GROWTH AND YIELD OF AROMATIC RICE KALIJIRA USING THREE PGRs (6-BAP, GA_3 AND NAA)

THESIS

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UDOY CHANDRA BARMON

Student No. 1505229

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MASTER OF SCIENCE (MS)
IN
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DEPARTMENT OF AGRICULTURAL CHEMISTRY
HAJEE MOHAMMOD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR-5200

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January-June, 2017

Dedicated

To

My Beloved Parents

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January-June, 2017 *The Author*

ABSTRACT

A field experiment was done to study the effect of 6-BAP (6-Butyl amino purine), GA_3 and Napthaline Acetic Acid (NAA) on morpho-physiological, yield and yield characters of rice varieties cv. Kalijira differently. The 6-BAP was applied 0, 30, 40, 50 and 60 ppm for GA_3: 0, 30, 40, 50 and 60 ppm and for NAA: 0, 50, 75, 100 and 125 ppm at vegetative and preflowering stage. Result showed that the morpho-physiological, yield and yield attributes were significantly different among the hormones studied under the application of different levels of 6-BAP, GA_3 and NAA. Three plant growth regulators (PGR_S) (6-BAP, GA_3 and NAA) showed their positive effect on growth and yield of aromatic rice cv. Kalijira differently. The growth parameters were influence by 6-BAP, GA_3 and NAA. The three PGR_S (6-BAP, GA_3 and NAA) showed their positive effect on growth and yield of aromatic rice cv. Kalijira. The growth parameters were influence differently by 6-BAP, GA_3 and NAA. There was no maeked effect on plant height but leaf numbers, leaf length and leaf blade width were influenced. The highest plant height was 162.3 cm produced by GA_3 while the lowest was 146.3 cm by NAA. The result showed that 40 ppm of 6-BAP had a significant effect on effective tiller number hill^{-1}. Than 40 ppm GA_3 land while 100 ppm of NAA. The similar trend was observed in grain number per panicle and 1000-grain weight. There was a significant variation among the PGR_S and their different levels. The highest grain yield was obtained by spraying BAP at vegetative and pre-flowering stages using 40 ppm than those of GA_3 and NAA. The grain yield of Kalijira was 2.55 (t ha^{-1}) for BAP at 40 ppm, while 2.25 (t ha^{-1}) for GA_3 at 40 ppm and 2.01 (t ha^{-1}) for NAA at 100 ppm, respectively. Plant growth regulators (6-BAP, GA_3 and NAA) enhanced growth and yield of aromatic rice cv. Kalijira which considered an environment friendly management practices for rice production.

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CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food most of the countries in the world. Rice crop is interwoven in the cultural, social and economic lives of millions of Bangladeshis and it holds the key for food and nutritional security of the country. In Bangladesh, more than four thousand landraces of rice are adopted in different parts of this country (Sajib *et al*., 2012). Some of which have nice quality namely fineness, aroma, taste and protein content. It is generally small in size and has soft texture. It is consumed as the staple food and has been given the highest priority in meeting the demands of its ever-increasing population in Bangladesh.

Rice crop is one of the important strategic crops in Egyptian economy. It is also one of the important summer crops representing an area of about 27.8%, 10.7% of total planted area with summer crops and crop area, respectively. Besides, it is an important export crop, where its exports are about 32.2% of total value of agricultural exports on average during the period between the years of 2000 and 2011 (El-Eshmawiy *et al*., 2013).

It is the main food for at least 63% of our planet inhabitants and contributes on an average 20% of apparent calorie intake of the world population and 30% of population in Asia (Calpe and Prakash, 2007). Among the 150 different crops grown in Bangladesh, rice alone occupies about 77% of the total cultivated area, of which aromatic rice is cultivated only on the 10% of the rice growing area (Anon., 2008). Mainly because of a still-growing population, demand for rice is expected to keep increasing in the coming decades (Pingali *et al*., 1997).

In recent years, aromatic rice has been introduced to the global market. The demand for aroma rice is increasing day by day. Unfortunately, the aromatic rice often has undesirable agronomic characters, such as low yield, susceptibility to pests and diseases, and strong shedding (Faruq *et al*., 2011).

Aromatic rice constitutes a small but an important sub-group of rice. These are rated best in quality and fetch much higher price than high quality non-aromatic rice in international market. Aromatic rice has great potential to attract rice consumer for its taste and deliciousness, and high price to boost up the economic condition of the rice grower in the developing countries like Bangladesh. Because of its natural chemical compounds which give it a distinctive scent or aroma when cooked, aromatic rice commands a higher price than non-aromatic rice. In Bangladesh, a number of fine rice cultivars are grown by the farmers. Some of them have special appeal for their aroma. Such common cultivars are Chinisagar, Badshabhog, Kataribhog, Kalizira, Tulsimla, Dulabhog, Basmati, Banglamoti (BRRI dhan50), BRRI dhan34, BRRI dhan37 and BRRI dhan38. Aromatic rice is generally used to prepare dishes such as polau and biriani which are served on special occasions. Demand for aromatic rices in recent years has increased to a great extent for both internal consumption and export.

The introduction of chemical growth regulatorshas added a new dimension to the possibility for improving the growth and yield of rice corp. Plant growth regulators are one of the most important factors for increasing higher yield in leafy vegetables. Application of growth regulators has good management effect on growth and yield of field crops. Hormones regulate physiological process and synthetic growth regulators may enhance growth and development of field crops thereby increased total dry mass of a field crop.

Plant growth regulators are synthesized indigenously by plants, however, several studies demonstrated that plants can respond to exogenous application of these chemicals. An exogenous application of plant growth regulators affects the endogenous hormonal pattern of the plant, either by supplementation of sub-optimal levels or by interaction with their synthesis, translocation or inactivation of existing hormone levels (Arshad and Frankenberger, 1993). Hormones regulate physiological process and synthetic growth regulators may enhance growth and development of field crops thereby increased total dry mass of a field crop (Das and Das, 1996; Abd-el-Fattah, 1997; Chibu *et al*., 2000; Dakua, 2002; Islam, 2007; Cho *et al*., 2008). Some investigations indicated that naphthalene acetic acid (NAA) is a potential antifungal agent (Nakamura *et al*., 1978; Tomita *et al*., 1984; Michniewicz and Rozej, 1988). The use of plant growth regulators in the field of agriculture has become commercialized in some advanced counties like Europe, USA and Japan.

The current uses for plant growth regulators are not only in a high value horticultural crops but it also increase field crop yield directly either by increasing total biological yield or the harvest index. Growth substances can be divided into five classes as Auxin, Gibberellins, Cytokinins, Abcisic acid, and Ethylene.

Foliar application of growth regulator such as, Indole acetic acid (IAA), Naphthalene acetic acid (NAA), Ethrel, 2,4-D, Gibberellic acid (GA_3) and Malic hydrazide (MH) produce more fertile grain $hill^{-1}$. Foliar application of NAA has also found to increase plant height, number of leaves per plant, fruit size with consequent enhancement in seed yield in different crops (Lee, 1990).

Naphthalene acetic acid (NAA) belongs to synthetic forms of Auxins. Auxins play key role in cell elongation, cell division, vascular tissue, differentiation, root initiation, apical dominance, leaf senescence, leaf and fruit abscission, fruit setting and flowering (Davies, 1987). Growth and yield parameters of rice are significantly promoted in response to various Auxin levels (Zahir *et al.*, 1998). Planofix (Naphthalene acetic Acid) had a significant effect on plant height, number of fruiting branches, volume of boll and yield in cotton (Abro *et al.,* 2004). Naphthalene Acetic Acid 20ppm showed better performance in enhancing the straw and grain yields of wheat cultivars (Alam *et al.*, 2002).

Naphthalene acetic acid has been used for the enhancement of growth and yield of cereals (Lilani *et al.,* 1991). PGRs also increase the root growth and also help promoting new roots. Rice spraying with 10 and 100 ppm NAA at tillering stage significantly increased root dry weight (Wang and Deng, 1992). Naphthalene acetic acid, a wide broad, somatotrophin-like growth regulator in plants. It produces significant effects in promoting development of pointed ends for the root system, resulting in more, straighter and thicker roots. NAA can increase fruit setting ratio, prevent fruit dropping, promote flower sex ratio.

Naphthalene acetic acid (NAA) is an aromatic acid.Naturally, it is insoluble in water; however, it is soluble up to 380 ppm in water. It is a synthetic acid, but is similar to naturally occurring indole acetic acid in its action on plants. Thus it is a synthetic plant hormone in the auxin family.

Naphthalene acetic acid has been used for the enhancement of growth and yield of cereals. Naphthalene acetic acid, a wide broad, somatotrophin-like growth regulator in plants. Functions of NAA arestimulation of cell division, cell elongation, elongation of shoot, photosynthesis, RNA synthesis, membrane permeability and water uptake involved in many physiological processes like prevention of preharvest fruit drop, flower induction, fruit set, delayed senescence and prevention ofbud sprouting, leaf chlorophyll content and increased yield in fruit crops. An exogenous application of naturally occurring or synthetic plant growth regulators affects endogenous hormonal pattern of the plant either by supplementation of sub-optimal levels or by interaction with their synthesis, translocation or inactivation of existing hormone levels. Naphthalene Acetic (Acid 20ppm) showed better performance in enhancing the straw and grain yields of wheat cultivars (Alam *et al*., 2002).

Most of the aromatic rice varieties in Bangladesh are of traditional type, photoperiod-sensitive and are grown during Aman season in the rainfed lowland ecosystem. A recent study (Islam et al., 1996) revealed that 12.49% of the study area was cultivated by aromatic rice varieties. Another study (Baqui *et al*., 1997) revealed that among the aromatic rice varieties, Chinigura is the predominant one that covers more than 70% farms in the northern districts of Naogaon and Dinajpur. In these districts, 30% of rice lands were covered by aromatic rice varieties during Aman season. The other important aromatic varieties are Kalijira (predominant in Mymensingh) and Kataribhog (predominant in Dinajpur). Islam *et al*. (1996) observed that the yield of aromatic rice was lower (1.5-2.0 t/ha) but its higher price and low cost of cultivation generated higher profit margins compared to other varieties grown in the area.

There are hardly 3,000-5,000 local cultivars under cultivation in Bangladesh (Alim *et al.,* 1962). The rapid rate of extinction of indigenous cultivars of local rice points to the danger of narrowing genetic base. For the development of high yielding aromatic rice varieties our indigenous aromatic rice cultivars may play a vital role as parent material because they are most adaptive to our environment.

The uses of growth substances such as naphthalene acetic acid (NAA) at different concentrations that may increase aromatic rice plant production. It is quite clear that endogenous and exogenous plant growth regulators play an important role in modifying and regulating many physiological processes in plants and these processes are greatly influenced by environmental conditions. Although some research works were done and a few high yielding aromatic rice varieties were released by BRRI, our indigenous cultivars were given less attention and their yielding ability was not studied well.

Work on PGRs is limited in our country, studies in other countries of the world although provides useful information, that cannot be recommended or practiced without trial in our local condition. Therefore, more researches or trials are necessary to investigate the efficacy of PGRs on aromatic rice. Thus, the present study was carried out based on following objectives-

- To study the growth characteristics and yield potential of aromatic rice cv. Kalijira cultivars under different levels of three PGRs: 6-Butyl amino purine (6-BAP), GA_3 and Naphthaline acetic acid (NAA).
- To find out the suitable dose of 6-BAP, GA_3 and NAA to recommending for the farmers' level.
- To provide a suitable technology to the farmers level and policy makers.

CHAPTER II

REVIEW OF LITERATURE

Plant growth regulators are the elements which regulate the growth of plant quite spontaneously. 6-BAP, GA_3 and NAA are three of them. Many plant scientists are engaged in changing the pattern of growth and development of plants for a long time. 6-BAP, GA_3 and NAA are important growth regulators that may have uses to modify the growth, yield and yield contributing characters of cereal crops. Extensive works on the regulatory effect of these growth regulators on various crops have been carried out. Some of the related works are reviewed here.

2.1 Growth regulators on the morphological characters of rice and similar crops

Plant height

Plant height is one of the most important morphological parameters. It is a measure of longitudinal or vertical distribution of plants.

Roxy (2016) revealed that 50 ppm 6-BAP showed better performance on plant height of Kataribhog rice variety at both vegetative and harvesting stage.

Rahman (2013) revealed that plant height was increased in their succession stages at different days after transplanting (DAT) due to age and application of PGRs. He found NAA had more pronounced effect than GA_3 in regard to plant height of some selected rice variety.

Jahan *et al.* (2011) indicated that NAA has both stimulatory and inhibitory effect on different growth parameters viz. plant height, shoot length, leaf area which is in accord with the fact that plant growth regulators at identical concentration can have quite different effects on different plants and even on different organs of the same plant.

Islam (2010) conducted an experiment on fine rice varieties (BRRI dhan34 and Kalijira). Results revealed that plant height was significantly influenced due to variety at all the DATs. It was found that the plant heights increased progressively with the advancement of time and growth stages. It was observed that the plant height of Kalijira was higher during the experiment and Kalijira produced the tallest plant (119.39cm) at 75 DAT than that of BRRI dhan34 (116.75 cm) and the variation in plant height was probably due to heredity or varietal character.

Khanam (2008) revealed that four fine rice varieties (BRRI dhan34, Basmoti, Kataribhog and Kalijira) showed the significant varietal differences on plant height. The tallest plant (116.7 cm) was obtained from Kalijira and shortest one (90.22cm) was from variety Basmoti.

Khan (2016) revealed that 150 ppm 6-BAP showed better performance on plant height of Kataribhog rice variety at both vegetative and harvesting stage.

Sahiduzzaman (2008) from an experiment on four fine rice varieties (Kataribhog, BRRI dhan34, Basmoti, and Kalijira) found plant height was significantly influenced by variety at different days after transplanting at 1% level of probability. He found Kalijira as the tallest variety followed by BRRI dhan34, Kataribhog and Kalijira, respectively. Chinigura-1 produced the tallest plant atharvest (148.20 cm) than Begunbitchi and Kalijira as reported by Kabir *et al.* (2004).

Islam *et al.* (2005) reported that the highest plant height was observed where GA3 was applied @ 75 g ha-1.

Hao *et al.* (2000) published that different growth regulators (2,4-D and NAA) on different agronomic characteristics of MT^{10} rice mutant and observed that in general, the hormonal treated plant, MT^{10} had higher value for most of the characters including plant height.

Ahmad *et al.* (1991) revealed that seed soaking with IAA (100 and 200 ppm) and concluded that shoot length increased with soaking of IAA was followed by the soaking with $CaCl_2$. In a pot trial of green house sorghum was sprayed with 100 ppm auxin (IAA or NAA) at 8 or 12 leaf stage which resulted in increased internodes length as well as plant height (Mirhadi and Kobayashi, 1979).

Miraculan (triacontanol), agromax and planofix (NAA) significantly increased wheat plant height. The highest grain yield were obtained with 250 ml Miraculan/ha applied at tillering and booting stages (Singh and Uttam, 1994).

Singh and Darra (1971) found that pre-soaking of wheat seedling with GA_3 and IAA enhanced the plant height while IBA and IAA increased root length in comparison with

NAA in wheat. All the hormones more or less increased the dry weight of shoots and grain yield, the optimum concentration was 200 ppm and above supra optimal concentration the activity was either increased or decreased.

Hsiao *et al.* (1976) reported that plant height is the function of cell growth and vertical enlargement. GA_3 is well known for its role on stem elongation. The effect of GA_3 on plant height was studied in various parts of the world by many scientists.

Kurtyka *et al.* (2009) found that the treatment of maize coleoptiles' segments with IAA (0.01 mmol x dm^{-3}) or/and IBA (0.01 mmol × dm^{-3} or 0.1 mmol × dm^{-3}) stimulates their elongation growth. The addition of IAA together with IBA (0.01 mmol × dm^{-3}) caused a synergistic effect of both auxins on the growth of maize coleoptiles segments.

Oduro *et al.* (2011) reported that shoot length, and enzyme activity were significantly affected by the GA_3 hormone at concentrations of 0.001, 0.1, 10, and 100 mg L^{-1}. 10 mg L^{-1} of GA_3 solution stimulated the highest production of diastase (1305 U g^{-1} dry malt), and shoot length of 2.93 cm after 60 hours of germination. The maximum diastatic activity of GA_3 treated rice grains was found on the 8th day of germination, occurring earlier than the untreated that peaked at the 10th day. GA_3 treatment at a concentration of 10 mg L^{-1} is adequate to stimulate higher production of diastase in rice malt.

Pareek *et al.* (2000) observed that the increase in plant height was due to plant hormones promoted vegetative growth by active cell division, cell enlargement and cell elongation and thus helped in improving growth characteristics and also facilitated reproductive growth. These findings were in closely agreement with the results of Subbaih and Mittra (1997).

Ghodrat *et al.* (2012) showed that increasing salinity would decrease the components of germination including germination percentage, germination rate, root and shoot length and fresh and dry weight of seedling. Priming with GA_3 had no effect on seed germination however in some concentrations GA_3 increased shoot length, root length, dry weight, fresh weight and tissue water content.

Ghodrat *et al.* (2013) showed that the highest increase of crop growth rate (11.4 g m^{-2} $days^{-1}$) belonged to IBA 100ppm and GA_3-100ppm treatment in 4 to 6 leaf stage. The best net assimilation rate was obtained in the treatment IBA 100 ppm and GA_3-50 ppm with 2.72 g m^{-2} day^{-1}. Totally, the results showed that in both stages of growth, application of IBA and GA_3 improved growth parameters.

Leaf blade length

Khan (2016) revealed that 150 ppm 6-BAP showed better performance on leaf blade no. of Kataribhog rice variety at both vegetative and harvesting stage.

Islam (2008) reported that 100 ppm IAA+ continuous flooded irrigation increases leaf length and breadth, Leaf dry weight, total dry matter at 80 DAT over control.

Niknejhad and Pirdashti (2012) found a positive and significant correlations between flag leaf length, flag leaf area, grain number, panicle length and 1000 grain weight with paddy yield by the application of both GA_3 and Ecormon.

Number of tillers hill^{-1}

Khan (2016) revealed that highest tiller number per hill was found while 200 ppm 6-BAP was applied on Kataribhog rice variety.

Rahman (2013) found the maximum number of total tillers hill^{-1} (17.67) that was obtained from BRRI dhan28 with 100 ppm NAA.

Akter (2012) also revealed that highest tiller number per hill was found while 150 ppm NAA was applied as treatment with the residual effect of 2 ton lime.

Sarker (2012) observed that the highest number of total tillers hill^{-1} was obtained from BRRI dhan52 and number of total tiller hill^{-1}were significant at 1% level of probability. He found number of total tillers hill^{-1} ranged from 13.160 to 17.253. Sahiduzzaman (2008) from an experiment on four fine rice varieties (Kataribhog, BRRI dhan34, Basmati and Kalijira) found significant effect on total number of tiller hill^{-1}. The highest number of tiller hill^{-1} (17.58) was observed in Kalijira and lowest (14.4) in Basmati.

Khanam (2008) from an experiment on four fine rice varieties (BRRI dhan34, Basmoti, Kataribhog and Kalijira) found highest number of tillers hill^{-1} (13.39) was recorded in Kalijira and the lowest (11.43) in Kataribhog. Kabir *et al.* (2004) observed that the cultivar Kalijira produced the highest number of tillers hill^{-1} at maturity followed by Begunbitchi and Chinigura-1 varieties. Nuruzzman *et al. (*2000) studied with 14 rice varieties and IR36 followed by suweon 258 produced the lowest value.

Khanam (2008) from an experiment on four fine rice varieties (BRRI dhan34,Basmoti, Kataribhog and Kalijira) found highest number of effective tillers hill-1(9.4) in Kalijira and the lowest number of effective tiller hill^{-1} (8.68) in Basmati which was statistically identical to BRRI dhan34(8.77). Kabir *et al.* (2004) observed that the cultivar Kalijira produced the highest number of effective tillers hill^{-1} than Chinigura-1. BRRI (2000) conducted an experiment to evaluate yield performance of three high yielding varieties namely BRRI dhan30, BRRI dhan31, BRRI dhan32 in *Aman* season and revealed that effective tillers hill-1 of the abovementioned varieties were 7.8 and 8, respectively.

Liu *et al*. (2012) indicated that application of 10 mg L^{-1} GA_3 and 1000 mg L^{-1} NAA significantly inhibit the growth of unproductive tillers, and the elimination of unproductive tillers promoted the growth of productive tillers at the middle and late growth stages, and promoted the development of heavy panicles, and finally increased the grain yield in rice plant.

Liu *et al.* (2012) demonstrated that auxin and cytokinin (CTK) play important and different roles in the regulation of tiller bud growth. Auxin in the nodes inhibits tiller bud growth, while CTK is transferred to the tiller buds to promote growth. The inhibitory effects of GA_3 and NAA on tiller bud growth are mainly due to the control of the indole-3-acetic acid (IAA) or CTK contents in plants. As opposed to auxin and CTK, the ABA contents in nodes and tiller buds remained unchanged before tiller bud growth after panicle removal. Mean while, external application of ABA only slightly slowed the growth of the tiller buds, suggesting that ABA may not be a key regulator of tiller bud growth.

Islam (2008) reported that maximum number of tillers hill^{-1}, number of leaves hill^{-1}, leaf area hill^{-1} was recorded in treatment of 100 ppm IAA+ continuous flooded irrigation. Results also showed that maximum Leaf dry weight, stem dry weight, root dry weight and total dry matter was recorded at 40 and 80 DAT in 100 ppm IAA+ continuous flooded irrigation over control.

Chhipa and Lal (1988) carried out an experiment with IAA on wheat cv. Raj 911. Plants were grown in 4-non saline sodic soils and seeds were treated with 200 ppm IAA. The plants increased the number of tillers significantly.

Chauhan *et al.* (1985) stated that the effect of growth regulators like as benzyladenine (BA), 2-chloroethyl trimethyl ammonium chloride, GA_3, kinetin, and NAA on ratoontillering depended on their concentration and time of application but all growth regulators increased rationing.

Gill and Singh (1985) revealed that spraying of 100 ppm NAA on wheat and barley had decrease to a great extent the number of non effective tiller hill^{-1} as compared to control. Wheat and barley, spraying with 100 ppm NAA at the tillering and heading stage significantly increase the number of tiller hill^{-1}.

Ling and Ma (1998) studied on winter wheat with endogenous growth regulator IAA and demonstrated that non effective tiller was decreased by IAA.

Akter (2012) revealed that the combined application of 100 ppm to 200 ppm NAA and residual effect of 1.5 to 2.0 ton lime may be used in the field for obtaining better tiller number hill^{-1} of Karari rice.

Saha *et al.* (1996) observed that application of 600 and 900 ppm of IAA at the beginning of the tillering stage in kanchan variety of wheat increased number of tillers and 1000 grain weight compared to the control.

Number of Leaves plant^{-1}

Khanm (2016) revealed that maximum number of leaves was obtained from Kataribhog rice variety while 200 ppm 6-BAP was applied.

Rahman (2013) found the maximum number of leaves that was obtained from (BRRI dhan28) while the lowest number of leaves was emerged from Jirashail and Pasurshail varieties due to the application of GA_3 and NAA as a plant growth regulators and also in controlled condition.

Jahan *et al.* (2011) showed on a plot experiment,100 and 200 ppm naphthalene acetic acid (NAA) plant height, number of leaves per plant and number of tillers per plant were found to increase due to 100 ppm NAA only in BRRI dhan-29 (V1) and varied significantly at 60 DAS.

Obaidur (2008) reported that 100 ppm NAA + flooded irrigation were found to be superior to others treatments for increasing the leaf number plant^{-1}.

Mahla *et al*. (1999) reported that spraying of 20 ppm NAA on *Vignamungo* had greater effect to increase the number of branches. The effect of NAA on number of leaves was studied by various authors. Rao *et al*. (1992) reported that NAA sprayed at 5, 10, 15, or 20 ppm at 30 and 60 days after planting increased leaf number /hill and leaf area/hill.

Gurdev and Sexena (1991) reported that 10^{-4} M IAA application on wheat plant increased number of leaves. Rao *et al.* (1992) reported that NAA sprayed at 5, 10, 15, or 20 ppm at 30 and 60 days after planting increase leaf area plant^{-1} in turmeric.

Gurdev and Sexena (1991) reported that 10^{-4} M IAA application on wheat plant increased number of leaves.

Gill and Singh (1985) observed that on late sown wheat and barley, spraying with 100 ppm NAA at the tillering and heading stages significantly increased leaf number hill^{-1} and number of grain ear^{-1}.

Guoping and Etmal (1992) observed that ABT, an auxin type of phytohormone increase speed of leaf sprouting and area of leaf in maize.

2.2 Growth regulators on the yield components of rice and similar crops

Panicle length

Khanm (2016) revealed that highest panicle length was obtained from Kataribhog rice variety while 50 ppm 6-BAP was applied.

Kabir *et al.* (2004) observed that the cultivar Chinigura produced the highest panicle length (26.86 cm) followed by Begunbitchi and Kalijira varieties. Hossain *et al.* (2003) carried out an experiment with new rice cv. Sonar Bangla-1, BRRIdhan39 and Nizershail and reported that the cultivars did not differ significantly in panicle length.

Hao *et al.* (2000) revealed that application of NAA and 2, 4-D increased panicle length and number of panicles hill^{-1} of rice cv. IR18.

Gurbaksh *et al*. (1985) studied with 5 ppm IAA and sprayed on rice cv. Java at anthesis and grain one week later. IAA increased percentage of hilled spikelet.

Salam and Islam (1995) reported that spraying of ABT growth promoter increased panicle number of rice.

Tao and Shiying (1992) stated that treating with ABT increased panicle number and grains panicle^{-1} of rice.

Zhou (2005) reported that 20% spikelet of a panicle are enclosed in the sheath of flag leaf in most *indica* CMS lines their three internodes are shorter than those of pollen parents, especially the top most internodes. He also observed that GA_3 enhance panicle and stigma exertion. Adjust plant height of both parents. Moreover he reported that the best time for first spraying is when 2-5% panicles have emerged out of bracts and 4-5 in consecutive days time 7 am to 11 am or 4 pm to 7 pm.

Effective and non-effective tiller

Khanm (2016) found highest number of effective tillers hill^{-1}from Kataribhog rice variety while 1000 ppm 6-BAP was applied and highest number of non effective tillers hill^{-1} at controlled level of 6-BAP.

Khanam (2008) from an experiment on four fine rice varieties (BRRI dhan34,Basmoti, Kataribhog and Kalijira) found highest number of effective tillers hill^{-1}(9.4) in Kalijira and the lowest number of effective tiller hill^{-1} (8.68) in Basmati which was statistically identical to BRRI dhan34 (8.77). Kabir *et al.* (2004) observed that the cultivar Kalijira produced the highest number of effective tillers hill^{-1} than Chinigura-1. BRRI (2000) conducted an experiment to evaluate yield performance of three high yielding varieties namely BRRI dhan30, BRRI dhan31, BRRI dhan32 in *Aman* season and revealed that effective tillers hill^{-1} of the above mentioned varieties were 7.8 and 8, respectively.

Zahir *et al*. (1999) carried out an experiment on rice cv. Basmati 385 seedlings roots were dipped in solution containing seven IAM levels (10^{-9}to10^{-3}) for an hour just before transplanting into the field. IAM (indoleacetamide) is an intermediate metabolite in the biosynthesis of IAA. The IAM 10^{-5} significantly increased numbers of tiller as compared with control.

Singh and Gill (1985) reported that spraying of 100 ppm NAA on wheat and barley had decrease to a great extent the number of non effective tillers hill^{-1}as compared to control.

Ling and Ma (1998) studied on winter wheat with endogenous growth regulator IAA and demonstrated that non effective tiller was decrease by IAA.

1000 grain weight (g)

Khanm (2016) reported that Kataribhog produced the highest 1000-grain weight while 50 ppm 6-BAP was applied.

Kabir *et al.* (2004) studied with rice new cv. Begunbitchi, Chinigura and Kaijiraand reported that Chinigura produced the highest 1000-grain weight.

Akter *et al.* (2012) revealed that 100 ppm NAA with 1.0 ton lime residual effect showed the best performance in all yield contributing characters in kataribhog rice such as number of filled grain, 1000-grain weight and yield production.

Bakhsh *et al.* (2012) revealed that the highest number of panicles, spikelets panicle^{-1}, normal kernels,1000-grain weight, paddy yield and water productivity was recorded by applying naphthalene acetic acid @ 90 mL ha^{-1} and I_2 (75 cm) level of irrigation water (10 irrigations).

Khan *et al.* (2011) revealed that application of growth regulator (NAA) at the rate of 90 mL ha^{-1} at panicle initiation stage resulted in highest number of 88 and 90 % normal kernel, 23.00 and 23.20 g 1000-grain weight during 2004 and 2005, respectively.

Liuping *et al*. (1998) in an experiment with growth regulators such as NAA on wheat found that among growth regulators, NAA was the most effective to increase 1000 grain weight.

Singh and Gill (1985) reported that spraying of 100 ppm NAA on wheat and barley had greater effect to increase 1000 grain weight.

Sharma *et al.* (2007) stated that the application of gibberellic acid is an important component of hybrid rice seed production technology. It has several advantages, such as increasing the growth of secondary and tertiary tillers, enhancing panicle and stigma receptivity and 1000-grain weight. They observed that 1000 grain weight increment was found to be increasing order with higher dose of GA_3 application i.e.; 135 g ha^{-1} of GA_3 level.

Singh and Gill (1985) reported that spraying of 100 ppm NAA on wheat and barley had greater effect to increase thousand grain weights.

Saha *et al*. (1996) reported that 300, 600, and 900 ppm of IAA applied at the beginning of the tillering stage in kanchan variety of wheat increased 1000 grain weight.

Various factors are seemed to be involved in influencing 1000-grain weight in rice. During ripening of grain, assimilates supply to the grain is more essential than any of the other factors of crop growth and the plant growth regulators like GA_3 control this assimilates flow from grain walls to grain. (Bouttier and Morgan, 1992).

Grain yield (t ha^{-1})

The effect of higher concentration of NAA was significant in increasing the grain yield of some crops. Increase in grain yield due to NAA application as reported by many scientists as stated below.

Khanm (2016) reported that 100 ppm 6-BAP produced highest grain yield and yield components of rice.

Roxy (2016) reported that 50 ppm 6-BAP increased the grain yield and yield components of rice.

Akter (2012) revealed that 200 ppm NAA produced highest grain yield in both 2.00 and 2.50 t lime residual effect.

Bakhsh *et al*. (2012) reported that application of NAA increased the grain yield and yield components of rice.

Adam and Jahan (2011) reported that due to 100 and 200 ppm NAA, grain yield per plant increased by 27.67 and 6.85%, respectively in BRRI dhan-29 and in BRRI dhan-50 grain yield per plant decreased by 26.54% due to 100 ppm and 27.67% due to 200 ppm. He also reported that out of the two concentrations 100 ppm NAA produced better stimulation.

Peng *et al.* (2011) observed that spraying PBZ with 50 mg L^{-1} or 6-BA with 30 mg L^{-1} at the heading stage could also increase number of spikelets per panicle, seed setting rate and grain yields in both cultivars of *Peizataifeng* and *Huayou 86* in both seasons. There was more noticeable effect on yield in *Huayou 86* than in *Peizataifeng* with foliar application of PBZ or 6-BA.

Islam (2008) found that application of IAA markedly influenced on yield and yield contributing characters in rice plant. The highest yield was observed (3.42 kg/plot) in 100 ppm IAA+ continuous flooded irrigation.

Singh and Gill (1985) reported that in wheat and barley spraying with 100 ppm NAA at the tillering and heading stages significantly increase grain yield compared to control.

Chaptol *et al.* (1992) reported that black gram (*Vignamungo*), green gram (*Vignaradiata*) and soyabean were sprayed with NAA at the flower initiation and resulted higher seed yield.

Singh and Uttam (1994) revealed that spraying of planofix (NAA) on wheat plant, significantly increased grain yields.

Mahla *et al.* (1999) showed that *Vignamungo* sprayed with 2 ppm mixtalal (tricontanol) and/or 20 ppm NAA increased yield and yield components. The seed yield was the best with combined application of the 2 growth regulators.

Kalita *et al.* (1995) reported that combined foliar spray of 3 per cent P_2O_5, 100 ppm NAA in greengram resulted in higher total dry matter accumulation, seed yield and harvest index. Foliar spray of brassinosteroid, salicylic acid, NAA and mepiquot chloride and 0.1,100, 40, 50 ppm increased the grain yield in pearl millet. Among the treatments, brassinosteroid recorded the maximum yield of 3591 kg ha^{-1} followed by tricontanol (3505), NAA (3484) and salicylic acid (3427) as compared to control (3018 kg ha^{-1}) (Sivakumar *et al*., 2002).

Kaur and Gurbaksh (1987) revealed that foliar application of IAA on Semi dwarf varieties java, Palman and IR-8 increased vascular bundle number and phloem area. This treatment significantly increased grain yield and yield components.

Mir (2010) Indicated that the process of growth and development in addition to the yield of plants is significantly affected by the phytohormones along with nutrients in both irrigated and non -irrigated conditions in rice plant.

Obaidur (2008) reported that 100 ppm NAA+flooded irrigation were found to be superior to others treatments for yield and other yield parameters.

Singh and Gill (1985) reported that in wheat and barley spraying with 100 ppm NAA at the tillering and heading stages significantly increase grain yield compared to control.

Muthukumar *et al.* (2005) reported that Cob yield was higher under Mepiquat chloride @ 200 ppm spray (8003 kg ha^{-1}) which was comparable with NAA @ 40 ppm spray (7872 kg ha^{-1}). With regard to split application of nitrogen, application of nitrogen as ½ basal + ¼ at 25 DAS + ¼ at 45 DAS produced significantly higher cob yield (8122 kg ha^{-1}) when compared to other treatments.

Zheng *et al.* (2011) found that suitable application of plant growth regulators (such as NAA-Na, GA_3 or 6-BA) could improve the photosynthetic capacity, delay the leaf senescence and promote the rate of rice seed-setting. In this study, we observed that spraying PBZ with 50 mg L^{-1} or 6-BA with 30 mg L^{-1} at the heading stage could also increase number of spikelets per detrimental effects of rice senescence by modulating the activity of enzymatic antioxidants, improving antioxidant system, which helped in sustaining plant growth and yield.

Dunand (1998) reported that significant increase in stem elongation and yield in response to Gibberellic acid application.

Gangadharaiah *et al.* (2008) studied on the effect of supplementary pollination and row ratios on the parental line seed production of hybrid rice. Leaf cutting, rope pulling and GA_3 application increased seed yield and seed set.

Gavino *et al.* (2008) reported that GA_3 application was very effective in increasing seed set rate and seed yield through elongation of plant height, promoting panicle and spikelet exertion, enhancing stigma exertion and longevity and receptivity in hybrid rice.

Jagadeeswari *et al.* (2004) reported that increased level of GA_3 significantly improved for seed setting percentage, plant height and seed yield. They got 2.7 t ha^{-1} seed yield using 135 g ha^{-1} GA_3 level.

Kalita *et al.* (1995) reported that combined foliar spray of 3 per cent P_2O_5, 100 ppm NAA in greengram resulted in higher total dry matter accumulation, seed yield and harvest index. Foliar spray of brassinosteroid, salicylic acid, NAA and mepiquot chloride and 0.1,100, 40, 50 ppm increased the grain yield in pearl millet. Among the treatments, brassinosteroid recorded the maximum yield of 3591 kg ha^{-1} followed by tricontanol

(3505), NAA (3484) and salicylic acid (3427) as compared to control (3018 kg ha^{-1}) (Sivakumar *et al*. 2002).

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Mir (2010) Indicated that the process of growth and development in addition to the yield of plants is significantly affected by the phytohormones along with nutrients in both irrigated and non -irrigated conditions in rice plant.

Tiwari *et al*. (2011) revealed that treatment combination T_{26} (45 g GA_3 + 10 g Urea + 2 g Boric acid + 2 g K_2PO_4) gave the best results in yield performance and could be used to enhance hybrid rice seed production and substitute of GA_3 in India as well as other hybrid rice growing countries.

Muthukumar *et al.* (2005) reported that Cob yield was higher under Mepiquat chloride @ 200 ppm spray (8003 kg ha^{-1}) which was comparable with NAA @ 40 ppm spray (7872 kg ha^{-1}). With regard to split application of nitrogen, application of nitrogen as ½ basal + ¼ at 25 DAS + ¼ at 45 DAS produced significantly higher cob yield (8122 kg ha^{-1}) when compared to other treatments.

Zhang *et al.* (2007) reported that spraying external 6-BA on the leaves at late growth period of the late-season rice could increase seed setting rate and grain yield by delaying leaves senescence.

Straw yield

Khanm (2016) reported that the straw yield of kataribhog was significantly increased at the controlled level.

Singh and Uttam (1994) reported in field experimentsin 1985-1987 with Miraculan, Agromax and Planofix (NAA) significantly increased wheat plant straw yields. The height grain yields and return were obtained with 250 ml Miraculan ha^{-1} applied at tillering and booting growth stages.

Zahir *et al.* (2007) concluded that maximum straw yield (5.3 t ha^{-1}) was recorded in IAA-blended N-enriched compost plus 60 kg ha^{-1} N fertilizer which was at par with kinetin-treated N-enriched compost plus 60 kg ha^{-1} N fertilizer and full dose of N fertilizer.

Balki and Padole (1982) reported that the grain and straw yield of wheat was significantly reduced with the increase in the level of salinity, but improved by seed soaking treatments with IAA, NAA and GA increased the straw yield as well as the uptake of nutrients significantly.

Harvest index

Harvest index is the ratio of economic yield and biological yield, and the ultimate partitioning of dry matter between grain and vegetative parts is indicated by HI, the economic yield of rice is its grain, biological yield of a crop is the TDM at final harvest (Davald and Hamblin, 1976). HI is the measure of the efficiency of conversion of photosynthate into economic yield of a crop plant (Dutta and Mondal, 1998).

Khanm (2016) reported that 100 ppm 6-BAP produced highest harvest index.

Akter (2012) revealed that 100 ppm NAA application obtained highest harvest index. It means dry matter partitioning to economic yield is superior in case of 100 ppm NAA application and inferior in 200 ppm NAA application.

Rahman (2013) found the highest harvest index (49.60 %) which obtained from BRRI dhan2 with 100 ppm NAA and the lowest harvest index (42.01%) which obtained from the Nerica-4 without GA_3 or NAA.

Roxy (2016) reported that 50 ppm NAA application obtained highest harvest index

Venkatenet *et al.* (1984) stated that the application of NAA at various concentrations at 30 and 50 DAS in groundnut increased harvest index. The treatment combinations of 3% P_2O_5+100 ppm NAA resulted maximum harvest index (Kalita *et al.*, 1995). Gurbaksh *et al.* (1985) studied with 5 ppm IAA and sprayed on rice cv. Java at anthesis and grain one week later. IAA increased percentage of hilled spikelet. Hao *et al.* (2000) revealed that application of NAA, 2, 4-D, increased panicle length and number of panicles $hill^{-1}$ of rice cv. IR18. Salam and Islam (1995) reported that spraying of ABT growth promoter, increased panicle number of rice. Tao and Shiying (1992) stated that treating with ABT increased panicle number and grains $panicle^{-1}$ of rice

Biological yield

Khanm (2016) reported that 100 ppm 6-BAP produced maximum biological yield of Kataribhog rice.

Rahman (2013) was obtained maximum biological yield (15.51 t ha^{-1}) from the combination of variety BRRI dhan28 with 100 ppm GA_3. The lowest biological yield (10.50t ha^{-1}) was obtained from the combination of variety Nerica-4 and 100 ppm of GA_3.

CHAPTER III

MATERIALS AND METHODS

A field experiment was done at the research farm of Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during the period of July to December, 2016 to ascertain the response of 6-Butyl amino purine 6-BAP, GA^3, naphthalene acetic acid (NAA) of kalijira, Aromatic rice variety. In this chapter the materials used and the methods followed during the experimental period are described under the following heads:

3.1 Location of the experimental site

Geographically the location of the experimental site is at 25°38' N latitude and 88°41' longitude at an average height of 34.5 m above the mean of sea level. The experimental site was medium high land and belonging to the Agro-ecological Zone 1 (AEZ-1) named Old Himalayan Piedmont Plain (FAO and UNDP, 1988).

3.2 Soil characteristics

The experimental land was characterized by non-calcareous dark grey floodplain soils. The land was medium high and well drained with silty loam texture. The initial soil (0-15 cm depth) test revealed that the soil contained pH value 5.84, 0.0364% total nitrogen, 35.4 ppm phosphorus, 0.58 meq /100 g available potassium, 25.34 ppm sulphur and low Ca and Mg content, respectively. The physical and chemical compositions of the soil of the experimental plot have been presented in Table 1.

3.3 Climate and weather

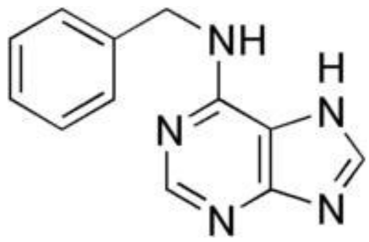
The research work was done during aman season (july to December, 2016) which is also known as Kharif-2 season. The experimental area possesses subtropical climatic condition. The air temperature was relatively high at the beginning of the season and was decreasing with advancement of the season towards Kharif with occasional gusty winds. Moderate rainfall was detected during experimental period.

Table 1: Physical and chemical characteristics of soil (0-15cm) of the experimental field

Parameters	Characteristics
Ph	5.84
% Sand	56.0
% Silt	34.0
% Clay	10.0
Textural class	Sandy loam
Total nitrogen (%)	0.036
Organic matter (%)	0.73
Available phosphorus (ppm)	35.4
Exchangeable potassium (meq /100g soil)	0.58
Available sulphur (ppm)	25.34
Parent material	Alluvial deposit

3.4 Experimental materials and treatment arrays

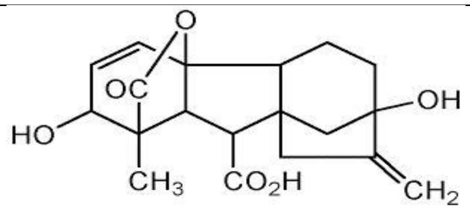
This experiment was conducted by using 6-BAP, GA_3 and NAA. Various doses plant growth regulator 6-BAP, GA_3 and NAA were applied in order to investigate its effect on the growth and yield of kaliJira.



Chemical structure of 6-Benzylaminopurine (6-BAP)

Properties of 6-BAP

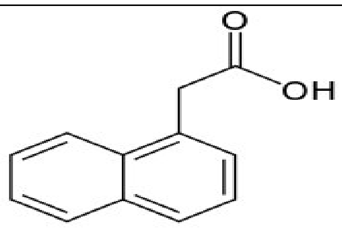
Chemical formula	$C_{12}H_{11}N_5$
Product Type	Biochemicals
Melting Point	226 - 236 °C
Appearance	White to off-white powder
Extinction Coefficient (E1%)	E (270) = ~19,054 (methanol)(Lit.)
Presentation	Off-white Powder
Format	Powder
Detection Method	FTIR
Solubility	Soluble in glacial Acetic Acid (50 mg/mL). Soluble in concentrated ammonium hydroxide, 0.1 N Sodium hydroxide (10 mg/mL - slightly hazy and yellowish solution), methanol, or dioxane.
Storage & Handling	Store at Room Temperature (15-30 °C).
Packsize Numeric Quantity	500 mg||5 g||25 g



Chemical structure of Gibberellic acid (GA_3)

Properties of Gibberellic acid (GA_3)

Properties	
Chemical formula	$C_{19}H_{22}O_6$
Molar mass	346.37 g/mol
Melting point	233 to 235 °C (451 to 455 °F; 506 to 508 K) (decomposition)
Solubility in water	5 g/l (20 °C)



Chemical structure of Naphthalene acetic acid (NAA)

Properties of Naphthalene acetic acid (NAA)

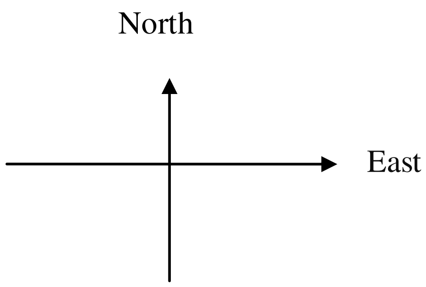
Properties	
Chemical formula	$C_{12}H_{10}O_2$
Molar mass	186.21 g·mol^{-1}
Appearance	White powder
Melting point	135 °C (275 °F)
Solubility in water	0.38 g/L (17 °C)
Acidity (pK_a)	4.24

3.5 Experimental design and layout:

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. There are two factors in this experiment.

Factor A: PGR	**Factor B: Doses of PGRs**				
	Level (ppm)				
	T_0	T_1	T_2	T_3	T_4
H_1: 6-BAP	0	30	40	50	60
H_2: GA_3	0	30	40	50	60
H_3: NAA	0	50	75	100	125

Therefore total number of plots for this experiment was 45. The unit plot size was (3 × 2) m^2. The block to block distance was 1 m and plot to plot distance 50 cm. Plant to plant distance 15 cm and row to row distance 20 cm were maintained. The experimental field layout was given below:



REPLICATION 1	REPLICATION 2	REPLICATION 3
H_3T_0	H_3T_1	H_3T_2
H_3T_1	H_3T_2	H_3T_3
H_3T_2	H_3T_3	H_3T_4
H_3T_3	H_3T_4	H_3T_0
H_3T_4	H_3T_0	H_3T_1
	DRAIN	
H_2T_1	H_2T_2	H_2T_0
H_2T_2	H_2T_3	H_2T_1
H_2T_3	H_2T_4	H_2T_2
H_2T_4	H_2T_0	H_2T_3
H_2T_0	H_2T_1	H_2T_4
	DRAIN	
H_1T_2	H_1T_0	H_1T_1
H_1T_3	H_1T_1	H_1T_2
H_1T_4	H_1T_2	H_1T_3
H_1T_0	H_1T_3	H_1T_4
H_1T_1	H_1T_4	H_1T_0

Figure 1: Field layout for the Experiment

3.6 Land preparation

The experimental field was first plough with a power tiller on first week of July, 2016 and subsequently ploughed twice followed by laddering obtain a desirable tilth. The corners of the land were spaded and larger clods were broken into smaller pieces. All the stubbles and weeds (mutha, bothua, chapra, titbegun, durba etc.) were collected and removed from the field. The land was puddled thoroughly by the application of water mixed organic matter in the field. After 3-4 days, plots were leveled properly by wooden plank that no water pocket could remain in the puddle field. Finally the land was ready for transplantation.

3.7 Fertilizer application

The chemical fertilizers Urea, TSP, MOP and Gypsum were applied @ 215, 180, 100, and 20 kg ha^{-1}, respectively. At the beginning of land preparation one half of urea, full dose of TSP, MOP and Gypsum were applied to the experimental plot.

3.8 Transplanting of seedlings

About 40 days healthy seedlings were transplanted on puddle plots on July, 2016 according to the experimental design. Seedlings for local cultivars were transplanted in each hill with a spacing of 25 × 20 cm.

3.9 Preparations and application of plant growth regulators

Plant growth regulator 6-BPA solution was prepared and the spraying was done at afternoon by using a hand sprayer with two distinct capacities. The solution of 6-BPA 0, 30, 40, 50 and 60 ppm was prepared by dissolving 0, 30, 40, 50 and 60 mg of 6-BPA in a 1 litre measuring cylinder in which 5ml of ethanol prior to dilution was made in distilled water. The distilled water was added to make the volume 1 liter to get respective concentration of 6-BPA solution. Plant growth regulator GA_3 solution was prepared and the spraying was done at afternoon by using a hand sprayer with two distinct capacities. The solution of GA_3 0, 30, 40, 50, 60 ppm was prepared by dissolving 0, 30, 40, 50 and 60 mg of GA_3 in a 1 litre measuring cylinder in which 5ml of ethanol prior to dilution was made in distilled water. The distilled water was added to make the volume 1 liter to get respective concentration of GA_3 solution. Plant growth regulator NAA solution was prepared and the spraying was done at afternoon by using a hand sprayer with two distinct capacities. The solution of NAA 0, 50, 75, 100 and 125 ppm was prepared by dissolving 0, 50, 75, 100 and 125 mg of NAA in a 1 litre measuring cylinder in which 5ml of ethanol prior to dilution was made in distilled water. The distilled water was added to make the volume 1 liter to get respective concentration of NAA solution. Three PGRs were sprayed twice, at vegetative stage and panicle initiation stage.

3.10 Intercultural operations

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

3.10.1 Gap filling

Gap filling was done after one week of transplanting where it was necessary using the seedlings from the same source.

3.10.2 Weeding and plant protection measures

Weeding by hand picking and applications of pesticides by hand sprayer at the vegetative growth stages were done as and when necessary. As a precautionary measures to the crops from the pest attack, Confidor 2 g /10 L water was sprayed 2 times at vegetative and pre flowering stages during the entire crops season.

3.10.3 Irrigation and drainage

Sufficient irrigation water was given by irrigation water pump as and when needed. Excess water was drained out from the plots before 15 days of harvesting to enhance maturity of the crop.

3.11 Harvesting and processing

Maturity of crops was prefered when some 90% of the grains became golden yellow in color. After attainment of the maturity, the whole plant was cut at ground level by a sickle. After recording some necessary data the harvested crops hill was dried in sun and then in an oven at $65^{o}C$.

3.12 Parameters studied

The data regarding various essential parameters were collected accordingly during the experimental period. The parameters studied are-

- Plant height
- No of leaves $plant^{-1}$
- Leaf blade length
- Total tiller number and effective tiller number per hill
- Grain yield per hill

- Panicle number per hill
- Grain number per panicle
- Straw yield per ha
- Grain hill per ha

Yield and yield contributing parameters

- Panicle length
- Effective tiller
- Non effective tiller
- Grain number per panicle
- Grain weight per panicle
- 1000- grain weight
- Grain yield per plot
- Straw yield per plot
- Biological yield
- Harvest index

3.13 Data recording

3.13.1 Morphological parameters

3.13.1.1 Plant height (cm)

The height of plant was determined by measuring with a graduated scale placed from ground level to top of the leaves. The data was collected per plant at 30 days interval from 30 DAT to 90 DAT.

3.13.1.2 Number of total tillers hill^{-1}

Number of total tillers of each hill was noted at different sampling dates from the selected hills and was recorded in a note book for statistical analysis and interpretation.

3.13.1.3 Number of leaves plant^{-1}

Number of leaves per plant was counted from the age of 30 DAT at an interval of 30 days up to 90 DAT.

3.13.1.4 Leaf length (cm)

Leaf length was taken to be the length between the base and leaf tip using meter scale and was recorded for statistical analysis and interpretation.

Data were recorded on the following crop characters: plant height, leaf number per hill, leaf length, tiller number per hill, root length per hill, total tiller no., effective tillers, non effective tillers, panicle number per plant, grain number per panicle, 1000 grain weight and straw weight.

3.13.2.1 Number of panicles hill^{-1}

3 hills were randomly selected from different replication to record the number of panicles per hill.

3.13.2.2 Effective tiller

The total numbers of effective tillers per hill were counted and recorded for statistical analysis and finally used for interpretation.

3.13.2.3 Non effective tiller

The total numbers of non effective tillers per hill were counted and recorded.

3.13.2.4 Grain number per panicle

Grain numbers per panicle were counted and recorded in the notebook for statistical analysis and finally used for interpretation.

3.13.2.5 Grain weight per panicle (g)

Grain weight per panicle was weighed by electrical balance and recorded for statistical analysis and finally used for interpretation.

3.13.2.6 1000-grain weight (g)

One thousand clean oven dried grains were counted from the seed stock obtained from hill in each plot and weighed by using an electrical balance.

3.13.2.7 Grain yield (t ha^{-1})

Grain obtained from each plot was sun dried and weighed carefully. Then it was converted into yield ha^{-1}.

3.13.2.8 Straw yield (t ha^{-1})

Straw obtained from the selected hill of each unit plot were sun dried and weighed to record the straw yield $plot^{-1}$ and finally to t ha^{-1}.

3.13.2.9 Biological yield (t ha^{-1})

Grain yield and straw yield are all together regarded as biological yield. Biological yield was calculated using the following formula:

Biological yield= Grain yield + Straw yield

3.13.2.10 Harvest index (%)

Harvest index is the ratio of economic yield and biological yield, and the ultimate partitioning of dry matter between grain and vegetative parts is indicated by HI, the economic yield of rice is its grain, biological yield of a crop is the TDM at final harvest (Davald and Hamblin, 1976).

Harvest index was calculated on the basis of grain yield and straw yield using the following formula (Gardener *et al.,* 1985):

$$\text{Harvest index (\%)} = \frac{\text{Grain Yield}}{\text{Biological Yield}} \times 100$$

3.14 Statistical analysis

The data collected on different parameters under the experiment were statistically analyzed to compare treatment means using the MSTATC- computer software developed, (Russell 1986) and GENSTAT. If the treatments were significant the differences between pairs of means were compared by LSD followed by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

This chapter regards with the presentation and discussion of the results of the experiment on the response of plant growth regulators of 0, 30, 40, 50 and 60 ppm 6-BAP, 0, 30, 40, 50 and 60 ppm GA_3 and 0, 50, 75, 100 and 125 ppm NAA to observe their effect on selected aromatic rice cultivars. The result obtained on the performance of the 6-BAP, GA_3 and NAA on various morpho-physiological, yield and yield contributing characters have been presented below:

4.1 Effect of PGRs on growth characters of selected aromatic rice varieties

4.1.1 Plant height

Plant height indicates the nature of any kind of plants, its plant type and nature of leaf or canopy arrangement. It determines the nature of lodging, light, and air penetration. The height of rice plant at different growth stages was not influenced by the application of PGRs in aromatic rice varieties which have been presented in Table 2. Result shows that plant height was insignificant at their seedling stage. The highest plant height was 107.5 cm in $H_2{\times}L_0$ treatment and the lowest was 94.0 cm in $H_3{\times}T_3$ treatment at vegetative stage. At harvesting stage, the highest plant height was observed in $H_2{\times}T_0$ (162.3 cm). The lowest plant height was 146.3 cm in $H_2{\times}T_4$. There was no significant relationship among the varieties as well as NAA treatment on plant height at all growth stages in the present study.

Roxy (2016) revealed that 50 ppm 6-BAP showed better performance on plant height of Kataribhog rice variety at both vegetative and harvesting stage. Khanm (2016) reported that 150 ppm 6-BAP showed better performance on plant height of Kataribhog rice variety at both vegetative and harvesting stage. Akter (2012) revealed that 100 ppm NAA with 1.5 ton lime residual effect treatment combination showed highest plant height of Karari rice variety. Tiwari and Mishra (2002) reported that application of GA_3 at the level of 135 g ha^{-1} increased plant height from 9 to 15 cm. Awan and Alizai (1989) stated out that application of 100 ppm IAA to rice plant at panicle emergence stage significantly increase plant height and other Similar result was obtained by Adam and Jahan (2011) and they reported that both 100 ppm and 200 ppm NAA increases the plant height and tiller number in selected rice cultivar. Liu *et al.* (2012) concluded that NAA were used to inhibit the growth of unproductive tillers of rice plants. Singh and Uttam (1994) reported that wheat treated with planofix (NAA) significantly increased plant height that supported the result of the present study. Islam (2001) also reported the similar results with the application of IAA on rice.

Table 2: Plant height (cm) of kalijira under different levels of 6-BAP, GA_3 and NAA

Treatment	Vegetative stage	Harvesting stage
$H_1 \times T_0$	102.3	154.2
$H_1 \times T_1$	103.5	154.3
$H_1 \times T_2$	98.0	157.9
$H_1 \times T_3$	89.5	155.3
$H_1 \times T_4$	98.3	158.2
$H_2 \times T_0$	107.5	162.3
$H_2 \times T_1$	102.3	150.3
$H_2 \times T_2$	100.00	158.3
$H_2 \times T_3$	102.2	152.2
$H_2 \times T_4$	101.4	146.3
$H_3 \times T_0$	105.1	152.9
$H_3 \times T_1$	104.5	159.6
$H_3 \times T_2$	105.5	153.6
$H_3 \times T_3$	94.0	156.74
$H_3 \times T_4$	102.0	147.30

4.1.2 Leaf blade length

The leaf length of kalijira was not influenced by the application of 6-BAP, GA_3 and NAA which have been presented in Table 3. Result shows that the highest leaf length was 65.70 cm in $H_2 \times T_2$ treatment and the lowest was 50.70 cm in $H_2 \times T_3$ at vegetative stage. At harvesting stage, the highest leaf blade length was 68.00 in $H_2 \times T_2$. The lowest leaf blade length was 55 cm in $H_1 \times T_1$.

There was no significant relationship among the varieties as well as NAA treatment on leaf blade length at all growth stages. Roxy (2016) also found no significant relationship among the variety as well as 6-BAP treatment on leaf blade length. Khanm (2016) revealed that 150 ppm 6-BAP showed better performance on leaf blade length of Kataribhog rice variety at both vegetative and harvesting stage. Rahman (2013) revealed that the effect of NAA was more than that of GA_3 on the rice varieties. Niknejhad and Pirdashti (2012) revealed that application of GA_3 and Ecormon markedly increased leaf length. They found a positive and significant correlation between flag leaf length, flag leaf area and panicle length with paddy yield. Islam (2008) reported that 100 ppm IAA+ continuous flooded irrigation increases leaf length and breadth, Leaf dry weight, total dry matter at 80 DAT over control.

Table 3: Leaf blade length (cm) of kalijira under different levels of 6-BAP, GA_3 and NAA

Treatment	Vegetative stage	Harvesting stage
$H_1 \times T_0$	50.90	55.70
$H_1 \times T_1$	51.40	55.00
$H_1 \times T_2$	59.00	62.00
$H_1 \times T_3$	56.00	58.00
$H_1 \times T_4$	55.00	60.00
$H_2 \times T_0$	58.20	60.30
$H_2 \times T_1$	51.30	58.70
$H_2 \times T_2$	65.70	68.00
$H_2 \times T_3$	50.70	56.70
$H_2 \times T_4$	51.00	55.70
$H_3 \times T_0$	53.00	58.30
$H_3 \times T_1$	58.00	60.70
$H_3 \times T_2$	55.30	58.30
$H_3 \times T_3$	58.00	62.70
$H_3 \times T_4$	55.00	58.70

4.1.3 Tiller numbers hill^{-1}

Effective tiller is the potential factors for yield and yield components (Yoshida, 1981).The tillers hill^{-1} of kalijira at different growth stages was not influenced by the application of 6-BAP, GA_3, which have been presented in Table 4. Result shows that, the maximum number of tillers hill^{-1} (10.50) at 40 ppm of 6-BAP while the lowest number of tillers hill^{-1} (6) at 30 ppm of NAA.

Akter (2012) also revealed that the highest tiller number per hill was found while 150 ppm NAA was applied as treatment with the residual effect of 2 ton lime. Roxy (2016) revealed that 50 ppm 6-BAP had the better performance to increase the tiller number per hill. She observed highest highest tiller number per hill (8.66) at 50ppm while the lowest plant height was 6.33 in controlled level at harvesting stage. Khanm (2016) revealed that highest tiller number per hill was found while 200 ppm 6-BAP was applied on Kataribhog rice variety. Rahman (2013) revealed that 100 ppm NAA had the better performance to increase the tiller number per hill in different stages of plant growth. Liu *et al.* (2012) indicated that external 10 mg L^{-1} GA^3 and 1000 mg L^{-1} NAA significantly inhibit the growth of unproductive tillers, and the elimination of unproductive tillers promoted the growth of productive tillers at the middle and late growth stages, and promoted the development of heavy panicles, and finally increased the grain yield. Gill and Singh (1985) reported that spraying of 100 ppm NAA on wheat and barley had decrease to a great extent the number of non effective tiller hill^{-1} as compared to control. Sarker (2012) observed that the highest number of total tillers hill^{-1} was obtained from BRRI dhan52 and number of total tiller hill^{-1} was significant at 1% level of probability. He found number of total tillers hill^{-1} ranged from 13.160 to 17.253. Sahiduzzaman (2008) from an experiment on four fine rice varieties (Kataribhog, BRRI dhan34, Basmati and Kalijira) found significant effect on total number of tiller hill^{-1}. The highest number of tiller hill^{-1} (17.58) was observed in Kalijira and lowest (14.4) in Basmati.

Table 4: Number of tiller of kalijira under different levels of 6-BAP, GA_3 and NAA

	Treatment	Vegetative stage	Harvesting stage
	$H_1 \times T_0$	6.00	6.50
	$H_1 \times T_1$	7.00	8.00
	$H_1 \times T_2$	9.00	10.50
	$H_1 \times T_3$	7.23	8.37
	$H_1 \times T_4$	7.00	7.33
Interaction	$H_2 \times T_0$	5.00	6.33
	$H_2 \times T_1$	6.00	6.33
	$H_2 \times T_2$	7.33	8.63
	$H_2 \times T_3$	6.57	8.23
	$H_2 \times T_4$	6.67	7.00
	$H_3 \times T_0$	5.97	6.37
	$H_3 \times T_1$	5.67	6.00
	$H_3 \times T_2$	6.33	7.67
	$H_3 \times T_3$	6.13	7.97
	$H_3 \times T_4$	6.23	6.57

4.1.4 Leaf number

The effect of three PGRs on the leaf number of kalijira were not remarkable. The maximum number of leaves was obtained due to the application of NAA in H_3T_3 treatment at vegetative and harvesting stage.

The effect of NAA on the number of leaf was studied by several workers. Khanm (2016) revealed that maximum number of leaves was obtained from Kataribhog rice variety while 200 ppm 6-BAP was applied. Rahman (2013) found the maximum number of leaves from (BRRI dhan28) while the lowest number of leaves was emerged from Jirashail and Pasurshail varieties due to the application of GA_3 and NAA as a plant growth regulators and also in controlled condition .

Table 5: Leaf numbers of kalijira under different levels of 6-BAP, GA_3 and NAA

Treatment	Vegetative stage	Harvesting stage
$H_1 \times T_0$	4.07	4.5
$H_1 \times T_1$	5.44	6.0
$H_1 \times T_2$	5.66	6.0
$H_1 \times T_3$	5.00	5.0
$H_1 \times T_4$	4.22	4.5
$H_2 \times T_0$	4.66	5.0
$H_2 \times T_1$	5.55	5.0
$H_2 \times T_2$	5.22	5.0
$H_2 \times T_3$	5.55	6.0
$H_2 \times T_4$	4.78	6.0
$H_3 \times T_0$	5.55	5.0
$H_3 \times T_1$	5.77	5.70
$H_3 \times T_2$	4.11	4.0
$H_3 \times T_3$	5.66	6.0
$H_3 \times T_4$	4.77	5.0

Table 6: Yield contributing characters of three PGRS under 6-BAP, GA_3 and NAA

Treatment	Panicle Length (cm)	Number of Effective tiller	Non effective tiller	Grain no. panicle^{-1}	Grain wt. per pan	1000 grain wt. (g)
$H_1 \times T_0$	21.00	5.00	1.00	180	2.00	10.5
$H_1 \times T_1$	24.00	6.00	1.97	182	2.20	11.20
$H_1 \times T_2$	28.00	9.00	1.00	220	2.90	12.50
$H_1 \times T_3$	25.00	7.33	1.23	190	2.50	12.00
$H_1 \times T_4$	23.00	7.00	1.00	200	2.70	11.98
$H_2 \times T_0$	19.16	5.67	0.57	120	1.26	10.00
$H_2 \times T_1$	20.00	6.00	0.57	130	1.50	11.28
$H_2 \times T_2$	21.26	8.00	0.57	160	2.00	12.44
$H_2 \times T_3$	18.00	7.23	0.57	140	1.45	11.28
$H_2 \times T_4$	19.00	5.33	1.00	145	1.47	12.00
$H_3 \times T_0$	21.00	4.00	1.00	100	1.00	10.10
$H_3 \times T_1$	20.00	5.47	0.57	140	1.42	10.44
$H_3 \times T_2$	21.00	6.00	1.23	150	1.52	11.14
$H_3 \times T_3$	22.00	7.13	0.23	170	1.86	11.45
$H_3 \times T_4$	21.00	5.00	0.33	140	1.44	11.18

Table 7: Grain Yield, straw, %HI and biological yield of kalijira under different levels of 6-BAP, GA_3 and NAA

Treatment	Grain yield t ha^{-1}	Straw yield t ha^{-1}	Biological yield (t ha^{-1})	% Harvest index
$H_1 \times T_0$	1.88	3.06	5.33	35.10
$H_1 \times T_1$	2.00	3.00	5.45	38.75
$H_1 \times T_2$	2.55	3.50	6.15	43.95
$H_1 \times T_3$	1.13	3.10	5.53	40.83
$H_1 \times T_4$	2.03	2.80	5.10	42.12
$H_2 \times T_0$	1.48	2.98	4.53	36.78
$H_2 \times T_1$	1.78	2.88	4.80	44.40
$H_2 \times T_2$	2.25	3.27	5.01	38.64
$H_2 \times T_3$	2.01	3.03	4.88	35.55
$H_2 \times T_4$	1.85	3.09	4.78	37.05
$H_3 \times T_0$	1.58	3.01	4.57	32.45
$H_3 \times T_1$	1.75	3.01	4.83	36.64
$H_3 \times T_2$	1.87	3.13	5.13	35.67
$H_3 \times T_3$	2.01	3.43	5.45	37.56
$H_3 \times T_4$	1.88	3.33	5.20	36.00
SE	0.09	0.19	0.23	1.55
LSD	0.25	0.55	0.65	4.5

Mean followed by the same letter (ns) did not differ significantly at 5% level.

4.2 Yield and yield contributing characters of selected rice varieties under different levels of 6-BPA, GA_3, NAA

4.2.1 Panicle Length

Yield and yield contributing characters of selected kalijira, rice under different levels of 6-BAP, GA_3 and NAA.

There was no significant relationship was found between the ineraction of Kalijira and levels due to opplication of various levels of 6-BAP, GA_3 and NAA Table 6. Among the hormones 6-BAP showed. The highest (28) panicle per hill was found in $H_1 \times T_2$ treatment and the lowest number of panicle per hill (18) was in $H_2 \times T_3$ treatment. In case of 6-BAP and GA_3 Kalijira showed better performance at 40 ppm, while NAA showed better performance at 100 ppm.

Khanm (2016) revealed that highest panicle length was obtained from Kataribhog rice variety while 50 ppm 6-BAP was applied. Rahman (2013) showed that all the varieties produced lower number of panicle $hill^{-1}$ in controlled plants than those of PGR treated plants. He observed the highest number of panicle $hill^{-1}$ using NAA applied plots, intermediate due to GA_3 over control. Tao and Shiying (1992) reported that treatment with ABT increased panicle numbers. Zhou (2005) reported that 20% spikelet of a panicle are enclosed in the sheath of flag leaf in most *indica* CMS lines their three internodes are shorter than those of pollen parents, especially the top most internodes. He also observed that GA_3 enhance panicle and stigma exertion. Adjust plant height of both parents. Moreover he reported that the best time for first spraying is when 2-5% panicles have emerged out of bracts and 4-5 in consecutive days, time 7 am to 11 am or 4 pm to 7 pm.

4.2.2 Effective tiller

There was no significant relationship was found between the interaction of varieties and levels due to application of various levels of 6-BAP, GA_3 and NAA.

6-BAP showed better performance than that of GA_3 and NAA.

The highest number of effective tiller per $hill^{-1}$ was (9.00) in $H_1 \times T_2$ treatment at the levels of 40 ppm of 6-BAP. The lowest number of effective tiller $hill^{-1}$ was (4.00) in $H_3 \times T_0$ treatment.

Akter (2012) revealed that highest effective tillers $hill^{-1}$ was found while 150 ppm NAA was applied as treatment with the residual effect of 2 ton lime. Khanm (2016) found highest number of effective tillers $hill^{-1}$ from Kataribhog rice variety while 1000 ppm 6-BAP was applied and highest number of non effective tillers $hill^{-1}$ at controlled level of 6-BAP.

4.2.3 Non effective tiller

By spraying different levels of 6-BAP, GA_3 and NAA on non effective tiller $hill^{-1}$ was insignificant (Table 6). Result showed that non effective tiller of kalijira among three hormones at different levels are average both vegetative and harvesting stage.

Khanm (2016) found highest number of non effective tillers $hill^{-1}$ from Kataribhog rice at controlled level. Singh and Gill (1985) reported that spraying of 100 ppm NAA on wheat and barley had decrease to a great extent the number of non effective tiller/hill as compared to control. Ling and Ma (1998) studied on winter wheat with endogenous growth regulator IAA and demonstrated that non effective tiller was decrease by IAA.

4.2.4 Grain number per panicle

There is a significant effect among the hormones and levels of kalijira rice variety on grain number per panicle. Among the hormones 6-BAP and among the levels 40 ppm (T_2). The highest number of grains panicle ware (220) in $H_1 \times T_2$ treatment and the lowest number of grains per panicle were in $H_3 \times T_0$ treatment.

In this study 6-BAP showed better performance at 40 ppm.

Roy (2016) reported that 50 ppm BAP increased the grain number per panicle of Kataribhoy rice verity.

4.2.5 Grain weight (g) per panicle

There is a significant effect among the PGRs and levels of kalijira on grain weight per panicle. Among the PGRs and among the levels 40 ppm (T_2) of 6-BAP showed the better performance. The interaction effect of different levels of 6-BAP, GA_3 and NAA was also significant for grain weight per panicle (Table 6). The highest grain weight per panicle was observed at $H_1 \times T_2$ (2.90g). The $H_3 \times T_0$ (1.00 g) showed the lowest performance in controlled plots.

Roxy (2016) reported that 50 ppm BAP increased the grain weight per panicle of Kataribhog rice variety.

4.2.6 1000- Grain weight

There is a significant effect among the PGRs on 1000-grain weight, but no significant relationship was found between the interaction of PGRs and levels due to application of various levels of 6-BAP, GA_3 and NAA (Table 6). Among the PGRs 6-BAP and among the levels 40 ppm (T_2) showed the better performance. The highest weight of thousand grains was observed at $H_1 \times T_2$ (12.50 g). The treatment $H_2 \times T_0$ (10.00g) showed the lowest performance in 60 ppm.

Roxy (2016) reported that 50 ppm BAP increased the 1000-grain wt. of Kataribhog rice variety. Khanm (2016) also reported that Kataribhog produced the highest 1000-grain weight while 50 ppm 6-BAP was applied. Kabir *et al. (2004)* studied with rice new cv. Begunbitchi, Chinigura and Kaijira and reported that Chinigura produced the highest 1000-grain weight. Akter *et al.* (2012) revealed that 100 ppm NAA with 1.0 ton lime residual effect showed the best performance in all yield contributing characters in kataribhog rice such as number of filled grain, 1000-grain weight and yield production. Bakhsh *et al.* (2012) revealed that the highest number of panicles, spikelets panicle^{-1}, normal kernels,1000-grain weight, paddy yield and water productivity was recorded by applying naphthalene acetic acid @ 90 mL ha^{-1} and I_2 (75 cm) level of irrigation water (10 irrigations). Khan *et al*. (2011) revealed that application of growth regulator (NAA) at the rate of 90 ml ha^{-1} at panicle initiation stage resulted in highest number of 88 and 90 % normal kernel, 23.00 and 23.20 g 1000-grain weight during 2004 and 2005, respectively. Liuping *et al*. (1998) in an experiment with growth regulators such as NAA on wheat found that among growth regulators, NAA was the most effective to increase 1000 grain weight.

4.2.7 Grain yield (t ha^{-1})

The PGRs and their various levels were interacted significantly with each other in respect of grain yield which was presented in Table 7. There is also a significant effect among the PGRs and their different levels of kalijira on grain yield. Among the PGRs 6-BAP and among the levels 40 ppm (T_2) showed the better performance.

The highest yield was found in $H_1 \times T_2$ (2.55 t ha^{-1}) followed by $H_2 \times T_2$ and $H_3 \times T_3$ (2.25 t ha^{-1} and 2.01 t ha^{-1}) respectively. The lowest grain yield was found in $H_2 \times T_0$ (1.48 t ha^{-1}).

Roxy (2016) reported that 50 ppm 6-BAP increased the grain yield of Katari rice variety. Khanm (2016) reported that 100 ppm 6-BAP produced highest grain yield and yield components of rice. Akter (2012) revealed that 100 ppm NAA with 1.0 ton lime was the best for yield and yield contributing characters in kataribhog rice. Bakhsh *et al.* (2012) reported that application of NAA increased the grain yield and yield components of rice. Similar result was obtained by Liu *et al.* (2012). Singh and Uttam (1994) observed that spraying of planofix (NAA) on wheat plant, significantly increased grain yields, which supported the result of the present study.

4.2.8 Straw yield (t ha^{-1})

There is a significant effect among the PGRs and their various levels on straw yield between the interaction of PGRs and their different levels which was presented in Table 7. Among the PGRs 6-BAP showed the better performance than that of GA_3 and NAA. The highest straw yield was obtained from $H_1 \times T_2$ (3.50 t ha^{-1}) and the lowest yield was found in $H_1 \times T_4$ (2.80 t ha^{-1}).

Rahman (2013) and Akter (2012) also found no positive effect of NAA application on straw yield. Roxy (2016) revealed that 200 ppm NAA reduced the straw yield of Kataribhog rice cultivar. Khanm (2016) reported that the straw yield of kataribhog was significantly increased at the controlled level. Zahir *et al.* (2007) stated that maximum straw yield (5.3 t ha^{-1}) was recorded in IAA-blended N-enriched compost plus 60 kg ha^{-1} N fertilizer which was at par with kinetin-treated N-enriched compost plus 60 kg ha^{-1} N fertilizer and full dose of N fertilizer.

4.2.9 Biological yield

The biological yield was presented in Table 7. Table 7 showed that biological yield was not influenced due to the interaction effect of PGRs and their different levels. Among the PGRs and among the levels 40 ppm (T_2) and 6-BAP showed the better performance. The maximum biological yield was $H_1 \times T_2$ (6.15t ha^{-1}) and the lowest yield was found in $H_2 \times T_0$ (4.53t ha^{-1}).

Roxy (2016) found that the maximum biological yield (6.25 t ha^{-1}) that was obtained from the 50ppm 6-BAP. Khanm (2016) reported that 100 ppm 6-BAP produced maximum biological yield of Kataribhog rice. Rahman (2013) was obtained maximum biological yield (15.51 t ha^{-1}) from the combination of variety BRRI dhan28 with 100 ppm GA_3. The lowest biological yield (10.50t ha^{-1}) was obtained from the combination of variety Nerica-4 and 100 ppm of GA_3.

4.2.10 Harvest index

Harvest index (HI) is an important yield determining character which can through idea along partitioning efficiency. Table 7 showed that harvest index (HI) was influenced due to the interaction effect of PGRs and their different levels. The highest, harvest index $H_2 \times T_1$ (44.40 %) and the lowest yield was found in $H_3 \times T_0$ (32.45%).

Roxy (2016) found that the highest harvest index 39.24% at 50ppm 6-BAP. Khanm (2016) reported that 100 ppm 6-BAP produced highest harvest index. Rahman (2013) found the highest harvest index (49.60 %) which obtained from BRRI dhan2 with 100 ppm NAA and the lowest harvest index (42.01%) which obtained from the Nerica-4 without GA_3 or NAA. Akter (2012) revealed that 100 ppm NAA application obtained highest harvest index. HI is the measure of the efficiency of conversion of photosynthate into economic yield of a crop plant (Dutta and Mondal, 1998).

CHAPTER V

SUMMARY AND CONCLUSION

The research work was done at the agricultural farm under the department of Agricultural Chemistry of Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during the period of July to December, 2016 to study the response of 6-BAP, GA_3 and napthalene acetic acid (NAA) on the performance of kalijira rice cultivar. The experiment consisted of Kalijira and five levels of PGRs viz. 0 ppm (T_0), 30 ppm (T_1), 40 ppm (T_2), 50 ppm (T_3) and 60 ppm (T_4) of 6-BAP GA_3. In case of NAA, the doses are 0 ppm (T_0), 50 ppm (T_1), 70 ppm (T_2), 100 ppm (T_3) and 125 ppm (T_4).

Various morphological parameters like plant height, number of tiller per hill, number of effective tillers per hill, number of leaves per plant, grain yield, straw yield etc. were studied for the purposes.

There is a significant effect among the hormones on panicle length of kalijira due to application of various levels of 6-BAP, GA_3 and NAA. Among the PGRs 6-BAP showed the better performance. There is a significant effect among the PGRs and various levels of 6-BAP, GA_3 and NAA of kalijira on number. of effective tiller. Among the doses, 40 ppm of 6-BAP, showed the best performance than that of 40 ppm GA_3 and 100 ppm NAA. There is also a pronounced effect among the PGRs and various levels of 6-BAP, GA_3 and NAA of aromatic rice on 1000-grain weight, harvest index and biological yield. In these parameters 6-BAP showed the best performance than that of GA_3 and NAA.

The interaction between PGRs and their levels on some yield contributing characters such as grain number per panicle, grain weight per panicle and total grain yield were marketed influenced by 6-BAP, GA_3 and NAA.

The maximum number of panicle per hill (28) was found in $H_1 \times T_2$ treatment. The maximum number of effective tiller hill^{-1} was found in $H_1 \times T_2$ (9). The maximum number of grains per panicle was observed at $H_1 \times T_2$ (220). The highest grain weight per panicle was observed at $H_1 \times T_2$ (2.90 g). The highest weight of thousand grains was observed at $H_1 \times T_2$ (12.50 g). The highest gram yield was found in $H_1 \times T_2$ (2.55 t ha^{-1}). Highest straw yield was obtained from $H_1 \times T_2$ (3.50 t ha^{-1}). The maximum biological yield was $H_1 \times T_2$ (6.15 t ha^{-1}) and the highest harvest index $H_2 \times T_1$ (44.40 %).

It is concluded that aromatic rice cv. Kalijira showed the better performance at 40 ppm for 6-BAP while 40 ppm for GA_3 and 100 ppm for NAA and may be recommended for the farmers level. Three PGRs like, 6-BAP, GA_3 and NAA might be useful to increase aromatic rice production which is an environment-friendly tool for agricultural management practices.

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