# MORPHO-PHYSIOLOGICAL CHARACTERISTICS AND YIELD OF THREE AROMATIC RICE CULTIVARS UNDER DIFFERENT LEVELS OF 6-BAP

**THESIS**

**BY**

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**Student No. 1705243**

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**MASTER OF SCIENCE (MS)**
**IN**
**AGRICULTURAL CHEMISTRY**

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**HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR-5200**

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**December, 2018**

**Dedicated**

**To**

**My Beloved Parents**

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*July-December, 2018* *The Author*

## ABSTRACT

A field experiment was conducted to study the effect of 6-Benzyl aminopurine (6-BAP) on morpho-physiological, yield and yield characters of three aromatic rice varieties cv. Chinigura ($V_1$), Kataribhog ($V_2$) and Kalijira ($V_3$). The 6-BAP was sprayed 0, 20, 40, 60 and 80 ppm at vegetative and pre flowering stages. Results showed that the morpho-physiological, yield and yield attributes were significantly different among the varieties studied under the application of different levels of 6-BAP. There was a significant relationship among the varieties and different levels of 6-BAP on both vegetative and harvesting stages regarding tillers $hill^{-1}$. A statistically significant variaties was observed in plant length, root depth, panicle length, effective and non-effective tiller, grain yield, biological yield, harvesting index, chlorophyll-a, total chlorophyll content, and poline content except straw yield and 1000 grain weight. Among three varieties, Kataribhog had more yielding ability by using 60 ppm $T_4$ 6-BAP than those of chinigura and kalijira. The highest plant height (172.9 cm) was found in $V_1$ variety using 60 ppm of 6-BAP. The highest panicle length was in $V_1$ variety using 40 ppm of 6-BAP and the lowest was found in $V_2$ variety under control treatment. The maximum amount of grain per panicle (287.00) was found in $V_2$ variety in the treatment $T_4$ (60 ppm) and (241.1) was the lowest value which was found in $V_1$ variety in the control $T_1$ treatment. The maximum amount of chlorophyll-a (24.59 mg $g^{-1)}$ found at $V_1 \times T_4$ and the lowest amount of chlorophyll a (14.87 mg $g^{-1}$) showed by the treatment $V_2 \times T_2$. The highest amount of total chlorophyll content (25.95 mg $g^{-1}$) was in $V_1 \times T_4$ treatments while the lowest amount (18.35 mg $g^{-1}$) was at $V_3 \times T_5$ treatments. The highest proline content (0.35 mg $g^{-1}$) was recorded in $V_1 \times T_2$ and the lowest proline content (0.26 mg $g^{-1}$) was recorded in $V_2 \times T_4$. Some yield contributing characters of aromatic rice such as grain number per panicle, grain weight per panicle and total grain yield were influenced due to the interaction effect of variety and levels of 6-BAP. The spraying with 60 ppm 6-BAP had the better stimulation on growth on yield of Kataribhog and Kalijira but 80 ppm for Chinigura. The highest yield was in Kataribhog rice variety (1.66 t $ha^{-1}$) spraying 60 ppm 6-BAP twice at vegetative and preflowering stages. Plant growth regulators promote the growth and yield of aromatic rice varieties which might be an alternative eco-friendly tool for rice production. Out of the three rice varieties Kataribhog performed better considering growth and yield parameters.

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# CHAPTER 1

# INTRODUCTION

Rice (*Oryza sativa* L.) is the staple cereal food for about half portion of the world's populace. However, more than 90 % of rice is consumed in Asia, where it is the staple food for a greater part of the populace, including 560 million hungry people in the area (Mohanty, 2013). In Asian countries, Rice gives about half of the total dietary carbohydrate providing 50-80% starch and providing 50-80% of the daily calorie consumption (Khush, 2005).

Aromatic rice (*Oryza sativa* L.) is favored by consumer everywhere throughout the world because of its flavor and palatability. Small grain aromatic (SGA) rice has been the central elements for preparation of numerous fabulous dishes in Bangladesh and Eastern India.

The imperative element of this type of rice is its satisfactory aroma which has been considered as a high value added trait for rice. Grain nature of rice play a vital role in customers' acceptability and after yield, it is the second significant breeding consideration (Jewel *et al.*, 2011).

Aromatic rice contributes a little but unique group of rice and has increased greater significance with the overall increment in the demand for fine quality rice (Sun *et al.*, 2008). Now a days aromatic rice has been introduced to the global market.The demand of aromatic rice is increased markedly in recent years for both local and global market. Shockingly, the aromatic rice regularly has unfortunate agronomic characters, for example, low yield, weakness to nuisances and ailments, and solid shedding (Faruq *et al.*, 2011).

Aromatic rice has great potential to attract rice consumer for its taste and flavor, and high cost to support up the financial state of the rice producer in the developing countries like Bangladesh. As a result, of its characteristic substance mixes which give it a particular flavor or smell when cooked, aromatic rice directions a higher cost than non aromatic rice. A number of fine aromatic rice cultivars are grown by the farmers in Bangladesh. Such common variety are Kalijira, Dulabhog, Basmati, Chinisagar, Badshabhog, Kataribhog, Basmati, Banglamoti (BRRI dhan50), BRRI dhan34, BRRI dhan37 and

BRRI dhan38. Bangladesh has a bright prospect for export of fine rice thereby earning foreign exchange. The rices have for quite some time been famous in the orient and are currently becoming more famous in Middle East, Europe and the United States (Das *et al.*, 2000).

The production cost of aromatic and fine rice is low compared to coarse rice. Bangladesh is locally adapted, photoperiod-sensitive, and grown during aman season under rainfed lowland ecosystem. In Bangladesh, among the different aromatic rice varieties, Chinigura is the predominant one that covers more than 70% of rice farms in the northern districts of Naogaon and Dinajpur. Other important aromatic rice varieties are Kalijira (predominantly grown in Mymensingh) and Kataribhog (mainly cultivated in Dinajpur) (Baqui *et al.,* 1997).

Use of the plant growth regulators in rice has been one of the most potential tools for increasing crop production. PGR as either naturally or synthetic compounds that are applied directly to a target plant to alter its physiological processes or its structure to improve quality, increase yields, or facilitate harvesting control, undesirable vegetative growth of crop plants, enhancing fruiting bodies (Havargi, 2007). Same plant growth regulators are active in different stage of the same plant in different ways.

Auxin, cytokinins, gibberellines, abscisic acid, etylene are the major five group of plant hormones. Among this, 6-benzyl aminopurine (6-BAP) and kinetin are two synthetic cytokinine. Cytokinins such as 6-benzyl aminopurine (6-BAP) and kinetin are known to reduce the apical meristem strength and promote both axiliary and adventitious shoot formation from meristematic explants in banana (Jafari *et al*., 2011).

Among the plant growth regulators Cytokinins proved to stimulate cell division, induce shoot formation and axillary shoot proliferation and retard root formation. Cytokinines have been reported to induce the development of axillary buds and adventitious buds through breaking apical dominance (Taji *et al.*, 1995).

The quantitative and qualitative responses of plants to different Cytokinines, such as kinetin (Kin) and 6-Benzyl Aminopurine (6-BAP) may differ considerably (Muhammad and Muhammad, 2005). However, the application of higher BAP concentrations inhibits prolongation of adventitious meristems and the conversion into complete plants (Buising *et al*., 1994).

A recent study by Dissanayaka *et al.* (2015) revealed that BAP concentration of 3.0 $mgL^{-1}$ under 24 h exposure duration proved to be the optimum BAP treatment for the increase of seedling vigour of *E. trinervium* under the green house conditions. Use of 6-BAP found to build plant height, number of leaves per plant, natural product measure with resulting upgrade in seed yield in various plants. The utilization of plant growth regulators in the field of horticulture has been popularized in some developed nations like USA, Europe and Japan. The current employments of various plant growth regulators are in high value horticultural products as well as to expand field crop yield straight forwardly either by expanding harvesting index or organic yield (Basuchaudhuri, 2016).

The uses of growth substances such as 6-benzyl aminopurine (6-BAP) at different concentrations that may increase aromatic rice plant production. It is very certain that endogenous and exogenous plant development controllers assume a vital job in adjusting and directing numerous physiological procedures in plants and these procedures are significantly affected by natural conditions. Although some exploration 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 6-BAP is constrained in our nation, thinks about in different nations of the world in spite of the fact that gives valuable data, that can't be prescribed without preliminary examination. Therefore, more researches or trials are necessary to investigate the efficacy of 6-BAP on aromatic rice. Thus, the present study was done based on the following specific objectives

- To study the growth characteristics of three different varieties of aromatic rice cv. Kataribhog, Kalijira and Chinigura using 6-Benzyl aminopurine (6-BAP).
- To investigate the yield potentials of aromatic rice cv. Kataribhog, Kalijira and Chinigura under 5 levels of 6-BAP.
- To find out the suitable dose of 6-Benzylaminopurine (6-BAP) for recommending among the farmers' level.

# CHAPTER II

# REVIEW OF LITERATURE

Rice is one of the most important cereal crops in the world. Rice has wide adaptability to different environmental condition, as it is evident from its worldwide population. Plant growth regulators (PGRs) are organic compounds, other than nutrients, that modify plant physiological processes. 6-BAP is one of them. Many plant scientists are engaged in changing the pattern of growth and development of plants for a long time. 6-BAP is 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 this growth regulator 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 the most important morphological parameter. It is a measure of longitudinal or vertical distribution of plants. Khanam (2016) revealed that the application 150 ppm 6-BAP showed better performance on plant height of Kataribhog rice variety at both vegetative and harvesting stage.

Roxy (2016) reported that 50 ppm 6-BAP showed better performance on plant height of Kataribhog rice variety at both vegetative and harvesting stage. Sharmin (2016) stated that highest plant height was found at vegetative stage using 50 ppm NAA at harvesting stage, better result was found on Kalijira rice variety by applying 200 ppm NAA.

Rahman (2013) found that plant height was increased in their succession stages at different days after transplanting (DAT) due to age and application of PGRs and also found NAA had more pronounced effect than $GA_3$ in regard to plant height of some selected rice variety. Ghodrat *et al.* (2013) revealed that the highest increase of crop growth rate (11.4 g $m^{-2}$ $days^{-1}$) belonged to IBA 100 ppm and $GA_3$-100 ppm 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.

Ghodrat and Rousta (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.

Jahan *et al.* (2011) showed 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. Application of 100 ppm Naphthalene Acetic Acid increase the plant height, number of leaves plant$^{-1}$ and number of tillers plant$^{-1}$ in BRRI dhan29.

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.

Maximum increase in plant height (3%) was observed with Boron (1 kg ha$^{-1}$) application at sowing in rice cultivars (Ahmad and Irshad, 2011). Significant interaction effect was found between the applied of NAA 90 ml ha$^{-1}$ at panicle initiation stage which recorded highest plant height (140 cm) due to intact cells elongation (Bakhsh *et al.*, 2011). Tiwari *et al.* (2011) revealed that application of NAA @ 100 g ha$^{-1}$ showed significantly highest plant height (71.52 cm) compare to other treatment of applications.

Kurtyka *et al.* (2009) found that the treatment of maize coleoptiles' segments with IAA (0.01 mmol × 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.

Islam (2008) 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 (119.39 cm) 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) found that four fine rice varieties (BRRI dhan34, Basmoti, Kataribhog and Kalijira) showedthe 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. 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.

Virmani *et al.* (2007) reported that application of $GA_3$ also increased the relative height of the pollen parent over the seed parent. Dunand (2005) reported that application of Gibberellic acid in rice increased plant height from 91 to 95 cm. Chinigura-1 produced the tallest plant at harvest (148.20 cm) than Begunbitchi and Kalijira as reported by Kabir *et al.* (2004).

Application of Gibberellic acid ($GA_3$) showed significant difference in plant height in CMS line of rice hybrid. For each increasing dose of $GA_3$ by 25 g $ha^{-1}$, the plant height increased significantly and a maximum of 87.26 cm was recorded with 100g $GA_3$ spray while it was 69.31cm in the control (Jagadeeswari *et al.*, 2004).

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. 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).

The increase in plant height with the application of $GA_3$ has been ascribed to elongation of cells in the three upper most internodes (Li and Yuan, 2000).

Khripach *et al.* (1999) reported significantly difference in plant height at 42 and 70 days after sowing with soaking the seeds in solutions of 0.01, 0.05 or 0.1 mg $L^{-1}$ brassinosteriods for eight hours. Kumar (1999) reported that application of $GA_3$ 100 g $ha^{-1}$ + urea 2% recorded highest plant height of 101.8 cm. Application of $GA_3$ + 1.5% boric acid was one of the most effective combine for increasing the plant height (Singh and Sahoo, 1996).

Singh *et al.* (1994) indicated that miraculan (triacontanol), agromax and planofix (NAA) significantly increased wheat plant height. The highest grain yield were obtained with 250 ml Miraculan $ha^{-1}$ applied at tillering and booting stages. Viraktamath (1993) recommended an extra dose of $GA_3$ on pollen parent to significantly increase the plant height by 10.5 cm. 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 $CaCl_{2.}$

Duan and Ma (1992) reported that $GA_3$ application significantly increased plant height of hybrid Zhenghshani 97A × IR 26. 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 $CaCl_2$.

Srivastava *et al.* (1979) also noticed significant increase in plant height in 27 of the 32 tall and dwarf strains of rice (*Oryza sativa* L.) sprayed with 0, 10, 20 and 50 µg $ml^{-1}$ of $GA_{3.}$

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.

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.

Mitchell *et al.* (1970) reported that brassinosteriods can be used to promote stem elongation and cell division in plants. Brassinosteroids act along with auxins to stimulate cell elongation (Katsumi, 1991 and Sasse, 1991).

**Leaf blade length**

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

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.

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. Brassinosteroids affect many plant processes includes leaf size (Fujii *et al.,* 1991 and Morinaka *et al.,* 2006). Leaf area of rice at anthesis was significantly higher in BRs treated plants under both irrigated and moisture-stress conditions (Sairam, 1994).

**Number of tillers hill$^{-1}$**

Khanam (2016) found that highest tiller number per hill was found while 200 ppm 6-BAP was applied on Kataribhog rice variety. Sharmin (2016) observed that that the maximum number of tillers hill$^{-1}$ was obtained from Chinigura with 150 ppm NAA while the lowest number of tillers hill$^{-1}$ was emerged from variety Kataribog with 150 ppm NAA at harvesting stage.

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

Liu *et al.* (2012) stated that application of10 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. 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. Akter (2012) also showed 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. Yang 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.

Adam and Jahan (2011) showed that maximum number of tillers hill$^{-1}$ were observed by the application of boron (1 kg ha$^{-1}$) at sowing i.e., 21 % excess number of tillers over control in coarse rice and 17% in fine rice. Numbers of tillers plant$^{-1}$ (30.38%) were significantly increased with application of 100 ppm NAA in variety BRRI dhan-29.

Elankavi *et al.* (2009) observed that the exogenous application of $GA_3$ significantly increases the plant height and number of tillers in rice.

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.

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.

Brassinosteroids affect many plant processes that control tiller number (Fujii *et al.*, 1991 and Morinaka *et al.*, 2006). Kabir *et al.* (2004) showed that the cultivar Kalijira produced the highest number of tillers hill$^{-1}$ at maturity followed by Begunbitchi and Chinigura-1 varieties. The cultivar Kalijira produced the highest number of effective tillershill$^{-1}$ than Chinigura-1. BRRI (2000b) 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.

Kumar (1999) reported that more number of tillers observed with application of $GA_3$ @ 100 g $ha^{-1}$. Jagadeeswari *et al.* (1998) reported that spraying of 50 $GA_3$ g $ha^{-1}$ and $GA_3$ 100 g $ha^{-1}$ + $KH_2PO_4$ 2 % were improved the tiller number.

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

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) indicated that the effect of growth regulators like as benzyladenine (BA), 2-chloroethyl trimethyl ammonium chloride, $GA_3$, kinetin, and NAA on ratoon tillering depended on their concentration and time of application but all growth regulators increased rationing.

Singh and Gill (1985) showed 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. Singh and Gill. (1985) also observed that wheat and barley, spraying with 100 ppm NAA at the tillering and heading stage significantly increase the number of tiller $hill^{-1}$.

**Number of Leaves $plant^{-1}$**

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

Rahman (2013) showed 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) reported 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 dhan29 (V1) and varied significantly at 60 DAS.

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$^{-1}$ and leaf area hill$^{-1}$.

Gurdev and Sexena (1991) found 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.

Guoping and Etonal (1992) observed that ABT, an auxin type of phytohormone increase speed of leaf sprouting and area of leaf in maize. Singh *et al.* (1985) showed 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$^{-1}$.

**Root depth**

Khanam (2016) revealed that highest root length was obtained from Kataribhog rice variety while 200 ppm 6-BAP was applied.

Sharmin (2016) states that that highest root depth was obtained from Kalijira rice variety while0 ppm NAA was applied and lowest found in chinigura variety by the application of 150 ppm of NAA.

Wang and Deng (1992) observed that rice spraying with $10^{-1}$ and $10^{-3}$ ppm NAA at tillering stage significantly increase root dry weight. NAA also promoted new root growth.

### 2.2 Growth regulators on the physiological characters of rice and similar crops

**Chlorophyll**

Sharmin (2016) the highest amount of total chlorophyll content (39.37 mg g$^{-1}$) was found on kataribog rice at 100 ppm treatment while the lowest amount of total chlorophyll content (26.81 mg g$^{-1}$) at Kalijira rice at 0 treatments. There was no significant relationship among chlorophyll-b, varieties and different levels of NAA.

Roxy (2016) also found no significant variation with the treatment (BAP) on total chlorophyll content of the flag leaf of Kataribhog rice cultivar. Akter (2012) revealed that the highest total chlorophyll content of the flag leaf of Katari rice cultivar was obtained from 100 ppm NAA with no residual effect of lime treatment combination.

Total chlorophyll and its fractions 'a' and 'b' contents decreased with increased salinity (0, 100 and 200 mol $m^{-3}$ NaCl) in two spring wheat cultivars, Barani-83 (salt sensitive) and SARC-1 (salt tolerant). However, foliar application of $GA_3$ (100 mg $L^{-1}$) enhanced both the pigments in Borani-83 but total chlorophyll in both the lines (Ashraf *et al.*, 2002).

Medhi and Baruh (2001) reported that chlorophyll content in leaf increased significantly due to Gibberellic acid application in all the genotypes, among which IET 6155 exhibited maximum response to $GA_3$ application.

Fariduddin *et al.* (2008) revealed that application of 28-homobrassinolide at 15 DAS, had 42% and 29% more chlorophyll content in mung bean than the control at 30 and 50 days after sowing, respectively.

Kaufman *et al.* (1992) carried out that calli were induced from excised rice from whole seed's in the presence of 1-5 mg $L^{-1}$ NAA. Excised embryos accumulate up to 6 times higher NAA concentrations than whole seeds. In the presence of NAA at low concentrations and 2-10 mg $L^{-1}$ kinetin, green calli were induced from excised embryos; chlorophyll contents increased as kinetin concentration increased.

Sunohara and Matsumoto (1997) showed that application of Auxins (NAA, 2,4-D and IAA) on corn (maize) growth significantly increased in chlorophyll content. Ratna *et al.* (1995) revealed an increased root dry weight with ABT-6 at 20 ppm in soyabean.

Singh and Jain (1964) observed that both chlorophyll 'a' and 'b' as well as chlorophyll 'a'/'b' ratio decreased with increase in salinity *viz.*, 0, 4, 8 mMhos $cm^{-1}$ both in fruit wall and seed in chickpea, however, growth regulators spray viz., kinetin (10 ppm) and $GA_3$ (25 ppm) enhanced the chlorophyll contents.

## 2.3 Growth regulators on the yield components of rice and similar crops

### Panicle length

The aromatic rice cv. chinigura showed better performance at 150 ppm while Kataribhog showed better performance at 100 ppm and Kalijira showed better performance at 200 ppm of NAA, respectively (Sharmin, 2016)

Khanam (2016) revealed that highest panicle length was obtained from Kataribhog rice variety while 50 ppm 6-BAP was applied. The aromatic rice cv chinigura showed better performance using 150 ppm NAA while kataribhog showed better pefomance at 100 ppm. The external application of $GA_3$ on rice raton performance in north of Iran conditions during 2009, was significantly increased the panicle length (Niknejhad and Pirdashti, 2012).

The highest increased panicle length 18.12 cm was showed by the application of 45 g $GA_3$ + 10 g Urea + 2 g Boric acid + 2 g $ZnSO_4$ + 2 g $K_2PO_4$ $ha^{-1}$ (Tiwari *et al.,* 2011). Boron application at sowing and at tillering increased the panicle length over control significantly in coarse (10%) and fine (12%) cultivars of rice (Ahmad and Irshad, 2011).

Significant increase in the panicle length with application of 100 ppm Naphthalene Acetic Acid in BRRI dhan29 was reported by Adam and Jahan (2011).

Zhou *et al.,* (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.

Kabir *et al.* (2004) observed that the cultivar Chinigura produced the highestpanicle 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, BRRI dhan39 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.

Significantly increased panicle length with application of $GA_3$, it is elongates the three uppermost internodes below the neck of the panicle due to elongation of cells (Jagadeeswari *et al.*, 1998).

Gurbaksh *et al.* (1995) studied with 5 ppm IAA and sprayed on rice cv. Java at an thesis 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. Yuan and Virmani (1988) recommended 75 g $ha^{-1}$ of $GA_3$ to grow panicle longer than flag leaf to avoid clipping.

Prasad *et al.* (1988) reported that application of 1.5% Boric acid and combination with $GA_3$ promotes panicle exertion. Sharma (1991) observed that two sprays of $GA_3$ 60 ppm and 30 ppm concentration applied at 10% and 30 % heading stage respectively aided in enhancing.

Duan and Ma (1992) reported that foliar application of $GA_3$ significantly increased ear extension from the flag leaf sheath. Significantly higher panicle exsertion 86.9% was recorded with application of $GA_3$ @ 75 g $ha^{-1}$ followed by $GA_3$ @ 25 g $ha^{-1}$ in combination with 100 ppm NAA (86.5%) (Biradarpatil and Shekhargouda, 2006).

**Effective and non-effective tiller**

Khanam (2016) studied 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.

Sharmin (2016) showed that Chinigura variety showed better performance at 150 ppm, Kataribhog showed better performance at 100 ppm and Kalijira showed better performance at 100 ppm of NAA than that of other levels.

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.

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) reported 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.

Zahir *et al.* (1999) carried out an experiment on rice cv. Basmati 385 seedlings roots were dipped in solution containing seven IAM levels ($10^{-9}$ to$10^{-3}$) 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) observed 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. Ali *et al.* (1996) observed an increase in productive tillers plant$^{-1}$ in rice with boron application.

The number of productive tillers plant$^{-1}$ were maximum in 100 g $GA_3$ spray and gradual increase in productive tillers with each dose of $GA_3$ application (Jagadeeshwari *et al.*, 1998). Kumar (1999) reported that significantly highest productive tillers plant-$^{1}$ (13.28) observed with application of $GA_3$ g ha$^{-1}$ + urea 2%.

Tiwari *et al.* (2011) reported that significant increase in effective tillers is 26.35 with the application 45 g $GA_3$ + 10 g Urea + 2 g Boric acid + 2 g $ZnSO_4$ + 2 g $K_2PO_4$ ha$^{-1}$.

**Grain no. panicle$^{-1}$**

Sharmin (2016) states that 150 ppm NAA on kalijira variety showed better performance on grain no. per panicle of rice variety. Chinigura variety showed better performance at 100 ppm, Kataribhog showed better performance at 100 ppm and Kalijira showed better performance at 150 ppm of NAA than that of other levels.

Roxy (2016) reported that 50 ppm BAP increased the grain no. $panicle^{-1}$ of Kataribhog rice variety.

**1000 grain weight (g)**

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

Akter (2012) observed 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, spikelet $panicle^{-1}$, 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).

Boron application at sowing significantly increased 13% of the 1000 grain weight in coarse and fine rice (Ahmad and Irshad, 2011). Significantly highest 1000 grain weight was recorded with the application of 45 g $GA_3$ + 10 g Urea + 2 g Boric acid + 2 g $ZnSO_4$ + 2 g $K_2PO_4$ $ha^{-1}$ (Tiwari *et al.,* 2011).

Khan *et al.* (2011) observed 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.

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.

Foliar spray of $GA_3$ at higher concentrations alone or at lower concentration in combination with urea or boric acid or NAA increased the test weight significantly over rest of the treatments (Biradarpatil and Shekhargouda, 2006).

Kabir *et al.* (2004) studied with rice new cv. Begunbitchi, Chinigura and Kaijiraand reported that Chinigura produced the highest 1000-grain weight. Diaz *et al.* (2003) revealed that total dose (50 mg $ha^{-1}$) of BIOBRAS-16, applied during active tillering and at the beginning of heading, showed the best response regarding 1000 grain weight.

Liu *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. Saha *et al.* (1996) showed 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). Singh and Gill (1985) stated that spraying of 100 ppm NAA on wheat and barley had greater effect to increase 1000 grain weight.

**Grain yield (t $ha^{-1}$)**

The effect of higher concentration of 6-BAP was significant in increasing the grain yield of some crops. Increase in grain yield due to 6-BAP application as reported by many scientists as stated below. Roxy (2016) revealed that 200 ppm NAA reduced the straw yield of Kataribhog rice cultivar. Khanam (2016) reported that the straw yield of kataribhog was significantly increased at the controlled level.

Khanam (2016) found that 100 ppm 6-BAP produced highest grain yield and yield components of rice. Roxy (2016) revealed that 50 ppm 6-BAP increased the grain yield and yield components of rice. Rahman (2013) and Akter (2012) also found no positive effect of NAA application on straw yield.

Akter (2012) reported 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.

Application of $GA_3$ in ratoon rice markedly increased the grain yield up to 32% as compared to untreated plants (Niknejhad and Pirdashti, 2012).

Adam and Jahan (2011) revealed 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. Bakhsh *et al.* (2011) revealed that 90 ml NAA $ha^{-1}$ applied at panicle initiation stage produced maximum paddy yield in 2004 (9.00 Mg $ha^{-1}$) and 2005 (9.20 Mg $ha^{-1}$).

Tiwari *et al.* (2011) revealed that significantly highest grain yield noticed by the application 45 g $GA_3$ + 10 g Urea + 2 g Boric acid + 2 g ZnSO4 + 2 g $K_2PO_4$ $ha^{-1}$, followed by $GA_3$ 45 g $ha^{-1}$. Significantly highest biological yield (41.31g) was recorded with the application of $GA_3$ (45 g $ha^{-1}$) followed by NAA (100 g $ha^{-1}$) (Tiwari *et al.*, 2011). Maximum yield increased by Boron application before transplanting (31%) followed by application at tillering (24% and 10%) and booting stages (7% and 3%) in coarse and fine cultivars, respectively (Ahmad and Irshad, 2011).

Mir *et al.* (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.

Elankavi *et al.* (2009) observed 50.52% increases in grain yields over control with application of $GA_3$. Application of NAA @ 100 g $ha^{-1}$ and combination with borax @ 0.1 % + $KH_2PO_4$ @ 0.2% gave higher grain yields in rice hybrid, DRRH-1 (Reddy *et al.*, 2009).

Obaidur (2008) reported that 100 ppm NAA+flooded irrigation were found to be superior to others treatments for yield and other yield parameters. Islam (2008) showed that application of IAA markedly influenced on yield and yield contributing characters in rice plant. The highest yield was observed (3.42 kg $plot^{-1}$) in 100 ppm IAA+ continuous flooded irrigation.

Gangadharaiah *et al.* (2006) 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. Fariduddin *et al.* (2008) reported that mungbean plants raised from the seeds soaked in 28- homobrassinolide and also foliar application with 28-homobrassinolide (15 DAS), gave the maximum yield 32% than the control.

Rounds *et al.* (2007) reported that main-crop yields were not influenced by the application of GA, while ratoon-crop yields were increased 264 kg $ha^{-1}$ using GA application. The very early-maturing vigorous hybrids responded strongly to GA treatment, with average increases in ratoon yield due to the GA treatment of 697 kg $ha^{-1}$. The GA treatment slightly delayed main-crop development.

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.

Biradarpatil and Shekhargouda (2006) revealed that application of $GA_3$ @ 75 g $ha^{-1}$ recorded higher paddy seed yield 1412.3 kg $ha^{-1}$ followed by flag leaf clipping with $GA_3$ @ 50 g $ha^{-1}$ and $GA_3$ @ 25 g $ha^{-1}$ coupled with 100 ppm NAA.

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. Bodapati *et al.* (2005) reported that gibberellic acid accumulating ability of rice cultivars will result in higher cold tolerance.

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 and increased seed yield $plant^{-1}$ with each increment of $GA_3$ application up to 100 g $ha^{-1}$.

Singh *et al.* (2003) stated that there was a significant difference between the treatments for various characters with $GA_3$ application. There was significant increase in panicle bearing tillers, panicle length, and number of spikelet $panicle^{-1}$, spikelet fertility, test weight, panicle exertion and grain yield with each increase of $GA_3$ application up to 100 g $ha^{-1}$. High dose of $GA_3$ increased panicle exertion, out crossing percentage and seed yield $plant^{-1.}$

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).

Mahla *et al.* (1999) stated 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. Kumar (1999) reported that highest grain yield $plot^{-1}$ (0.628 Kg) recorded with application of $GA_3$ 100 g $ha^{-1}$.

Foliar spray of HBR (28-homobrassinolide) significantly increased grain yields in wheat, rice and mustard, pod yields in groundnut, tuber yields in potato and seed cotton yields, over control and the extent of yield improvement due to HBR (28- homobrassinolide) was influenced by crop species, concentration of HBR, plant growth stage at application and frequency of application (Ramraj *et al.*, 1997).

Singh and sahoo (1996) reported that application of $GA_3$ + 1.5 % boric acid was significantly increased the panicle exsertion percentage and grain yield $plant^{-1}$.

Kalita *et al.* (1985) reported that combined foliar spray of 3 per cent $P_2O_5$, 100 ppm NAA in green gram 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.

Singh *et al.* (1994) found that spraying of planofix (NAA) on wheat plant, significantly increased grain yields. Duan and Ma (1992) reported that increased seed yield 304% and 268% with foliar application of 180 g $GA_3$ $ha^{-1}$ and 225 g $GA_3$ $ha^{-1}$, respectively.

Duan and Ma (1992) reported that increased seed yield 304% and 268% with foliar application of 180 g $GA_3$ $ha^{-1}$ and 225 g $GA_3$ $ha^{-1}$, respectively. 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.

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. Xu and Li (1988) reported 13% higher seed yield with application of $GA_3$ in rice compare to control.

**Straw yield**

Khanam (2016) reported that the straw yield of kataribhog was significantly increased at the controlled level. Rahman (2013) 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. Khanam (2016) reported that the straw yield of kataribhog was significantly increased at the controlled level.

Singh and Uttam (1994) reported in field experiments in 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. Ali *et al.* (1996) observed an increase straw yield in rice with Boron application.

**Harvest index**

Khanam (2016) reported that 100 ppm 6-BAP produced highest harvest index. Roxy (2016) reported that 50 ppm NAA application obtained 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. Adam and Jahan (2011) reported that, harvest index was found to increase due to application of 100 ppm in BRRI dhan-29 (52.12 - 54.65%).

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.

Tiwari *et al.* (2011) reported that significantly highest harvest index with application 45 g $GA_3$ + 10 g Urea + 2 g Boric acid + 2 g $ZnSO_4$ + 2 g $K_2PO_4$ $ha^{-1}$. Adam and Jahan (2011) reported that, harvest index was found to increase due to application of 100 ppm in BRRI dhan-29 (52.12 - 54.65%).

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.

The treatment combinations of 3% $P_2O_5$+100 ppm NAA resulted maximum harvest index (Kalita *et al.*, 1985).

Homobrassinolide application caused significant increases in grain yield and related parameters grain number per ear, 1000 grain weight and harvest index under irrigated and rainfed conditions of two varieties C 306, HD 2329 @ 0.05 ppm either as a seed treatment or a spray (Sairam, 1994).

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

Gurbaksh *et al.* (1995) studied with 5 ppm IAA and sprayed on rice cv. Java at an thesis and grain one week later. IAA increased percentage of hilled spikelet.

**Biological yield**

Khanam (2016) showed that 100 ppm 6-BAP produced maximum biological yield of Kataribhog rice. Roxy (2016) reported that maximum biological yield (6.25 t $ha^{-1}$) from the 50 ppm 6-BAP. Sharmin (2016) revealed that the maximum biological yield 6.23 t $ha^{-1}$ was found from Chinigura with 150 ppm of NAA. Roxy (2016) found that the maximum biological yield (6.25 t $ha^{-1}$) that was obtained from the 50ppm 6-BAP.

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 $GA_3$.

The net returns were significantly higher with the treatments receiving $GA_3$ at lower concentration (25 g $ha^{-1}$) in combination with 100 ppm NAA (Rs. 29581 $ha^{-1}$) and the

$GA_3$ at higher concentration (75 g or 50 g $ha^{-1}$) recorded higher seed yield $ha^{-1}$, but the high cost of it resulted in low profit (Biradarpatil and Shekhargouda, 2006).

Reddy *et al.* (2009) revealed that application of NAA @ 100 g $ha^{-1}$ and combination of borax @ 0.1 % + $KH_2PO_4$ @ 0.2 % showed maximum Cost-Benefit ratio in rice hybrid, DRRH-1.

Application of 45 g $GA_3$ + 10 g Urea + 2 g Boric acid + 2 g $ZnSO_4$ + 2 g $K_2PO_4$ $ha^{-1}$ gave the best effects as compared to all other treatments, combinations for most of the characters and used as substitute of $GA_3$, to achieve higher seed yield with maximum economic return (Tiwari *et al.,* 2011).

Brassinosteriods were highly promising and environment friendly promoter of agricultural productivity and a potent stress alleviator. One of the major constraints to employ brassinosteroids at larger scale in the fields is their high cost. However, recent progress in the chemical synthesis of brassinosteroids economically feasible (Fariduddin *et al.,* 2014).

# CHAPTER III

# MATERIALS AND METHODS

A field experiment was carried out at the research farm of Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during the period of September to December, 2017 to ascertain the response of 6- Benzyl aminopurine (6-BAP) of some aromaticrice cultivars. 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, 1994).

## 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

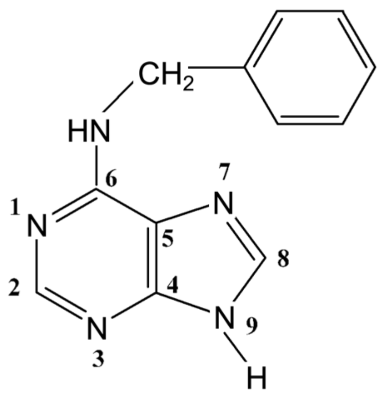
The research work was conducted during aman season (September to December, 2017) which is also known as aman season. The experimental area possesses subtropical climatic condition. The air temperature was relatively high at the beginning of the season and was decreasing with advancement of the season towards aman with occasional gusty winds. Moderate rainfall was detected during experimental period.

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

| **Parameters** | **Characteristics** |
|---|---|
| $P^H$ | 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 aromatic rice cultivar i.e. Kataribhog, Kalijira and Chinigura. Various doses plant growth regulator (6-BAP) were applied in order to investigate its effect on the growth, yield and leaf composition of Kataribhog, kalijira and Chinigura rice.




Chemical structure of 6- Benzyl aminopurin (BAP)

**Properties of 6-BAP**

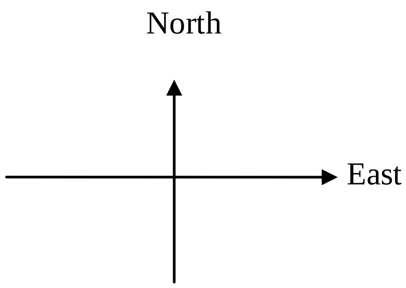
| Properties | |
|---|---|
| Chemical formula | $C_{12}H_{11}O_5$ |
| Molar mass | 225.26 g·mol$^{-1}$ |
| Appearance | White to off white powder |

### 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: variety**
  - ✓ $V_1$: Chinigura
  - ✓ $V_2$: Kataribhog
  - ✓ $V_3$: KaliJira
- **Factor B: PGRs BAP**
  - ✓ $T_1$: Control –(water)
  - ✓ $T_2$: 20 ppm
  - ✓ $T_3$: 40 ppm
  - ✓ $T_4$: 60 ppm
  - ✓ $T_5$: 80 ppm

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 1.0 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 |
|---|---|---|
| $V_3T_3$ | $V_3T_1$ | $V_3T_2$ |
| $V_3T_4$ | $V_3T_5$ | $V_3T_3$ |
| $V_3T_5$ | $V_3T_4$ | $V_3T_5$ |
| $V_3T_1$ | $V_3L_2$ | $V_3T_1$ |
| $V_3T_2$ | $V_3L_3$ | $V_3T_4$ |
| | DRAIN | |
| $V_2T_3$ | $V_2L_1$ | $V_2T_2$ |
| $V_2T_4$ | $V_2L_5$ | $V_2T_3$ |
| $V_2T_5$ | $V_2L_4$ | $V2T_5$ |
| $V_2T_1$ | $V_2T_2$ | $V_2T_1$ |
| $V_2L_2$ | $V_2T_3$ | $V_2T_4$ |
| | DRAIN | |
| $V_1T_3$ | $V_1T_1$ | $V_1T_2$ |
| $V_1T_4$ | $V_1T_5$ | $V_1T_3$ |
| $V_1T_5$ | $V_1T_4$ | $V_1T_5$ |
| $V_1T_1$ | $V_1T_2$ | $V1T_1$ |
| $V_1T_2$ | $V_1T_3$ | $V_1T_5$ |

**Figure 1: Field layout for the Experiment**

### 3.6 Land preparation

The experimental field was first plough with a power tiller on last week of August, 2017 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 with 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 September, 2017 according to the experimental design. Three 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-BAP solution was prepared and the spraying was done at afternoon by using a hand sprayer with two distinct capacities. The solution of BAP 0, 20, 40, 60 and 80 ppm was prepared by dissolving 0, 20, 40, 60 and 80 mg of 6-BAP 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-BAP solution. In a similar way, 100 ppm 6-BAP solution was made, by taking 100 mg 6-BAP in liter volumetric flask and the volume was made up to the mark with distilled water. 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

Seedling in some hills died off and these are replaced by gap filling after one week of transplanting where it was necessary using the seedlings from the same source.

### 3.10.2 Weeding and plant protection measures

Intercultural operations such as 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

The experimental plots were irrigated 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 determined 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 relevant parameters were collected accordingly during the experimental period. The parameters studied are-

**a. Morphological parameters**

- Plant height
- No of leaves plant$^{-1}$
- Leaf blade length
- Root depth
- Number of tillers hill$^{-1}$

**b. Physiological parameters in flag leaves**

- Chlorophyll-a content
- Chlorophyll-b content
- Total chlorophyll content
- Proline content

**c. Yield and yield contributing parameters**

- Panicle length
- Effective tiller hill$^{-1}$

- Non effective tiller hill$^{-1}$
- Grain no. 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 ascertained 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 Numbers of total tillers hill$^{-1}$**

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

**3.13.1.3 No of leaves plant$^{-1}$**

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

**3.13.1.4 Leaf length**

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.

**3.13.1.5 Root depth**

Root depth was measured from the age of 30 DAT at an interval of 30 days up to 90 DAT.

### 3.13.2 Physiochemical parameters

#### 3.13.2.1 Determination of chlorophyll content of rice flag leaves

The chlorophyll content of rice flag leaves was determined by following method described by Arnon (1949). Total chlorophyll was determined using the formula given by Porra (2002). Exactly 0.1 g fresh leaf tissues of rice flag leaves were taken in a test tube containing 10 mL of 80% acetone. It was then shaken overnight using a electric horizontal shaker. The optical density or absorbance of the supernatant was measured by using UV-visible spectrophotometer at different wavelengths. As 80% acetone was used in this study, the absorbance was measured at 663 nm, 645 nm and 470 nm wavelength for chlorophyll-a, chlorophyll-b, total chlorophyll. The concentration of chlorophyll-a (Chl-a), chlorophyll-b (Chl-b), total chlorophyll was measured by using following formula.

Chl- = 12.21 $A_{663}$ -2.81$A_{646}$ (µg ml of plant extract$^{1}$ or mg $g^{-1}$ fresh weight)

Chl-b = 20.13 $A_{646}$ – 5.03 $A_{663}$

Total chlorophyll = 17.76 ($A_{646}$) + 7.34 ($A_{663}$)

#### 3.13.2.2 Determination of proline content of rice flag leaves

For leaf chemical composition of selected flag leaves during reproductive stage, replicated leaves from differently treated plants was collected. Fresh leaf sample of 40-50 mg by weight was collected in an eppendorf tube and homogenized in 3% (w/v) salfosalicylic acid for the estimation. Proline content was estimated colorimetrically by the acid ninhydrin method following Bates *et al.* (1973).

### 3.13.3 Yield and yield contributing parameters

Data were recorded on the following crop characters: plant height, leaf number hill$^{-1}$, leaf length, tiller number hill$^{-1}$, root length hill$^{-1}$, total tiller no., effective tillers, non effective tillers, panicle number plant$^{-1}$, grain number panicle$^{-1}$, 1000 grain weight and straw weight.

#### 3.13.3.1 Number of panicles hill$^{-1}$

During harvesting 3 hills were randomly selected from different replications to record the number of panicles hill$^{-1}$.

### 3.13.3.2 Effective tiller

The total numbers of effective tiller hill$^{-1}$ were counted and recorded for statistical analysis and finally used for interpretation.

### 3.13.3.3 Non effective tiller

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

### 3.13.3.4 Grain number panicle$^{-1}$

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

### 3.13.3.5 Grain wt. panicle$^{-1}$

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

### 3.13.3.6 1000-grain weight

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.

### 3.13.3.7 Grain yield (t ha$^{-1}$)

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

### 3.13.3.8 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 converted to t ha$^{-1}$.

### 3.13.3.9 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

### 3.13.3.10 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 (Gardner *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 deals with the discussion of the results of the experiment on the response of plant growth regulators of 0, 20, 40, 60 and 80 ppm 6- Benzyl aminopurine (6-BAP) to observe their effect on selected three aromatic rice cultivars Chinigura, Kataribhog, and Kalijira respectively. The result obtained on the performance of the 6-BAP on various morpho-physiological, yield and yield contributing characters have been presented below:

## 4.1 Growth characters of selected three aromatic rice varieties

### 4.1.1 Plant height

Plant height states 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 6-BAP in aromatic rice varieties which have been presented in Table 2. Result shows that the highest plant height was 125.1 cm in $V_1 \times T_4$ and the lowest plant height 118.3 cm produced by $V_1 \times T_3$ treatment at their vegetative stage. At harvesting stage, the highest plant height was observed in $V_1 \times T_4$ (172.9 cm) which was statistically similar to $V_1 \times T_3$ (172.9 cm). The lowest plant height was 143.1 cm in $V_2 \times T_1$ plant.

Sharmin (2016) showed that highest plant height was found at vegetative stage using 50 ppm NAA at harvesting stage, better result was found on Kalijira rice variety by applying 200 ppm NAA. Roxy (2016) stated that 50 ppm 6-BAP showed better performance on plant height of Kataribhog rice variety at both vegetative and harvesting stage.

Khanam (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) observed that 100 ppm NAA with 1.5 ton lime residual effect treatment combination showed highest plant height of Kararibhog 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. 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.

**Table 2: Plant height of three aromatic rice varieties under different treatment levels of 6-BAP**

| Treatment | Vegetative stage | Harvesting stage |
|---|---|---|
| $V_1 \times T_1$ | 122.0 abc | 168.7 ab |
| $V_1 \times T_2$ | 119.7 bc | 170.4 ab |
| $V_1 \times T_3$ | 118.3 c | 172.9 a |
| $V_1 \times T_4$ | 125.1 a | 172.9 a |
| $V_1 \times T_5$ | 123.3 abc | 167.0 b |
| $V_2 \times T_1$ | 122.5 abc | 143.1 f |
| $V_2 \times T_2$ | 120.3 abc | 148.9 cdef |
| $V_2 \times T_3$ | 121.2 abc | 152.1 c |
| $V_2 \times T_4$ | 120.3 abc | 150.2cde |
| $V_2 \times T_5$ | 124.6 ab | 144.4 ef |
| $V_3 \times T_1$ | 121.3 abc | 147.3 cdef |
| $V_3 \times T_2$ | 122.1 abc | 147.4 cdef |
| $V_3 \times T_3$ | 124.6 ab | 145.6 def |
| $V3 \times T_4$ | 120.2 abc | 150.3 cd |
| $V_3 \times T_5$ | 119.4 bc | 148.0 cdef |
| LSD | 4.467 | 5.087 |
| CV % | 2.91 | 1.96 |

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

#### 4.1.2 Leaf blade length

The leaf length of three aromatic rice cultivars at different growth stages was influenced by the application of 6-BAP which have been presented in Table 3. Result shows that the leaf blade length was insignificant at their vegetative stage. At harvesting stage, the highest leaf blade length was observed in $V_1 \times T_5$ (60.45 cm) which was statistically similar with $V_1 \times T_4$ (60.44 cm). The lowest leaf blade length was 51.22 cm in ($V_3 \times T_5$) which was also statistically similar with $V_3 \times T_1$ (51.67 cm) plant.

Khanam (2016) revealed that 150 ppm 6-BAP showed better performance on leaf blade length of Kataribhog rice variety at both vegetative and harvesting stage. Roxy (2016) also found no significant relationship among the variety as well as 6-BAP treatment on leaf blade length. 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 of three aromatic rice varieties under different treatment levels of 6-BAP**

| Treatment | Vegetative stage | Harvesting stage |
|---|---|---|
| $V_1 \times T_1$ | 32.31 ns | 58.11 abc |
| $V_1 \times T_2$ | 31.77 ns | 58.44 ab |
| $V_1 \times T_3$ | 29.21 ns | 58.56 ab |
| $V_1 \times T_4$ | 30.98 ns | 60.44 a |
| $V_1 \times T_5$ | 31.68 ns | 60.45 a |
| $V_2 \times T_1$ | 31.14 ns | 53.56 cd |
| $V_2 \times T_2$ | 30.03 ns | 57.67 abc |
| $V_2 \times T_3$ | 31.20 ns | 57.22 abc |
| $V_2 \times T_4$ | 30.66 ns | 56.67 abc |
| $V_2 \times T_5$ | 30.38 ns | 57.22 abc |
| $V_3 \times T_1$ | 31.29 ns | 51.67 d |
| $V_3 \times T_2$ | 30.30 ns | 54.22 bcd |
| $V_3 \times T_3$ | 30.73 ns | 56.45 abc |
| $V3 \times T_4$ | 30.49 ns | 56.22 abc |
| $V_3 \times T_5$ | 29.32 ns | 51.22 d |
| LSD | 3.25 | 4.10 |
| CV % | 6.33 | 4.34 |

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

### 4.1.3 Tiller numbers hill$^{-1}$

The tillers hill$^{-1}$ of rice plant at different growth stages was influenced by the application of 6-BAP in aromatic rice varieties which have been presented in Table 4. Result shows that, there was a significant effect among the varieties and different levels of BAP on both vegetative and harvesting stage. Among the variety Kataribhog and among the treatments 60 ppm ($T_4$) 6-BAP showed the better performance. From the interaction it was found that the maximum number of tillers hill$^{-1}$ $V_2 \times T_4$ (21.00) was obtained from Kataribhog with 60 ppm 6-BAP while the lowest number of tillers hill$^{-1}$ $V_1 \times T_1$ (15.33) was found from variety Chinigura with 0 ppm BAP at harvesting stage.

Sharmin (2016) observed that that the maximum number of tillers hill$^{-1}$(was obtained from Chinigura with 150 ppm NAA while the lowest number of tillers hill$^{-1}$ (6) was emerged from variety Kataribog with 150 ppm NAA at harvesting stage. Roxy (2016) revealed that 50 ppm 6-BAP had the better performance to increase the tiller number per hill. She observed highest tiller number per hill (8.66) at 50ppm while the lowest plant height was 6.33 in controlled level at harvesting stage.

Khanam (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. The founding showed that number of total tillers hill$^{-1}$ ranged from 13.16 to 17.25. 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.

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: No of tiller of three aromatic rice varieties under different treatment levels of 6-BAP**

| | Treatment | Harvesting stage |
|---|---|---|
| Varieties | $V_1$ | 17.20 b |
| | $V_2$ | 19.33 a |
| | $V_3$ | 17.89 b |
| | LSD | 1.194 |
| | CV % | 8.80 |
| Treatments | $T_1$ | 16.63 b |
| | $T_2$ | 17.93 b |
| | $T_3$ | 18.22 b |
| | $T_4$ | 19.93 a |
| | $T_5$ | 18.00 b |
| | LSD | 1.542 |
| | CV % | 8.80 |
| Interaction | $V_1 \times T_1$ | 15.33 c |
| | $V_1 \times T_2$ | 17.22 bc |
| | $V_1 \times T_3$ | 17.44 bc |
| | $V_1 \times T_4$ | 19.22 ab |
| | $V_1 \times T_5$ | 16.78 bc |
| | $V_2 \times T_1$ | 18.89 ab |
| | $V_2 \times T_2$ | 19.22 ab |
| | $V_2 \times T_3$ | 19.33 ab |
| | $V_2 \times T_4$ | 21.00 a |
| | $V_2 \times T_5$ | 18.22 abc |
| | $V_3 \times T_1$ | 15.67 c |
| | $V_3 \times T_2$ | 17.33 bc |
| | $V_3 \times T_3$ | 17.89 bc |
| | $V3 \times T_4$ | 19.55 ab |
| | $V_3 \times T_5$ | 19.00 ab |
| | LSD | 2.670 |
| | CV % | 8.80 |

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

### 4.1.4 Leaf number

Table 5 shows that the effect of PGRs on the leaf number on three different varieties. The leaves number were non significant at both vegetative and harvesting stage among varieties due to the application of 6-BAP as plant growth regulators.

The effect of 6-BAP on the number of leaf was studied by several workers. Khanam (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 three aromatic rice varieties under different levels of 6-BAP**

| | Treatment | Vegetative stage | Harvesting stage |
|---|---|---|---|
| Varieties | $V_1$ | 3.735 ns | 4.509 ns |
| | $V_2$ | 3.735 ns | 4.486 ns |
| | $V_3$ | 3.533 ns | 4.509 ns |
| | LSD | 0.1689 | 0.3702 |
| | CV % | 6.18 | 10.99 |
| Treatments | $T_1$ | 3.668 ns | 4.739 ns |
| | $T_2$ | 3.631 ns | 4.516 ns |
| | $T_3$ | 3.631 ns | 4.369 ns |
| | $T_4$ | 3.668 ns | 4.293 ns |
| | $T_5$ | 3.741 ns | 4.590 ns |
| | LSD | 0.2181 | 0.4780 |
| | CV % | 6.18 | 10.99 |
| Interaction | $V_1 \times T_1$ | 3.667 ns | 4.777 ns |
| | $V_1 \times T_2$ | 3.780 ns | 4.660 ns |
| | $V_1 \times T_3$ | 3.670 ns | 4.333 ns |
| | $V_1 \times T_4$ | 3.780 ns | 4.220 ns |
| | $V_1 \times T_5$ | 3.777 ns | 4.553 ns |
| | $V_2 \times T_1$ | 3.780 ns | 4.663 ns |
| | $V_2 \times T_2$ | 3.557 ns | 4.443 ns |
| | $V_2 \times T_3$ | 3.670 ns | 4.440 ns |
| | $V_2 \times T_4$ | 3.780 ns | 4.220 ns |
| | $V_2 \times T_5$ | 3.890 ns | 4.663 ns |
| | $V_3 \times T_1$ | 3.557 ns | 4.777 ns |
| | $V_3 \times T_2$ | 3.557 ns | 4.443 ns |
| | $V_3 \times T_3$ | 3.553 ns | 4.333 ns |
| | $V3 \times T_4$ | 3.443 ns | 4.440 ns |
| | $V_3 \times T_5$ | 3.557 ns | 4.553 ns |
| | LSD | 0.3777 | 0.8279 |
| | CV % | 6.18 | 10.99 |

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

### 4.1.5 Root depth

The root depth of three aromatic rice cultivars at different growth stages was influenced by the application of 6-BAP which have been presented in Table 6. Among the variety Kataribhog and Chinigura show better performance and all the treatments are statistically insignificant. The highest root length was observed in $V_1 \times T_3$ (20.67 cm). The lowest root depth was 14.11 cm in $V_3 \times T_3$ plant.

Sharmin (2016) states that that highest root depth was obtained from Kalijira rice variety while 0 ppm NAA was applied and lowest found in chinigura variety by the application of 150 ppm of NAA. Khanam (2016) revealed that highest root depth was obtained from Kataribhog rice variety while 200 ppm 6-BAP was applied. Wang and Deng (1992) observed that rice spraying with $10^{-1}$ and $10^{-3}$ ppm NAA at tillering stage significantly increase root dry weight.

**Table 6: Root depth of three aromatic rice varieties under different treatment levels of 6-BAP**

| | Treatment | Harvesting stage |
|---|---|---|
| Varieties | $V_1$ | 18.78 a |
| | $V_2$ | 17.44 a |
| | $V_3$ | 14.78 b |
| | LSD | 1.343 |
| | CV % | 10.57 |
| Treatments | $T_1$ | 18.00 a |
| | $T_2$ | 16.81 a |
| | $T_3$ | 16.15 a |
| | $T_4$ | 17.56 a |
| | $T_5$ | 16.48 a |
| | LSD | 1.734 |
| | CV % | 10.57 |
| Interaction | $V_1 \times T_1$ | 18.22 abcde |
| | $V_1 \times T_2$ | 18.89 abc |
| | $V_1 \times T_3$ | 20.67 a |
| | $V_1 \times T_4$ | 18.33 abcd |
| | $V_1 \times T_5$ | 17.78abcdef |
| | $V_2 \times T_1$ | 18.45 abcd |
| | $V_2 \times T_2$ | 16.44 bcdefg |
| | $V_2 \times T_3$ | 16.11 cdefg |
| | $V_2 \times T_4$ | 19.78 ab |
| | $V_2 \times T_5$ | 16.45 bcdefg |
| | $V_3 \times T_1$ | 14.89 efg |
| | $V_3 \times T_2$ | 15.11 defg |
| | $V_3 \times T_3$ | 14.11 g |
| | $V3 \times T_4$ | 14.56 fg |
| | $V_3 \times T_5$ | 15.22 defg |
| | LSD | 3.004 |
| | CV % | 10.57 |

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

## 4.2 Effect of 6-BAP on chemical characters of selected rice varieties

### 4.2.1 Chlorophyll in flag leaves

Leaf chlorophyll content is one of the important physiological traits closely related to photosynthetic ability in rice (Teng *et al*., 2004).

Undoubtedly, understanding the genetic mechanisms underlying the leaf chlorophyll content across different developmental stages of rice has significant implications for improving photosynthetic ability in rice. Chlorophyll content in leaves is one of the major components in photosynthesis that helps in rice growth, development and yield.

Sunohara and Matsumoto (1997) observed that application of auxins (NAA, 2,4-D and IAA) on corn (maize) growth significantly increased in chlorophyll content.

Kaufman *et al.* (1992) pointed out that calli were induced from excised rice from whole seed's in the presence of 1-5 mg $L^{-1}$ NAA. Excised embryos accumulate up to 6 times higher NAA concentrations than whole seeds. In the presence of NAA at low concentrations and 2-10 mg $L^{-1}$ kinetin, green calli were induced from excised embryos; chlorophyll contents increased as kinetin concentration increased.

Ratna *et al.* (1995) observed an increased root dry weight with ABT-6 at 20 ppm in soyabean.

#### 4.2.1.1 Chlorophyll-a content

Almela (2000) states that Chlorophylls are the most widely distributed plant pigments responsible for the characteristic green color of fruit and vegetables. It is important to plants because it is the substance that the chloroplast organelles in the cells that carry out photosynthesis. The major chlorophylls in different plants are chlorophyll-a, which has a methyl group at C-3 carbon, and chlorophyll-b, which a formal group is bonded to the same carbon atom. Chlorophylls are known to be easily degraded by conditions such as dilute acids, heat, light and oxygen (Tonucci and Von-Elbe, 1992). An optimum temperature ranging from $25^{o}C$ to $35^{o}C$ is required for a good rate.

Table 7 shows that, there is a significant relationship among the varieties, levels and Interaction on chlorophyll-a, chlorophyll-b, total chlorophyll and proline content of three aromatic rice leaves.

**Table 7: Chlorophyll and proline content of flag leaf of three aromatic rice varieties under different levels of 6-BAP**

| | Treatment | Chl-a (mg $g^{-1}$) | Chl-b (mg $g^{-1}$) | Total chl (mg $g^{-1}$) | Prolin (mg $g^{-1}$) |
|---|---|---|---|---|---|
| Varieties | $V_1$ | 19.49 a | 5.389 a | 23.53 a | 0.3293 a |
| | $V_2$ | 16.24 b | 4.481 b | 20.61 b | 0.2807 b |
| | $V_3$ | 16.15 b | 4.539 b | 19.87 b | 0.2940 b |
| | LSD | 1.368 | 0.5755 | 1.703 | 0.02365 |
| | CV % | 10.57 | 16.02 | 10.67 | 12.58 |
| Treatments | $T_1$ | 16.74 b | 4.729 ab | 21.23 ab | 0.3000 ab |
| | $T_2$ | 16.06 b | 5.166 a | 20.85 b | 0.3256 a |
| | $T_3$ | 17.02 b | 4.759 ab | 20.70 b | 0.2978 ab |
| | $T_4$ | 19.44 a | 5.223 a | 23.22 a | 0.2989 ab |
| | $T_5$ | 17.20 b | 4.139 b | 20.68 b | 0.2844 b |
| | LSD | 1.766 | 0.7430 | 2.199 | 0.03054 |
| | CV % | 10.57 | 16.02 | 10.67 | 12.58 |
| Interaction | $V_1 \times T_1$ | 17.90 bc | 5.620 ab | 24.42 ab | 0.3100 abcd |
| | $V_1 \times T_2$ | 17.16 bc | 5.360 abc | 21.52 bcd | 0.3533 a |
| | $V_1 \times T_3$ | 19.65 b | 5.913 a | 23.59 abc | 0.3433 abc |
| | $V_1 \times T_4$ | 24.59 a | 5.357 abc | 25.95 a | 0.3500 ab |
| | $V_1 \times T_5$ | 18.15 bc | 4.693 abcd | 22.18 abcd | 0.2900 bcd |
| | $V_2 \times T_1$ | 15.44 c | 4.207 bcd | 19.98 bcd | 0.2900 bcd |
| | $V_2 \times T_2$ | 14.87 c | 5.450 abc | 20.12 bcd | 0.3033 abcd |
| | $V_2 \times T_3$ | 15.20 c | 4.523 abcd | 18.72 d | 0.2767 d |
| | $V_2 \times T_4$ | 18.21 bc | 4.543 abcd | 22.74 abcd | 0.2633 d |
| | $V_2 \times T_5$ | 17.48 bc | 3.683 d | 21.50 bcd | 0.2700 d |
| | $V_3 \times T_1$ | 16.89 bc | 4.067 cd | 19.29 cd | 0.3000 abcd |
| | $V_3 \times T_2$ | 16.13 bc | 4.687 abcd | 20.92 bcd | 0.3200abcd |
| | $V_3 \times T_3$ | 16.21 bc | 4.133 bcd | 19.80 cd | 0.2733 d |
| | $V3 \times T_4$ | 15.53 c | 5.770 a | 20.98 bcd | 0.2833 cd |
| | $V_3 \times T_5$ | 15.98 c | 4.040 cd | 18.35 d | 0.2933 abcd |
| | LSD | 3.058 | 1.287 | 3.808 | 0.05289 |
| | CV % | 10.57 | 16.02 | 10.67 | 12.58 |

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

Chinigura show the highest chlorophyll a among the variety and Treatment 60 ppm show the better results. The maximum amount of it's found at $V_1 \times T_4$ (24.59 mg $g^{-1)}$ and the lowest amount of chlorophyll a showed by the treatment $V_2 \times T_2$ (14.87 mg $g^{-1}$).

Sharmin (2016) noticed that 150 ppm NAA shows the better performance on chinigura rice cultivar for chlorophyll a.

Roxy (2016) revealed that 6-BAP, a plant growth regulator used in aromatic rice to boost up growth and yield and found similar amount of chlorophyll was synthesized in aromatic rice. Akter (2012) also found a significant variation in chlorophyll-a and total chlorophyll content in rice cultivar. Singh and Jain (1981) observed that both chlorophyll a and b as well as chlorophyll a/b ratio decreased with increase in salinity viz., 0, 4, 8 mMhos $cm^{-1}$ both in fruit wall and seed in chickpea, however, growth regulators spray viz., kinetin (10 ppm) and $GA_3$ (25 ppm) enhanced the chlorophyll contents.

**4.2.1.2 Chlorophyll-b content**

Almela (2000) revealed that Chlorophylls are the most widely distributed plant pigments responsible for the characteristic green color of fruit and vegetables. It is important to plants because it is the substance that the chloroplast organelles in the cells that carry out photosynthesis. The major chlorophylls in different plants are chlorophyll-a, which has a methyl group at C-3 carbon, and chlorophyll-b, which a formal group is bonded to the same carbon atom. Chlorophylls are known to be easily degraded by conditions such as dilute acids, heat, light and oxygen (Tonucci and Von-Elbe, 1992). Chlorophyll-b absorbs energy from wavelengths of green light at 640 nm. It is the accessory pigment that collects energy and passes it on to chlorophyll-a. It also regulates the size of antenna and is more absorbable than chlorophyll-a. Thus, chlorophyll-a is the primary photosynthetic pigment while chlorophyll-b is the accessory pigment that collects energy. Therefore, the amounts of chlorophyll-b in flag leaves of rice plant have a significant impact on the production of photosynthate resulting in grain production.

Maximum chlorophyll-b (5.91 mg $g^{-1}$) at $V_3 \times T_1$ statistically similar with $V_1 \times T_1$ (4.04 mg $g^{-1}$) and the lowest amount content in $V_2 \times T_5$ (3.68 mg $g^{-1}$) and $V_3 \times T_4$ (5.77 mg $g^{-1}$) respectively was observed from the interaction.

Sharmin (2016) noticed maximum chlorophyll-b (10.41 mg $g^{-1}$) was observed on kalijira rice at 100 ppm NAA and the lowest amount content (5.94 mg $g^{-1}$) was found on kalijira rice at 0 ppm NAA. Roxy (2016) also found no significant variation between the treatments (6-BAP) in relation to chlorophyll-b content.

Rahman (2013) experimented that the twice spraying concentration of 100 ppm NAA and $GA_3$ on rice varieties were significant on total chlorophyll-b content. The maximum chlorophyll-b (10.20 mg $g^{-1}$) was obtained from BRRI dhan2 with control treatment and lowest amount content is (5.91mg $g^{-1}$) with 100 ppm $GA_3$.

**4.2.1.3 Total chlorophyll content**

Tonucci and Von-Elbe (1992) showed that Chlorophylls are known to be easily degraded by conditions such as dilute acids, heat, light and oxygen. An optimum temperature ranging from 25°C to 35°C is required for a good rate.

Result showed that, there was a significant effect among the varieties and different levels of BAP. The interaction effect between variety and levels on total chlorophyll content also statistically significant which is presented in Table 7. Among the variety Chinigura and among the levels 60 ppm ($T_4$) BAP showed the better performance. From the interaction, the highest total chlorophyll content was 25.95 mg $g^{-1}$ with $V_1\times T_4$ and lowest value was $V_3\times T_5$ (18.35 mg $g^{-1}$) which was statistically similar with $V_2\times T_3$ (18.72 mg $g^{-1}$).

Sharmin (2016) the highest amount of total chlorophyll content (39.37 mg $g^{-1}$) was found on kataribog rice at 100 ppm treatment while the lowest amount of total chlorophyll content (26.81 mg $g^{-1}$) at Kalijira rice at 0 treatments. There was no significant relationship among chlorophyll-b, varieties and different levels of NAA.

Roxy (2016) also found no significant variation with the treatment (BAP) on total chlorophyll content of the flag leaf of Kataribhog rice cultivar. Akter (2012) revealed that the highest total chlorophyll content of the flag leaf of Katari rice cultivar was obtained from 100 ppm NAA with no residual effect of lime treatment combination. Total chlorophyll and its fractions ‘a’ and ‘b’ contents decreased with increased salinity (0, 100 and 200 mol $m^{-3}$ NaCl) in two spring wheat cultivars, Barani-83 (salt sensitive) and SARC-1 (salt tolerant). However, foliar application of $GA_3$ (100 mg $L^{-1}$) enhanced both the pigments in Borani-83 but total chlorophyll in both the lines (Ashraf *et al.*, 2002).

### 4.2.2 Proline content

Among the variety Chinigura and among the treatments 20 ppm of BAP showed the better result. From the interaction, the maximum proline content 0.35 mg $g^{-1}$ found with $V_1 \times T_2$ plants and the lowest proline content 0.26 mg $g^{-1}$ with $V_2 \times T_4$ which was statistically similar with $V_2 \times T_3$ (0.27 mg $g^{-1}$), $V_2 \times T_5$ (0.27 mg $g^{-1}$) and $V_3 \times T_3$ (0.27 mg $g^{-1}$) respectively. A strong correlation has been established between proline accumulation andabiotic stress tolerance in many plants (Saradhi *et al.,* 1995, Hare and Cress 1997 and Siripornadulsil *et al.,* 2002).

**Table 8: Yield contributing characters of selected rice varieties under BAP**

| | Treatment | Panicle length (cm) | Number of Effective tiller | Non effective tiller | Grain no. panicle$^{-1}$ | 1000 grain wt. (g) |
|---|---|---|---|---|---|---|
| Varieties | $V_1$ | 28.63 a | 15.78 b | 1.421 b | 263.9 ab | 10.93 ns |
| | $V_2$ | 27.69 ab | 17.31 a | 2.022 a | 274.0 a | 10.73 ns |
| | $V_3$ | 27.27 b | 16.31 ab | 1.576 b | 255.1 b | 11.00 ns |
| | LSD | 1.151 | 1.163 | 0.3687 | 10.94 | 0.3922 |
| | CV % | 5.52 | 9.44 | 29.47 | 5.54 | 4.81 |
| Treatments | $T_1$ | 26.55 b | 15.30 b | 1.333 b | 254.6 b | 10.78 ns |
| | $T_2$ | 28.52 a | 16.04 b | 1.889 a | 263.1 ab | 10.78 ns |
| | $T_3$ | 28.42 a | 16.78 ab | 1.442 ab | 275.6 a | 10.67 ns |
| | $T_4$ | 28.46 a | 18.04 a | 1.888 a | 268.5 ab | 11.22 ns |
| | $T_5$ | 27.37 ab | 16.19 b | 1.813 ab | 259.8 b | 11.00 ns |
| | LSD | 1.487 | 1.501 | 0.4760 | 14.13 | 0.5064 |
| | CV % | 5.52 | 9.44 | 29.47 | 5.54 | 4.81 ns |
| Interaction | $V_1 \times T_1$ | 27.00 bc | 14.22 d | 1.113 b | 257.4 abc | 10.67 ns |
| | $V_1 \times T_2$ | 30.22 a | 15.33 bcd | 1.887 ab | 269.0 abc | 11.00 ns |
| | $V_1 \times T_3$ | 29.15 ab | 16.22 abcd | 1.220 b | 276.1 ab | 11.00 ns |
| | $V_1 \times T_4$ | 29.14 ab | 17.78 ab | 1.443 ab | 265.7 abc | 11.00 ns |
| | $V_1 \times T_5$ | 27.66 abc | 15.33 bcd | 1.443 ab | 250.1 bc | 11.00 ns |
| | $V_2 \times T_1$ | 25.78 c | 17.11 abcd | 1.777 ab | 264.1 abc | 10.67 ns |
| | $V_2 \times T_2$ | 28.45 abc | 17.22 abcd | 2.003 ab | 263.7 abc | 10.33 ns |
| | $V_2 \times T_3$ | 29.45 ab | 17.45 abc | 1.887 ab | 277.0 ab | 10.33 ns |
| | $V_2 \times T_4$ | 27.67 abc | 18.78 a | 2.223 a | 287.0 a | 10.33 ns |
| | $V_2 \times T_5$ | 27.11 bc | 16.00 abcd | 2.220 a | 278.0 ab | 11.33 ns |
| | $V_3 \times T_1$ | 26.89 bc | 14.55 cd | 1.110 b | 241.1 c | 11.00 ns |
| | $V_3 \times T_2$ | 26.89 bc | 15.56 bcd | 1.777 ab | 256.6 bc | 11.00 ns |
| | $V_3 \times T_3$ | 26.67 bc | 17.67 abcd | 1.220 b | 263.8 abc | 11.00 ns |
| | V3×$T_4$ | 28.56 abc | 17.56 abc | 1.997 ab | 262.9 abc | 10.67 ns |
| | $V_3 \times T_5$ | 27.33 abc | 17.22 abcd | 1.777 ab | 251.3 bc | 11.33 ns |
| | LSD | 2.575 | 2.600 | 0.8245 | 24.47 | 0.8771 |
| | CV % | 5.52 | 9.44 | 29.47 | 5.54 | 4.81 |

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

**Table 9: Grain Yield, straw, %HI and biological yield of aromatic rice cultivars under different levels of 6-BAP**

| | Treatment | Grain yield t $ha^{-1}$ | Straw yield t $ha^{-1}$ | Biological Yield | % Harvest index |
|---|---|---|---|---|---|
| Varieties | $V_1$ | 0.8775 c | 3.016 ns | 3.894 b | 22.49 c |
| | $V_2$ | 1.394 a | 2.989 ns | 4.383 a | 31.62 a |
| | $V_3$ | 1.124 b | 2.962 ns | 4.086 ab | 27.48 b |
| | LSD | 0.1229 | 0.2828 | 0.3702 | 1.789 |
| | CV % | 14.47 | 12.66 | 12.02 | 8.79 |
| Treatments | $T_1$ | 0.9998 b | 2.833 ns | 3.833 b | 26.11 a |
| | $T_2$ | 1.074 b | 3.000 ns | 4.073 ab | 26.30 a |
| | $T_3$ | 1.171 ab | 2.992 ns | 4.163 ab | 27.84 a |
| | $T_4$ | 1.296 a | 3.231 ns | 4.527 a | 28.34 a |
| | $T_5$ | 1.120 b | 2.889 ns | 4.009 ab | 27.38 a |
| | LSD | 0.1587 | 0.3652 | 0.4780 | 2.309 |
| | CV % | 14.47 | 12.66 | 12.02 | 8.79 |
| Interaction | $V_1$×$T_1$ | 0.8053 ef | 2.805 ns | 3.610 b | 22.46 de |
| | $V_1$×$T_2$ | 0.8887 def | 3.055 ns | 3.944 b | 22.48 de |
| | $V_1$×$T_3$ | 0.9443 cdef | 3.083 ns | 4.027 ab | 23.44 cde |
| | $V_1$×$T_4$ | 0.9993 cdef | 3.250 ns | 4.249 ab | 23.48 cde |
| | $V_1$×$T_5$ | 0.7497 f | 2.888 ns | 3.638 b | 20.57 e |
| | $V_2$×$T_1$ | 1.111 cde | 2.805 ns | 3.916 b | 28.56 b |
| | $V_2$×$T_2$ | 1.194 cd | 2.972 ns | 4.166 ab | 28.66 b |
| | $V_2$×$T_3$ | 1.500 ab | 2.916 ns | 4.416 ab | 33.63 a |
| | $V_2$×$T_4$ | 1.666 a | 3.278 ns | 4.944 a | 33.80 a |
| | $V_2$×$T_5$ | 1.500 ab | 2.972 ns | 4.472 ab | 33.46 a |
| | $V_3$×$T_1$ | 1.083 cde | 2.888 ns | 3.972 b | 27.31 bc |
| | $V_3$×$T_2$ | 1.138 cd | 2.972 ns | 4.110 ab | 27.78 bc |
| | $V_3$×$T_3$ | 1.068 cde | 2.977 ns | 4.046 ab | 26.28 bcd |
| | V3×$T_4$ | 1.222 bc | 3.167 ns | 4.388 ab | 27.92 b |
| | $V_3$×$T_5$ | 1.111 cde | 2.805 ns | 3.916 b | 28.10 b |
| | LSD | 0.2748 | 0.6325 | 0.8279 | 3.999 |
| | CV % | 14.47 | 12.66 | 12.02 | 8.79 |

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

## 4.3 Yield and yield contributing characters of selected rice varieties under different levels of 6-BAP

### 4.3.1 Panicle Length

There is a significant effect among the varieties of aromatic rice on panicle length and also significant relationship was found between the interaction of varieties and levels due to application of various levels of 6-BAP (Table 8). Among the varieties Chinigura showed the better performance. The maximum panicle length per hill was found in $V_1 \times T_2$treatment (30.22 cm) and the lowest panicle length hill$^{-1}$ was in $V_2 \times T_1$ (25.78 cm).

The aromatic rice cv. chinigura showed better performance at 150 ppm while Kataribhog showed better performance at 100 ppm and Kalijira showed better performance at 200 ppm of NAA, respectively (Sharmin, 2016).

The highest panicle length was obtained from Kataribhog rice variety while 50 ppm 6-BAP was applied (Khanam, 2016). 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 *et al.*, (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.

### 4.3.2 Effective tillers

There is a significant effect of 6-BAP and different levels on effective tiller hill$^{-1}$ of aromatic rice. Among the varieties Kataribhog and among the levels 60 ppm ($T_4$) BAP showed the better performance. From the interaction the maximum number of effective tiller hill$^{-1}$ was found in $V_2 \times T_4$ (18.78) and the lowest number of panicle hill$^{-1}$ was in $V_1 \times T_1$ (14.22) in the controlled plot.

Sharmin (2016) showed that Chinigura variety showed better performance at 150 ppm, Kataribhog showed better performance at 100 ppm and Kalijira showed better performance at 100 ppm of NAA than that of other levels.

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. Khanam (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.

### 4.3.3 Non effective tiller

Spraying of different levels of 6-BAP on non effective tillers hill$^{-1}$ was significant which presented at (Table 8).Result showed that maximum non effective tiller found in $V_2 \times T_4$ (2.223) which is similar with $V_2 \times T_5$(2.220).

Khanam (2016) found highest number of non effective tillers hill$^{-1}$ from Kataribhog rice at controlled level. Ling and Ma (1998) studied on winter wheat with endogenous growth regulator IAA and demonstrated that non effective tiller was decrease by IAA.

### 4.3.4 Grain no. panicle$^{-1}$

There is a significant effect among the varieties and levels of aromatic rice on grain no. panicle$^{-1}$. Among the varieties Kataribhog and among the levels 40 ppm ($T_4$) 6-BAP showed the better performance. The interaction effect of PGRs and varieties was also significant for grain no. per panicle (Table 8). The highest no. of grains per panicle were observed at $V_2 \times T_4$ (287.0) and $V_3 \times T_1$ (241.1) was the lowest performance in controlled plots.

In this study 40 ppm 6-BAP on Chinigura variety showed better performance on grain no. per panicle of rice variety. Kataribhog showed better performance at 60 ppm and Kalijira showed better performance at 40 ppm 60 ppm of 6-BAP than that of other levels.

Sharmin (2016) states that 150 ppm NAA on kalijira variety showed better performance on grain no. per panicle of rice variety. Chinigura variety showed better performance at 100 ppm, Kataribhog showed better performance at 100 ppm and Kalijira showed better performance at 150 ppm of NAA than that of other levels. Roxy (2016) reported that 50 ppm BAP increased the grain no. panicle$^{-1}$ of Kataribhog rice variety.

### 4.3.5 1000- Grain weight

There is a significant effect among the varieties of aromatic rice on 1000-grain wt, as well as non significant relationship was found between the interaction of varieties and levels due to application of various levels of 6-BAP (Table 8). The highest value 11.33 was found with $V_3 \times T_5$ and lowest value was 10.67 with $V_1 \times T_1$ from the interaction.

Roxy (2016) reported that 50 ppm BAP increased the 1000-grain wt. of Kataribhog rice variety. Khanam (2016) also reported that Kataribhog produced the highest 1000-grain weight while 50 ppm 6-BAP was applied.

Kabir *et al.* (2004*)* studied with different rice varieties like Begunbitchi, Chinigura and Kaijira and reported that Chinigura produced the highest 1000-grain weight. Akter (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.

Liu *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.

### 4.3.6 Grain yield (t ha$^{-1}$)

The rice varieties and different levels of 6-BAP were interacted significantly with each other in respect to grain yield which was presented in Table 9. There is also a significant effect among the varieties and different levels of 6-BAP of aromatic rice on grain yield. Table 9 showed that all the varieties produced lower yield under controlled treatment than PGR treated plants. Among the varieties Kataribhog and among the levels 60 ppm ($T_4$) BAP showed the better performance for yielding grain.

The highest grain yield was found in $V_2 \times T_4$ (1.66 t $ha^{-1}$) and the lowest grain yield was found in $V_1 \times T_5$ (0.7497 t $ha^{-1}$). In the present study, Chinigura variety showed better performance at 80 ppm, Kataribhog showed better performance at 60 ppm and Kalijira showed better performance at 60 ppm of 6-BAP than that of other levels.

Shamin (2016) reveled that Chinigura variety showed better performance at 150 ppm, Kataribhog showed better performance at 100 ppm and Kalijira showed better performance at 150 ppm of NAA than that of other levels.

Roxy (2016) reported that 50 ppm 6-BAP increased the grain yield of Kataribhog rice variety. Khanam (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 *et al.* (1994) observed that spraying of planofix (NAA) on wheat plant, significantly increased grain yields, which supported the result of the present study.

### 4.3.7 Straw yield (t $ha^{-1}$)

There is no significant effect among the varieties of aromatic rice and 6-BAP had no positive effect on straw yield between the interaction of varieties and different levels of 6-BAP which was presented in Table 9.

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. Khanam (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.

### 4.3.8 Biological yield

The biological yield was presented in Table 9. Table 9 showed that biological yield was influenced due to the interaction effect of variety and levels of plant growth regulators 6-BAP. Among the varieties Kataribhog and among the levels 60 ppm ($T_4$) BAP showed the better performance. The maximum biological yield was $V_2 \times T_4$ (4.944 t $ha^{-1}$) and the lowest yield was found in $V_1 \times T_1$ (3.610 t $ha^{-1}$).

Sharmin (2016) revealed that the maximum biological yield 6.23 t $ha^{-1}$ was found from Chinigura with 150 ppm of NAA. Roxy (2016) found that the maximum biological yield (6.25 t $ha^{-1}$) that was obtained from the 50ppm 6-BAP.

Khanam (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 (10.50 t $ha^{-1}$) was obtained from the combination of variety Nerica-4 and 100 ppm of $GA_3$.

### 4.3.9 Harvest index

Harvest index (HI) is an important yield determining character which can through idea along partitioning efficiency. Table 9 showed that harvest index (HI) was not influenced due to the interaction effect of variety and levels of plant growth regulators and among the varieties but not influenced the levels of plant growth regulator.

Among the varieties Kataibhog showed the better performance and all the treatments are non significant. From the interaction, highest harvest index $V_2 \times T_4$ (33.80 %) which was statistically similar with $V_2 \times T_3$ (33.66 %) and $V_2 \times T_5$ (33.46 %), respectively. The lowest harvest index was found in $V_1 \times T_5$ (20.5 7%).

Roxy (2016) found that the highest harvest index 39.24% at 50 ppm 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.

# CHAPTER V

# SUMMARY AND CONCLUSION

The research work was conducted at the agricultural farm under the department of Agricultural Chemistry of Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during the period of September to December, 2017 to study the response of 6-Benzyl aminopurin (6-BAP) on the performance of three aromatic rice cultivars. The experiment consisted of three varieties cv. Chinigura, Kataribhog ana Kalijira and five levels of PGRs viz. 0 ppm ($T_1$), 20 ppm ($T_2$), 40 ppm ($T_3$), 60 ppm ($T_4$) and 80 ppm ($T_5$) BAP, respectively.

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. The chlorophyll status, proline of the flag leaf of aromatic rice plant were also investigated. Results revealed that there was a significant relationship among the varieties and different levels of 6-BAP on harvesting stage on tillers hill$^{-1}$. Chlorophyll-a status of the flag leaf of aromatic rice plant was improved in the treated plants compared to the control. There is a significant relationship among the varieties, levels and interaction on chlorophyll-a content of aromatic rice leaves. Among the different levels, 60 ppm 6- Benzyl aminpurin (6-BAP) showed the best performance in chlorophyll-a in flag leaves of Chinigura rice cultivar than that of Kataribhog and Kalijira ensuring the highest photo-activity that means photosynthesis by harvesting highest sunlight. Maximum chlorophyll b was found in Chinigura variety. A significant variation was found among the varieties and different levels of 6-Benzyl aminopurin (6-BAP) in total chlorophyll content of flag leaves. A significant variation was also found in flag leaves poline content of aromatic rice in relation to applied various levels of BAP. 20 ppm BAP showed the best performance in Chinigura variety than that of both Kalijira and Kataribhog rice cultivar.

There is a significant effect among the varieties of aromatic rice on panicle length due to application of various level of BAP. Among the varieties Chinigura showed the better performance and among the treatments, 40 ppm of BAP gave better result. There is a significant effect among the varieties and various levels of BAP of aromatic rice on no. of effective tiller. Among the doses, 60 ppm BAP and among the varieties Kataribhog rice cultivar showed the best performance than that of Chinigura and Kalijira. There was a non significant effect among the varieties and various levels of BAP of aromatic rice on 1000-grain wt, and straw yield. There was a significant effect among the varieties and various levels of 6-BAP of aromatic rice on % harvest index and biological yield. In these parameters Kataribhog rice cultivar showed the best performance than that of Chinigura and Kalijira.

The interaction between variety and levels of 6-BAP of some yield contributing characters such as grain number per panicle, grain weight per panicle and total grain yield were significantly influenced by 6-BAP.

The maximum number of effective tiller $hill^{-1}$ was found in $V_2 \times T_4$ (18.78). The maximum number of grains per panicle was observed at $V_2 \times T_4$ (287.0). The highest grain wt. per panicle was observed at $V_2 \times T_4$ (1.66 t $ha^{-1}$). The highest biological yield was found in $V_2 \times T_4$ (4.94 t $ha^{-1}$). There was no significant effect on straw yield. The maximum harvesting index $V_2 \times T_4$ (33.80 %) was statistically similar with $V_2 \times T_3$ (33.66 %) and $V_2 \times T_5$ (33.46 %), respectively.

Most of the yield and yield contributing parameters increased by the concentration of 60 ppm 6-BAP on Kataribhog rice cultivar than that of Chinigura and Kalijira. In regard to all parameters, application of 60 ppm 6-BAP on Kataribhog rice cultivar performed the best regarding the yield and yield components.

It is concluded that aromatic rice Kataribhog and Kalijira variety showed better performance at 60 ppm of 6-BAP while Chinigura showed better performance at 80 ppm and may the recommended for the farmers' level 6-BAP a growth regulator might be useful to increase aromatic rice production which is an environment-friendly tool for agricultural management practices.

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