (A)	3	319.52**	53.77**	770.52**	27.34**	97.34**	4.92**	198.51*	5.74*	3.82*	0.53**
Error-1	6	1.23	0.08	10.58	0.09	0.39	5.90	8.22	6.92	8.77	4.22
Potassium (B)	3	137.53**	17.70**	299.62**	8.63**	38.65**	9.22*	11.90*	4.45**	14.11*	45.04*
AxB	9	0.64**	0.19*	2.64**	0.23*	0.45**	1.06**	1.09**	33.40*	5.77*	11.43**
Error-2	24	1.33	0.09	8.50	0.17	0.85	5.03	55.43	18.45	168.92	74.45
Variety (C)	1	27.65**	1.82**	51.16*	1.33*	6.60*	4.89*	3.11*	34.03*	3.59*	0.89*
AxC	3	0.42^{NS}	0.08^{NS}	0.65^{NS}	0.02^{NS}	0.04^{NS}	5.56^{NS}	12.11^{NS}	8.01^{NS}	4.45^{NS}	9.56^{NS}
BxC	3	0.15^{NS}	0.01^{NS}	0.47^{NS}	0.01^{NS}	0.05^{NS}	5.02^{NS}	0.53^{NS}	24.55^{NS}	201.35^{NS}	43.00^{NS}
AxBxC	9	0.35^{NS}	0.02^{NS}	0.87^{NS}	0.014^{NS}	0.09^{NS}	0.89^{NS}	0.97^{NS}	23.09^{NS}	22.98^{NS}	3.09^{NS}
Error-3	32	1.04	0.12	9.60	0.16	0.58	2.01	23.78	33.09	7.44	3.65