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YIELD AND YIELD CONTRIBUTING CHARACTERISTICS OF AROMATIC RICE AS INFLUENCED BY VARIETY AND GIBBERELLIC ACID

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ABSTRACT
An experiment was carried out at the Agronomy Research Field, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh during aman season (June to December) of 2020, to investigate the effect of gibberellic acid on yield and yield contributing characteristics of three aromatic rice varieties of aromatic rice. The experiment included two factors; Factor A: Variety; namely V_1=Tulsimala, V_2= Kalizira, and V_3= Kataribhog; Factor B: Gibberellic acid viz. G_1= Control, G_2 = 100 ppm G_3= 200 ppm. The experiment was conducted in randomized complete block design (RCBD) with three replications. The yield and yield contributing characteristics were significantly influenced by gibberellic acid and aromatic rice varieties. Kataribhog was found significantly superior to Kalizira and Tulsimala concerning the hight grain yield (2.50 t ha^{-1}) was recorded from 100 ppm gibberellic acid. It also 100 ppm produced the highest panicle length (22.85 cm), grains $panicle^{-1}$ number (162.44), 1000 grains weight (13.81 gm), grain yield (2.75 t ha^{-1}), biological yield (7.15 t ha^{-1}), and harvest index (38.46 %). The result indicated that Kataribhog (V_3) with 100 ppm ha^{-1} gibberellic and application could give the highest yield of aromatic rice.

Keywords: Gibberellic acid, aromatic rice, variety, yield

INTRODUCTION
Aromatic rice (*Oryza sativa* L.) is known for its characteristic fragrance when cooked. This constitutes a small but special group of rice, which is considered best in quality. Aromatic varieties fetch higher prices in the rice market than the non-aromatic ones. Cereals occupy more than half of the world's harvested area and are the most important food source for human consumption. The vast expanse of approximately 11.70 million hectares contributes to the production of around 37.96 million tons of rice in Bangladesh. (FAO 2022). Bangladesh agriculture involves food production for 163.65 million people from merely 8.75 million hectares of agricultural land (Salam *et al*. 2014). In fact, 'Rice security' is synonymous to 'Food security' in Bangladesh as in many other rice-growing countries (Brolley 2015). As the population projection for Bangladesh estimates an increase to 220 million by 2050 from the current 169 million (FAO 2022), the importance of rice production becomes even more pronounced. The

yield of boro rice is still dominant in producing 54% higher yield than aus and 40% higher than aman (BRRI 2018). Aromatic rice is long and medium-grained, with a characteristic pleasant and fragrant aroma, which makes aromatic rice highly favored in Southeast Asian and international markets. Plant growth hormones regulate plant growth and signal molecules produced within the plant and occur in extremely low concentrations. Hormones regulate cellular processes in targeted cells locally and when moved to other locations, in other locations of the plant. Plant hormones shape the plant, affecting seed growth, time of flowering, the sex of flowers, senescence of leaves and fruits. It has a significant effect on growth and phenotypic development on leafy vegetables. Gibberellic acid (GA_3) is a hormone induced in plants and its chemical formula is $C_{19}H_{22}O_6$. The obtained favorable effect of GA_3 (as growth regulator) in improving rice growth, as well as, grain yield and its components of rice, might be due to its activation to α-amylase for breakdown of stored starch during germination, enhancing IAA exertion, promoting cell elongation and division particularly, mesocotyl length and internodes of rice plants, reducing Na and Cl uptakes, increasing K, P and N uptakes and chlorophyll content leading to high seedling vigor, reasonable rice growth at early and late stages, improving source-sink relation resulted in high grain yield and its components under salt stress (Pan *et al*. 2013). Thus, application of GA_3 may play an important role in rice cultivation when used alone or in combination with variety. Because of limited information on the problems mentioned above, this present study was therefore, undertaken with the following objectives: to identify the best concentration of GA_3 for maximum growth and yield of aromatic rice, to find out the suitable variety of aromatic rice and to assess the combined effect of gibberellic acid and variety of aromatic rice.

MATERIALS AND METHODS

The experiment was conducted in the Agronomy Research Field at the west side of the Hajee Mohammad Danesh Science and Technology University, Dinajpur. The floodplain soils on the experimental land were dark grey and non-calcareous. The field had a pH of 6.5, was medium-high, well-drained silty-loam texture, and had a low organic matter content of 1.67 % (SRDI 2020). The study was carried out in the aman season, also referred to as the Kharif-2 season, which runs from June to December 2021 in subtropical areas. The study consisted of the following factors and treatments Factor-A: Variety; V_1=Tulsimala, V_2=Kalizira, V_3= Kataribhog and Factor-B: Gibberellic acid (Three levels) G_1= control, G_2=100 ppm, G_3=200 ppm. Three replications and nine treatments were used in the randomized complete block design of the experiment. At first, we prepared the stock solution of GA_3, adding 1g of GA_3 into a 1.0 L beaker. 250 ml of distilled water was added in the beaker with stir until dissolved and make sure final volume 1000 ml. The final concentration of the stock solution was 1000 ppm (1 g L^{-1}). The working solution was prepared as per treatments and applied on the experiment plots at pre-flowering stage. The unit plot measured 4.0 m x 2.5 m and was separated by 50 cm and 25 cm, respectively. The seeds of fine rice variety (Kataribhog, Kalizira, and Tulsimala) were collected from the Seed Marketing Division, Bangladesh Agricultural Development Corporation (BADC), Dinajpur. Healthy seeds were selected by specific gravity method. Seeds were then immersed in water in a bucket for 24 hours. The seeds started sprouting after 48 hours and were sown after 72 hours of steeping. The land was

puddled with country plough, cleaned and leveled with ladder. Then the sprouted seeds were sown in the nursery beds on 25 June 2021. Weeds were removed and irrigation was provided in the seedling nursery as and when necessary. The experimental land was first opened with a tractor drawn disc plough. The land was then puddled thoroughly by repeated ploughing and cross ploughing with a country plough and subsequently leveled by laddering. Well decomposed cow dung was applied before transplanting. Recommended doses of other inorganic fertilizers of Urea, TSP, Mop, and Gypsum were applied at the rate of 150,120, 100 and 110 kg per ha, respectively (BRRI 2018). Thirty days old seedlings were transplanted on 25 July 2021 in the well puddle plot. Three seedlings were transplanted on each hill with a spacing of 25 cm x 15 cm. Gap filling, weeding, irrigation and drainage, pest and disease protection measures were done for ensuring and maintaining normal growth of the crop. The crop was harvested at maturity on 30 November 2021. Five hills were randomly selected for measuring plant height and tiller production and to record data on yield contributing characters. The harvested crops of each plot were separately bundled, properly tagged and then brought to the threshing floor. The following parameters were recorded at harvest: i) Plant height (cm) ii) Number of fertile tillers hill^{-1} iii) Panicle length (cm) iv) Number of grains panicle^{-1} v) Total grains weight (g) vi) Grain yield (t ha^{-1}) vii) Straw yield (t ha^{-1}) viii) Biological yield (t ha^{-1}) ix) Harvest index (HI). All the collected data were analyzed following the analysis of variance (ANOVA) technique and mean differences were adjudged by Duncan's Multiple Range Test (DMRT) using a computer-operated program namely, MSTAT-C.

RESULTS AND DISCUSSION

Varietal differences on yield contributing characteristics and yield

The main effect of variety on plant height at the harvest stage was significant. The highest plant height (151.41 cm) was obtained from V_3 and the lowest plant height (138.27 cm) was obtained in V_2. The maximum number of effective tillers hill^{-1} (16.14) was recorded in V_3 and the minimum number of effective tillers hill^{-1} (15.86) was produced in V_2 (Kalizira) (Table 1). These findings collaborate with those reported by Shiyam *et al.* (2014) who studied that number of fertile tillers hill^{-1} was varied with variety. Significant variation was observed in panicle length among the varieties of aromatic rice (Table 1). The results showed that the maximum panicle length (21.91 cm) was found in V_3 which is statistically different from others. The minimum panicle length was obtained in V_1 (21.36 cm). The results agreed with the findings of Hossain *et al.* (2014). However, the highest number of grains panicle^{-1} (147.72) was found in V_3=Kataribhog which is statistically different from others. The lowest number of grains panicle^{-1} was obtained in Kalizira (112.85). Hossain *et al.* (2014) and Sarker *et al.* (2013) also find similar results under irrigated conditions. The variety of aromatic rice had a significant effect on the weight of 1000-grain. The highest 1000 grain weight (13.27g) was observed in V_3 and the lowest weight (11.84 g) was observed in V_1. The result showed that V_3 produced 50.65% heavier seed than V_1. The results agreed with the findings of Shiyam *et al.* (2014). Varieties differed significantly in producing grain yield. Among the varieties, V_3 showed its superiority in producing highest grains compared to other varieties, respectively. However, V_3 produced the highest grain yield (2.12 t ha^{-1}) which was statistically similar to V_2. The lowest grain yield (1.64 t ha^{-1}) was found in V_1 (table 1). The results agreed with the findings of Hossain *et al.* (2014), Straw yield differed significantly due to

Table 1. Effect of variety on growth, and yield and yield contributing characteristics of aromatic rice

Varieties	Plant height (cm)	Effective Tillers (no.)	Panicle length (cm)	Grains panicle^{-1} (no.)	1000 grains weight(g)	Grain Yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
V_1	138.27	16.25 b	21.36 b	120.88 b	11.84 c	1.64c	3.97b	6.02c
V_2	147.89	15.86 c	21.52 ab	112.85 b	12.43 b	1.82.b	4.20 a	6.47 b
V_3	151.41	16.14 a	21.91 a	147.72 a	13.27 a	2.12a	4.35 a	6.77 a
LS	NS	**	**	**	**	**	**	**
CV(%)	7.72	6.90	3.10	9.03	2.12	3.85	3.88	3.59

Here, CV= Coefficient of variation, LS = Level of significant, **= significant at 1% level of probability, *= significant at 5% level of probability, V_1= Tulshimala, V_2, = Kalizira ,V_3= Kataribhog.

varietal effect. V_3 gave the highest straw yield (4.35 t ha^{-1}) and the lowest straw yield was found in V_1 (3.97 t ha^{-1}). The differences in straw yield among the varieties might be attributed to the genetic makeup of the varieties. Patel (2000) also obtained variable straw yield among the varieties.

Gibberellic acid on yield contributing characteristics and yield

The result showed that gibberellic acid significantly affected the plant height (Table-2). The highest plant height (155.23 cm) was found in G_3. The lowest plant height (133.68 cm) was obtained in treatment G_1 (Table-2). Plant height was increased due to the application of gibberellic acid which ensured a favorable condition for the growth of rice plant with optimum vegetative growth and the ultimate results was the tallest plant.

The effect of gibberellic acid significantly increased the number of fertile tillers hill^{-1}. The effect of gibberellic acid on the number of fertile from the treatment G_3 recorded the highest number of tillers hill^{-1} (17.80) that was statistically significant ($P \leq 0.01$) and superior to other treatments and the lowest (13.86) from the control. The maximum panicle length (22.43 cm) was found in G_2 which was statistically different from others. The minimum panicle length (20.99 cm) was obtained in G_1. The results agreed with the findings of Islam *et al*. (2008). There was a significant variation in panicle length at harvest due to the interaction effect of variety and gibberellic acid (Table 2).

Table 2. Effect of gibberellic acid on growth, and yield and yield contributing characteristics of aromatic rice

Gibberellic acid	Plant height (cm)	Effective Tillers (no.)	Panicle length (cm)	Grains panicle^{-1} (no.)	1000 grains weight(g)	Grain Yield (Tha-1)	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
G_1	133.68 b	13.86 c	20.99 b	114.63b	12.22 b	1.62c	4.02b	6.02 c
G_2	148.66ab	16.60 b	22.43 a	137.76 a	12.91 a	1.72b	4.24a	6.74 a
G_3	155.23 a	17.80 a	21.36 b	129.06 a	12.41 b	2.08a	4.26 a	6.50 b
LS	**	**	**	**	**	**	**	**
CV(%)	7.72	6.90	3.10	9.03	2.12	4.21	3.88	3.59

Here, CV= Coefficient of variation, LS = Level of significant, **= significant at 1% level of probability, *= significant at 5% level of probability,G_1= Control (no gibberellic acid),G_2, = 100 ppm ,G_3= 200 ppm

From the obtained result in Table 2 also found that the length of panicle significantly varied from 20.76 cm to 22.85 cm. The number of grains panicle^{-1} was significantly affected due to application of gibberellic acid. The highest number of grains panicle^{-1} (137.76) was obtained due to application of G_2 and the lowest number of grains panicle^{-1} (114.63) was obtained in G_1. The weight of 1000-grain was significantly influenced by the different levels of gibberellic acid (Figure 2). The highest weight of 1000-grains was recorded due to application of gibberellic G_2 (12.91g). The lowest weight (12.22 g) of 1000-grain was recorded from the G_1 treatment. The results agreed with the findings of Mannan *et al.* (2010). The effect of gibberellic acid on aromatic rice varieties significant was found on the weight of 1000-grains (Table 2). Grain yield was significantly influenced by different sources of gibberellic acid. The maximum grain yield (2.08 t ha^{-1}) was obtained due to application of treatment G_2 followed by treatment G_3 (1.72 t ha^{-1}). The minimum grain yield (1.62 t ha$^{-1)}$ was obtained due to application of treatment G_1 followed by others treatment (Table 2). Among the different levels of gibberellic acid, G_2 produced 41.83% higher grain than the other treatments. Improvement of yield components such as number of effective tillers hill^{-1} and number of grains panicle^{-1} in these treatments ultimately resulted in high yield of grains. The results agreed with the findings of Mannan *et al.* (2010) under irrigation conditions. Straw yield was recorded highest (4.26 t ha^{-1}) at treatment G_3 followed by treatment G_2 (4.246 t ha^{-1}). The lowest straw yield (4.02 ha^{-1}) was found in G_1 = control treatment. There was observed a significant difference between the interactions of varietal variation and gibberellic acid in respect of straw yield (Table 2). Straw yield varied significantly with the different levels of gibberellic acid Significant variation in biological yield was observed due to varietal variations and it ranges from 6.028 to 6.77 t ha^{-1}. Biological yield differed significantly due to the different levels of gibberellic acid. Treatment GA_2 produced the highest biological yield (6.747 t ha^{-1}) which was statistically similar to G_3 and the lowest biological yield (6.02 t ha^{-1}) was recorded at G_1 treatment. GA_3 application during heading to flowering stage may have influenced seed setting rate and seed yield (Seetharamaiah *et al.* 1994). Susilawati *et al.* (2014) reported that the optimum

rate of 200 ppm of GA_3 application with two splits at the 5-10% panicle heading stage increased stigma exsertion, panicle length, panicle exsertion, seed setting rate and seed yield.

Interaction of variety and gibberellic acid on yield contributing characteristics and yield

Interaction effect of variety and gibberellic acid was significant on plant height. The highest plant height (159.89) was obtained from V_3G_3. The lowest plant height (122.65 cm) was obtained in the treatment V_1G_1 where gibberellic acid was used. The productivity of rice plants is greatly dependent on the number of productive tillers rather than the total number of tillers. In the present investigation, the maximum number of effective tillers per panicle was observed in the all the treated plants. A significant interaction between variety and gibberellic acid was found in producing fertile tillers hill aromatic rice (Table 3).

Table 3. Interaction effect of varietal variation and gibberellic acid on the growth and yield and yield contributing characteristics of aromatic rice

Combined effect of V & G	Plant height (cm)	Effective Tillers (no.)	Panicle length (cm)	Grains panicle^{-1} (no.)	1000-grains weight (g)	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
V1G1	122.65 c	13.96 b	20.76 d	108.60 de	11.56 e	3.77 d	5.58 e
V1G2	150.59ab	16.86 a	22.18ab	132.41 bc	12.15 cd	4.05 c	6.31 cd
V1G3	155.89 ab	17.93 a	21.14cd	121.63cde	11.81 de	4.10 bc	6.18 cd
V2G1	133.21bc	13.76 b	21.19cd	106.10 e	12.17cd	4.07 c	6.08 d
V2G2	152.98 ab	16.53 a	22.26ab	118.43cde	12.78 b	4.28abc	6.77 ab
V2G3	156.64 a	17.30 a	21.11 cd	114.04cde	12.33 c	4.27abc	6.55 bc
V3G1	145.19 ab	13.86 b	21.04 cd	129.19 cd	12.93 b	4.24abc	6.41bcd
V3G2	152.41 ab	16.40 a	22.85 a	162.44 a	13.81 a	4.39 ab	7.15 a
V3G3	159.89 a	18.16 a	21.85 bc	151.52 ab	13.09 b	4.4 a	6.77 ab
LS	**	**	**	**	**	**	**
CV(%)	7.72	6.90	3.10	9.03	2.12	3.88	3.59

Here, CV= Coefficient of variation, LS = Level of significant, **= significant at 1% level of probability, V_1G_1 =(Tulsimala + 0 or Control) ,V_1G_2=(Tulsimala + 100 ppm), V_1G_3 =(Tulsimala+ 200ppm), V_2G_1 =(Kalizira+ 0 or Control), V_2G_2 =(Kalizira+ 100 ppm), V_2G_3=(Kalizira + 200ppm), V_3G_1=(Kataribhog + 0 or Control), V_3G_2=(Kataribhog +100 ppm), V_3G_3=(Kataribhog+ 200ppm).

The number of effective tillers hill^{-1} ranged from 13.76 to 18.16. The highest number of tillers hill^{-1} (18.16) was obtained from V_3G_3 treatment, which was statistically significant over all other treatments. The lowest number of total tillers hill^{-1} (13.76) was obtained from V_2G_1 treatment. The longest panicle (22.85 cm) was recorded from the treatment V_3G_2 containing, while the

shortest panicle (20.76 cm) was obtained from the treatment V_1G_1 containing. Significant variation was observed in the number of grains panicle^{-1} among the varieties in aromatic rice. The maximum weight of 1000 grains (13.81 g) were obtained in the interaction of V_3G_2 treatment that was statistically similar to the interaction of V_3G_1, V_3G_3 and V_2G_2. The minimum weight of 1000-grains (11.56 g) was obtained in the interaction of V_1G_1 that was statistically similar to V_1G_3, V_1G_2 and V_2G_1. The result also showed that Kataribhog produced a higher level of 1000-grains weight than other interactions irrespective of different levels of gibberellic acid. Grain yield is influenced significantly by the interaction of variety and gibberellic acid. Among the interaction treatments, the highest grain yield (2. 54 t ha^{-1}) was recorded in the interaction of V_3G_2 followed by V_2G_2 (2.49 t ha^{-1}). The lowest grain yield (1.62 t ha^{-1}) was observed in V_1G_1 followed by V_2G_1 and V_1G_3 (Fig. 1).

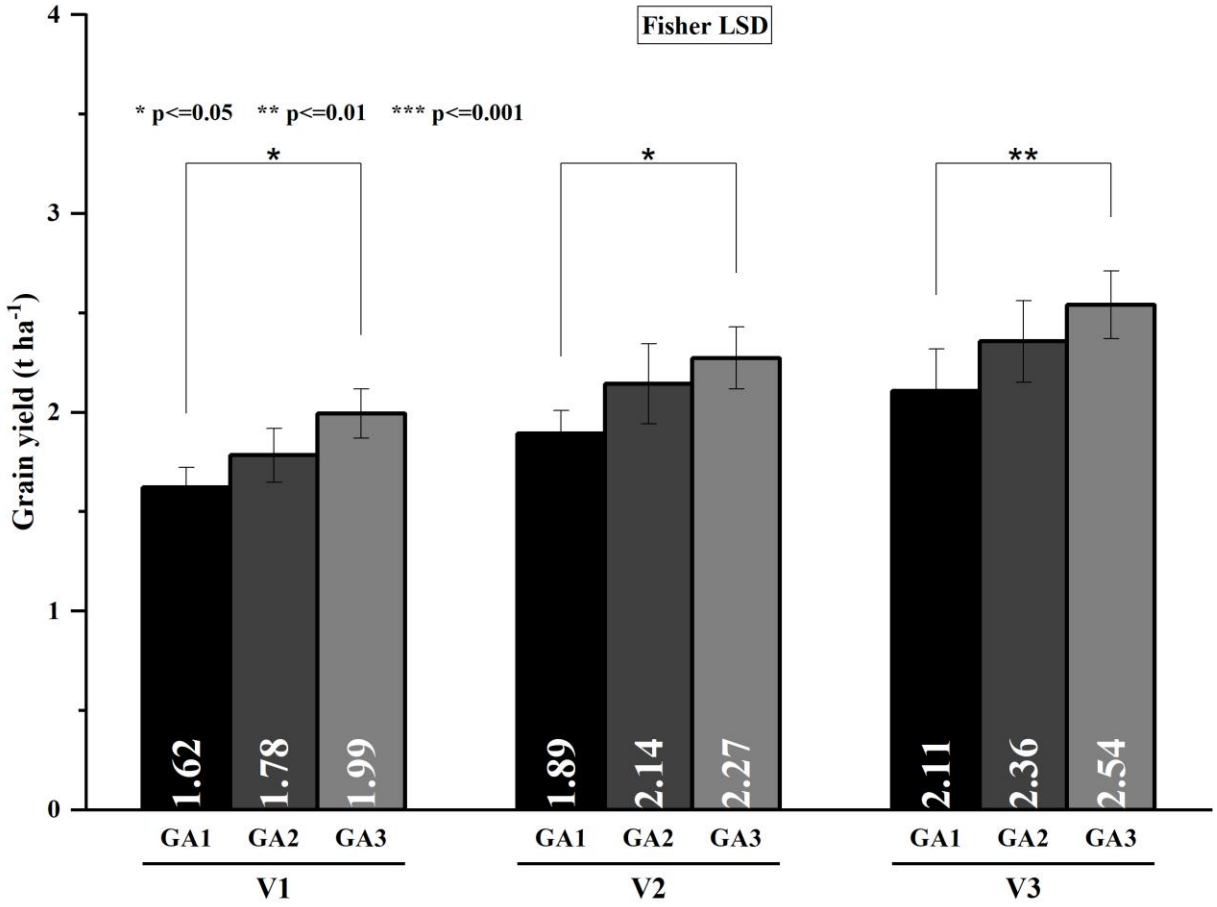

Figure 1. Effect of interaction of Variety and GA_3 o grain yield of aromatic rice. Here, GA_1= Control (no gibberellic acid), GA_2, = 100 ppm, GA_3= 200 ppm, V_1= Tulshimala, V_2, = Kalizira ,V_3= Kataribhog.

The maximum straw yield (4.42 t ha^{-1}) was found from the interaction of V_3G_3 followed by V_3G_2. Significant variation in biological yield was observed in the interaction effect of varietal variation and fertilizer management (Table 3). The study observed that GA_3 apparently influences agronomical and morphological attributes in aromatic rice due to stimulating the rapid call division resulting faster vegetation and reproductive growth. Local cultivars of aromatic rice were highly prepared by the farmers due to their wide adaptability and good taste. Considering the above fact significant steps should be undertaken to improve yield and performance of aromatic rice.

CONCLUSION

The variety and gibberellic acid have a significant influence on growth and productivity in aromatic rice. Yield and yield contributing characteristics variation were observed with different gibberellic acid levels of all varieties along with the improvement of yield contributing characters. Kataribhog was found significantly superior to Kalizira and Tulsimala with respect to the highest grain yield (2.50 t ha^{-1}) was recorded from @ 100 ppm ha^{-1} gibberellic acid. The effect of interactions of variety and gibberellic acid management were statistically significant on several yield contributing characteristics. The cultivar Kataribhog (V_3), @ 200 ppm ha $^{-1}$ gibberellic acid produced highest plant height (159.89 cm), effective tillers number (18.16) and straw yield (4.42 t ha $^{-1}$) .The application of gibberellic acid @ 100 ppm ha $^{-1}$ produced the highest panicle length (22.85 cm), grains $panicle^{-1}$ number (162.44), 1000 grains weight (13.81 gm), grain yield (2.75 t ha $^{-1}$), biological yield (7.15 t ha $^{-1}$), and harvest index (38.46 %).The result indicated that Kataribhog (V_3) with the application of @ 100 ppm ha^{-1} could give the highest yield of aromatic rice.

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