Original Research Article

Leaf Characteristics and Grain Yield of Three Aromatic Rice Cultivars as Influenced by 6-Benzylaminopurine

ABSTRACT

~~In order~~To explore the effectsof 6-Benzylaminopurine (BAP)on leaf characteristics and grain yield of aromatic rice the present investigation was carried out. The experimental materials comprising four concentrations of BAP (0 ppm, 30 ppm, 60 ppm and 90 ppm) and three aromatic rice cultivars (Chinigura, Kataribhog and Kalijira). The experiment was laid out in randomized complete block design and replicated thrice. Statistical analysis indicated that leaf characteristics and grain yield of aromatic rice were significantly influenced by the concentrations of BAP. Leaf number, leaf length, leaf breadth, leaf dry weight, panicle length, 500-grain weight and grain yield were increased with the increasing concentration of BAP. Among the concentrations, the 90 ppm of BAP performed better regarding the parameters studied. Maximum number of leaf, longest leaf, maximum leaf dry weight, highest length breadth ratio of leaf and maximum 500-grain weight was observed in Kataribhog which was statistically at par with that of Kalijira. Broader leaf was observed in Chinigura, whereas longest panicle and highest grain yield was recorded from Kalijira. Among different treatment combinations the highest grain yield (4.10 t ha^{-1}) was recorded from Kalijira × 90 ppm BAP treatment and the lowest grain yield (3.08 t ha^{-1}) was recorded from Chinigura × control treatment.

Keywords: Grain yield; leaf characteristics; flag leaf;6-Benzylaminopurine; aromatic rice.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the staple foods in the global food system ~~which provides energy, protein and vitamins for about half of the world population. Rice consumers are increasing day by day and the number has been doubled by the year of 2020 than that of the last ten years. Rice~~ and its requirement is increasing dramatically due to the rapid growth of world population.~~and~~Many nations are facing second-generation challenge of producing more rice to ensure food and nutritional security.

There are two types of rice grain: one is coarse grain and another is fine grain. Fine grains are generally aromatic, which are a special group of rice considered as best in quality and known for its characteristic fragrance when cooked. Cultivation of aromatic rice has been gaining popularity in Bangladesh over the recent years due to its high prices [1] and huge demand both for internal consumption and export [2]. Most important aromatic rice cultivars of Bangladesh are Basmati, Chiniatop, Kataribhog, Chinigura and Kalijira which have pleasant aroma, fine small grain, soft texture upon cooking and good taste. These cultivars are very popular in Asia and has recently gained wider acceptance in the United States, Europe and the Middle East [3]. Although, the demand for aromatic rice is increasing day by day, they have some undesirable agronomic characters, such as low yield [4], susceptibility to pests and diseases and strong shedding [5]. In this situation, improved technologies are required to bridge the gapto feed the increasing population and a substantial yield increaseof aromatic rice through different agronomic management could be an effective way to face the future challenge to feed the increasing population.

Plant growth regulators are organic substances produced naturally in the higher plants acts in different stages of the same crop in a different way. Among the different plant growth regulators, BAP has found to stimulate cell division, induce shoot formation and axillary shoot proliferation, increase plant height, number of leaves plant^{-1} and fruit size with consequent enhancement in seed yield in different crops [6,7]. The introduction of growth regulators has added a new dimension to the possibility for improving the growth and yield of crop and the scientists of Bangladesh are being advised to use plant growth regulators to get higher rice production. But the research work on examining the effect and suitable dose of BAP for better rice yield is still in initial stage, especially on aromatic rice.

Rice is mainly grown for its grain yield and grain yield is a complex trait genetically controlled by a series of complex biochemical and physiological processes [8]. Photosynthesis of carbohydrate is the primary source of grain yield in rice and plant leaves are considered as the important determinant and characterized for higher photosynthetic capacities [9]. Grain filling is sustained by current photosynthesis of the flag leaf, penultimate leaf and the ear [10]. Flag leaf provides the most important source of photosynthetic energy during reproduction which is metabolically active and has proved as the closest source of food to the grain [9,11]. As leaf has important role on grain yield it is prerequisite to analyze the morphological and the physiological characteristics of functional leaves to improve grain yield in rice [12]. Leaf contributes most to grain yield so it is hypothesized that improvement of morpho-physiological characters of flag leaf and other leaves through some agronomical treatments may increase grain yield in aromatic rice. Therefore, the experiment was carried out to evaluate the effects of different concentrations of BAP on leaf characteristics and grain yield of three aromatic rice cultivars.

2. MATERIALS AND METHODS

2.1 Location and Duration

The experiment was conducted at research farm of Department of Agricultural Chemistry, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh during September to December, 2016. The experimental area is located under the Agro-ecological zone “Old Himalayan Piedmont Plain”. The experimental field is a medium high land belonging to the non-calcareous dark gray floodplain soil with sandy loam texture located at 25º39′ N latitude and 88º41′ E longitude with an elevation of 37.58 m above the sea level.

2.2 Experimental Design and Layout

The experiment was laid out in a randomized complete block design with three replications. The selected land area was divided into three equal blocks. Each block was divided into twelve plots and total number of plots for this experiment was thirty-six where four treatments were allotted at random. First block was considered as first replication, second one as second replication and last one as third replication. The unit plot size was 3 m × 2 m having plot to plot and block to block distance of50 cm and 1.0 m, respectively. 15 cm plant to plant distance and 20 cm row to row distance was also maintained.

2.3 Experimental Treatments

The treatments consisted of two factors; Factor 1: Four concentrations of BAP and Factor 2: Three cultivars of aromatic rice. The four concentrations of BAP were $B_{1=}$ control (no BAP), B_2 = 30 ppm BAP, B_3 = 60 ppm BAP and B_4 = 90 ppm BAP and the three rice cultivars were

Chinigura, Kataribhog and Kalijira. There were twelve treatment combinations and they were distributed randomly in thirty-six plots.

2.4 Preparation and Application of BAP

The 30, 60 and 90 ppm solution of BAP was prepared by dissolving 30, 60 and 90 mg of BAP, respectively in a 1 liter measuring cylinder in which 5ml of ethanol was added prior to dilution. The distilled water was added to make the volume 1 liter to get desired concentration. The prepared BAP solution was sprayed twice, one at 30 days after transplanting and another at 60 days after transplanting at afternoon by using a hand sprayer.

2.5 Intercultural Operations

Necessary intercultural operations *viz.* weeding, gap filling, fertilization, irrigation, drainage and plant protection measures were taken when and as necessary.

2.6 Data Collection

Data were recorded on number of leaf plant^{-1}, length of leaf blade, leaf dry weight, flag leaf characteristics, panicle length, 500-grain weight and grain yield.

2.7 Statistical analysis

The collected data were analyzed by partitioning the total variance using the statistical software small STATA and the means were compared by Duncan's Multiple Range Test (DMRT) at 5% level of significance.

3. RESULTS AND DISCUSSION

3.1 Number of Leaf

Number of leaf of aromatic rice at different stages was significantly varied by both the individual effect and interaction effect of cultivars and concentrations of BAP except varietal effect on number of leaf at 30 days after transplanting (DAT) (Tables 1 & 2). Among the three cultivars, the maximum number of leaf was recorded in Chinigura (3.60) at 30 DAT, in Kalijira (8.20) at 60 DAT and in Kataribhog (12.45) at harvest which was statistically similar with that of Kalijira (11.99), whereas minimum was recorded in Kataribhog at 30 and 60 DAT (3.28 and 7.07, respectively) in Chinigura (10.84) at harvest. Among the different concentrations, 90 ppm of BAP produced the maximum number of leaf (4.43, 8.64 and 12.76, respectively) at different stages of aromatic rice, while minimum number of leaf was recorded from treatment where no BAP was applied.

At 30 DAT, the Kalijiracultivar spraying with 90 ppm BAP had the maximum leaf number (4.47) which was statistically at par with other two cultivars spraying with 90 ppm BAP. At 60 DAT, Kalijira × 60 ppm BAP had the highest leaf number (8.73) which was statistically similar with that of Kalijira × 90 ppm BAP (8.67), Kataribhog × 90 ppm BAP (8.59), Chinigura × 90 ppm BAP (8.67) and Chinigura × 60 ppm BAP (8.62). At harvesting period, the maximum leaf number (13.34) was again recorded from Kalijira × 90 ppm BAP which was statistically similar with leaf number (13.18) recorded from Kataribhog × 90 ppm of BAP. At 30 DAT, Chinigura and Kalijira with control (2.67) and Kataribhog with control and 30 ppm BAP (2.34 and 2.67) had the statistically similar and minimum leaf number. At 60 DAT, Chinigura with control and Kataribhog with control, 30 and 60 ppm BAP had the statistically similar and minimum leaf number, whereas at harvesting Chinigura × control produced the minimum number of leaf in aromatic rice. The increase in number of leaf in rice plant under BAP application possibly due to the stimulatory effect of BAP on vegetative growth of plant.

Table 1. Effect of cultivar and concentration of BAP on number of leaf of aromatic rice

Treatment	Number of leaf at		
	30 DAT	60 DAT	Harvest
Rice cultivars			
V_1	3.60	7.84b	10.84b
V_2	3.28	7.07c	12.45a
V_3	3.54	8.20a	11.99a
Level of significance	NS	0.05	0.05
Concentration of BAP			
B_0	2.56c	6.81d	10.49c
B_1	3.27bc	7.34cd	11.49b
B_2	3.63ab	8.00b	12.30a
B_3	4.43a	8.64a	12.76a
Level of significance	0.05	0.05	0.05
CV%	14.34	13.56	10.70

In a column, means sharing common letters did not differ significantly from each other at 5% probability level by DMRT. V_1 = Chinigura, V_2 = Kataribhog and V_3 = Kalijira. B_0 = Control, B_1 = 30 ppm BAP, B_2 = 60 ppm BAP and B_3 = 90 ppm BAP. DAT = Days after transplanting.

Table 2. Interaction effect of cultivar and concentration of BAP on number of leaf of aromatic rice

Interaction	Number of leaf at		
	30 DAT	60 DAT	Harvest
V_1B_0	2.67b	6.39b	9.14d
V_1B_1	3.66ab	7.67ab	10.79cd
V_1B_2	3.67ab	8.62a	11.67bc
V_1B_3	4.39 a	8.67a	11.77bc
V_2B_0	2.34b	6.44b	11.73bc
V_2B_1	2.67b	6.58b	12.34ab
V_2B_2	3.67ab	6.67b	12.56ab
V_2B_3	4.44 a	8.59a	13.18a
V_3B_0	2.67b	7.59ab	10.60cd
V_3B_1	3.47ab	7.78ab	11.34bc
V_3B_2	3.54ab	8.73a	12.67ab
V_3B_3	4.47 a	8.67a	13.34 a
Level of significance	0.05	0.05	0.01
CV%	10.34	11.56	8.70

In a column, means sharing common letters did not differ significantly from each other at 5% probability level by DMRT. V_1 = Chinigura, V_2 = Kataribhog and V_3 = Kalijira. B_0 = Control, B_1 = 30 ppm BAP, B_2 = 60 ppm BAP and B_3 = 90 ppm BAP. DAT = Days after transplanting.

3.2 Length of Leaf Blade

Table 3 shows that the individual effect of cultivars was not significant on length of leaf blade of aromatic rice at different stages of growing but the effect of BAP concentrations was significant on length of leaf blade except at 30 DAT. Among the three cultivars, the Kataribhog had the longest leaf blade (34.60 cm and 39.65 cm, respectively) at 60 DAT and at harvest, while the Kalijira had the longest leaf blade (24.26 cm) at 30 DAT. Shortest leaf blade was recorded in the cultivarChinigura at 30 and 60 DAT (23.88 cm and 33.35, respectively), while the cultivarKalijira had the shortest leaf blade (39.03 cm) at harvest. Among the different concentrations of BAP, 90 ppm of BAP produced the longest leaf blade at different stages of growing (24.72cm at 30 DAT, 35.31 cm at 60 DAT and 40. 77 cm at harvest). At harvest, 60 ppm BAP produced the lower but statistically similar length of leaf blade to 90 ppm BAP. The shortest leaf blade was obtained from treatment where no application of BAP was done.

The length of leaf blade of aromatic rice was also significantly influenced by the interaction effect of cultivars and BAP concentrations at different growing stage except at 30 DAT (Table 4). However, at 30 DAT, the longest leaf blade (24.89 cm) was recorded from the interaction of Kalijira × 90 ppm BAP. At 60 DAT, highest length of leaf blade (35.84 cm) was found in Kataribhog × 90 ppm BAP which was statistically identical with that of Kataribhog × 60 ppm BAP (35.24 cm) and Kalijira × 90 ppm BAP (35.35 cm). At harvest, the longest leaf blade (41.83 cm) was again observed in Kalijira × 90 ppm BAP. The shortest leaf blade was

Table 3. Effect of cultivar and concentration of BAP on length of leaf blade of aromatic rice

Treatments	Length of leaf blade (cm) at		
	30 DAT	**60 DAT**	**Harvest**
Rice cultivars			
V_1	23.88	33.35	39.09
V_2	24.05	34.60	39.65
V_3	24.26	33.59	39.03
Level of significance	NS	NS	NS
Concentration of BAP			
B_0	24.07	31.96d	36.88c
B_1	23.28	33.56c	39.07b
B_2	24.17	34.56ab	40.29a
B_3	24.72	35.31a	40.77a
Level of significance	NS	0.05	0.05
CV (%)	4.22	2.86	3.78

In a column, means sharing common letters did not differ significantly from each other at 5% probability level by DMRT. V_1 = Chinigura, V_2 = Kataribhog and V_3 = Kalijira. B_0 = Control, B_1 = 30 ppm BAP, B_2 = 60 ppm BAP and B_3 = 90 ppm BAP. DAT = Days after transplanting.

Table 4. Interaction effect of cultivar and concentration of BAP on length of leaf blade of aromatic rice

Interaction	Length of leaf blade (cm) at		
	30 DAT	**60 DAT**	**Harvest**
V_1B_0	23.44	31.44c	35.78d
V_1B_1	23.34	33.22bc	39.42bc
V_1B_2	23.86	34.00ab	40.93ab
V_1B_3	24.88	34.74ab	40.23ab
V_2B_0	24.27	33.04bc	38.00c
V_2B_1	23.26	34.29ab	39.69bc
V_2B_2	24.26	35.24a	40.63ab
V_2B_3	24.39	35.84a	40.26ab
V_3B_0	24.50	31.40c	36.87cd
V_3B_1	23.24	33.17bc	38.11c
V_3B_2	24.40	34.45ab	39.31bc
V_3B_3	24.89	35.35a	41.83a
Level of significance	NS	0.05	0.05
CV%	4.22	2.86	3.78

In a column, means sharing common letters did not differ significantly from each other at 5% probability level by DMRT. V_1 = Chinigura, V_2 = Kataribhog and V_3 = Kalijira. B_0 = Control, B_1 = 30 ppm BAP, B_2 = 60 ppm BAP and B_3 = 90 ppm BAP. DAT = Days after transplanting.

recorded from Kalijira × 30 ppm BAP at 30 DAT (23.24 cm), Kalijira × control (31.40 cm) (statistically similar with that of Chinigura × control) at 60 DAT and Chinigura × control at harvest (35.78 cm). BAP significantly influences both the vegetative and reproductive growth. It also increases rate of photosynthesis, accelerates translocation and efficiency of utilization of photosynthase thus resulting in the cell elongation and rapid cell division which might be the reason behind the increase in leaf length.

3.3 Leaf Dry Weight

Leaf dry weight of aromatic rice was significantly varied by the individual effect as well as the interaction effect of cultivar and concentration of BAP (Tables 5 & 6). Among the three cultivars, Kataribhog accumulated maximum leaf dry weight at both 60 DAT and harvest (1.50 g and 1.56 g, respectively) which was statistically at par with leaf dry weight accumulated by Chiniguracultivar (1.49 g at 60 DAT and 1.50 g at harvest), whereas the Kalijiracultivar accumulated minimum leaf dry weight at both stages (1.34 g at 60 DAT and 1.36 g at harvest). Among different levels of BAP, 60 ppm BAP produced the maximum leaf dry weight by 1.63 g at 60 DAT followed by that of 90 ppm BAP and by 1.72 g at harvest, whereas minimum leaf dry weight (1.22 g at 60 DAT and 1.28 g at harvest) was recorded from treatment where no application of BAP was done.

Table 5. Effect of cultivar and concentration of BAP on leaf dry weight of aromatic rice

Treatments	**Leaf dry weight (g) at**	
	60 DAT	**Harvest**
Rice cultivars		
V_1	1.49a	1.50a
V_2	1.50a	1.56a
V_3	1.34b	1.36b
Level of significance	0.01	0.01
Concentration of BAP		
B_0	1.22c	1.28c
B_1	1.44b	1.36bc
B_2	1.63a	1.72a
B_3	1.49ab	1.53b
Level of significance	0.05	0.05
CV (%)	4.56	5.68

In a column, means sharing common letters did not differ significantly from each other at 5% probability level by DMRT. V_1 = Chinigura, V_2 = Kataribhog and V_3 = Kalijira. B_0 = Control, B_1 = 30 ppm BAP, B_2 = 60 ppm BAP and B_3 = 90 ppm BAP. DAT = Days after transplanting.

Among different treatment combinations, the Chinigura × 60 ppm BAP and the Kalijira × 60 ppm BAP accumulated statistically similar and maximum leaf dry weight at 60 DAT (1.69 g and 1.67 g, respectively) followed by leaf dry weight obtained from Chinigura × 30 ppm BAP (1.59 g) and Kataribhog × 90 ppm BAP (1.59 g). At harvest, the treatment combination Kataribhog × 60 ppm BAP produced the maximum leaf dry weight (1.80 g) which was statistically similar to leaf dry weight produced by treatment Kataribhog × 90 ppm BAP (1.76 g) and Chinigura × 60 ppm BAP (1.72 g). However, at 60 DAT the minimum leaf dry weight (1.03 g) was obtained from Kalijira × control followed by that of Kalijira × 30 ppm BAP (1.18 g). At harvest the minimum leaf dry weight (1.24 g) was again obtained from Kalijira × control followed by that of Kataribhog × control (1.29 g) and Kalijira × 30 ppm BAP (1.31 g). BAP stimulates the source capacity as well as sink size results in increased leaf length and breadth.It could be stated that the beneficial effect of BAP on improving leaf dry weight might be due to the increased leaf area and more stored photo assimilates in to the leaf.

Table 6. Interaction effect of cultivar and concentration of BAP on leaf dry weight of aromatic rice

Interaction	Leaf dry weight (g) at	
	60 DAT	Harvest
V_1B_0	1.27cd	1.31bc
V_1B_1	1.59ab	1.39c
V_1B_2	1.69a	1.72a
V_1B_3	1.42bc	1.59b
V_2B_0	1.35bcd	1.29de
V_2B_1	1.54abc	1.39c
V_2B_2	1.52abc	1.80a
V_2B_3	1.59ab	1.76a
V_3B_0	1.03e	1.24e
V_3B_1	1.18cde	1.31de
V_3B_2	1.67a	1.63b
V_3B_3	1.46bc	1.39c
Level of significance	0.05	0.01
CV%	4.86	5.78

In a column, means sharing common letters did not differ significantly from each other at 5% probability level by DMRT. V_1 = Chinigura, V_2 = Kataribhog and V_3 = Kalijira. B_0 = Control, B_1 = 30 ppm BAP, B_2 = 60 ppm BAP and B_3 = 90 ppm BAP. DAT = Days after transplanting.

3.4 Length of Leaf Blade of Flag Leaf

The length of leaf blade of flag leaf of aromatic rice was significantly influenced by the individual effect as well as theinteraction effect of cultivar and concentration of BAP (Tables 7 & 8). The longest leaf blade (42.46 cm) was observed in cultivarKataribhog, whereas other two cultivars were statistically identical in producing the shorter leaf blade. Among four levels of BAP, 90 ppm produced the longest leaf blade (43.58 cm) which was statistically similar to length of leaf blade (43.10 cm) produced by 60 ppm of BAP, whereas shortest leaf blade (39.69 cm) was recorded in control where no BAP was applied.

Among different treatment combinations, the longest leaf blade (44.64 cm) was recorded in Kalijira × 90 BAP followed by that of Chinigura × 60 ppm BAP (43.74 cm), Chinigura × 90 ppm BAP (43.04 cm), Kataribhog × 60 ppm BAP (43.44 cm) and Kataribhog × 90 ppm BAP (43.07 cm). The shortest leaf blade (38.59 cm) was found in Chinigura × control followed by Kalijira × control (39.68 cm).

3.5 Breadth of Leaf Blade of Flag Leaf

Breadth of leaf blade of flag leaf of aromatic rice was significantly varied by the individual effect as well as the interaction effect of cultivar and concentration of BAP (Tables 7 & 8). Among the three cultivars, Chinigura produced the broader leaf blade (1.82 cm), whereas other two cultivars were statistically identical in producing narrower leaf blade. Among four levels of BAP, both the 60 and 90 ppm of BAP produced statistically similar and broader leaf blade (1.78 cm and 1.80 cm, respectively), while treatment without BAP application produced the narrowest leaf blade (1.69 cm).

Among different treatment combinations, Chinigura × 60 ppm BAP and Chinigura × 90 ppm BAP produced statistically identical and maximum leaf breadth (1.86 cm and 1.88 cm respectively), while minimum leaf breadth (1.64 cm) was found in Kataribhog × control which was statistically at par with that of Kataribhog × 30 ppm BAP (1.67 cm).The increased length and breadth of flag leaf under BAP application might be due to stimulatory effect of BAP on vegetative growth of rice plant. Foliar application of BAP during stem elongation and leaf growth positively affected leaf length and breadth as BAP has a positive regulatory effect on vegetative growth of plant.

Table 7. Effect of cultivar and concentration of BAP on flag leaf characteristics of aromatic rice

Treatments	Length of leaf blade (cm)	Breadth of leaf blade (cm)	Length breadth ratio
Rice cultivars			
V_1	41.90b	1.82a	23.02
V_2	42.46a	1.70b	24.98
V_3	41.84b	1.73b	24.18
Level of significance	0.05	0.05	NS
Concentration of BAP			
B_0	39.69c	1.69b	23.49
B_1	41.88b	1.72b	24.35
B_2	43.10a	1.78a	24.21
B_3	43.58a	1.80a	24.21
Level of significance	0.05	0.05	NS
CV (%)	7.45	6.33	5.36

In a column, means sharing common letters did not differ significantly from each other at 5% probability level by DMRT. V_1 *= Chinigura,* V_2 *= Kataribhog and* V_3 *= Kalijira.* B_0 *= Control,* B_1 *= 30 ppm BAP,* B_2 *= 60 ppm BAP and* B_3 *= 90 ppm BAP.*

Table 8. Interaction effect of cultivar and concentration of BAP on flag leaf characteristics of aromatic rice

Interaction	Length of leaf blade (cm)	Breadth of leaf blade (cm)	Length breadth ratio
V_1B_0	38.59d	1.75b	22.05c
V_1B_1	42.23bc	1.79b	23.59bc
V_1B_2	43.74ab	1.86a	23.52bc
V_1B_3	43.04ab	1.88a	22.89c
V_2B_0	40.81c	1.64c	24.88ab
V_2B_1	42.50bc	1.67c	25.45a
V_2B_2	43.44ab	1.73bc	25.11a
V_2B_3	43.07ab	1.75bc	24.61b
V_3B_0	39.68cd	1.68c	23.62bc
V_3B_1	40.92c	1.71bc	23.93bc
V_3B_2	42.12bc	1.76b	23.93bc
V_3B_3	44.64a	1.77b	25.22a
Level of significance	0.05	0.05	0.01
CV%	7.45	6.33	10.42

In a column, means sharing common letters did not differ significantly from each other at 5% probability level by DMRT. V_1 *= Chinigura,* V_2 *= Kataribhog and* V_3 *= Kalijira.* B_0 *= Control,* B_1 *= 30 ppm BAP,* B_2 *= 60 ppm BAP and* B_3 *= 90 ppm BAP.*

Growth regulator like BAP increases rate of photosynthesis activity, accelerates translocation and efficiency of utilization of photosynthase, thus results in the cell elongation and rapid cell division in the growing portion which ensure longest leaf ultimate broader leaf area.Niknejhad and Pirdashti [13] found a positive and significant effect of plant growth regulator (GA3 and Ecormon) on flag leaf characteristics of rice. Their findings support the findings of our present study. The results of the present study are also in agreement with the results made by (Ashrafuzzaman*et al.* [14] who reported that length and breadth of flag leaf was varied in different aromatic rice varieties.

3.6 Length Breadth Ratio of Flag Leaf

The individual effect of cultivar and concentration of BAP was not significant on length breadth ratio of flag leaf of aromatic rice but it was significantly influenced by the interaction effect of cultivar and concentration of BAP (Tables 7 & 8). However, maximum ratio (24.98) was observed in Kataribhogcultivar and minimum ratio (23.02) was observed in Chiniguracultivar. Among four levels of BAP, maximum ratio (24.35) was observed in treatment where 30 ppm BAP was sprayed and minimum ratio (23.49) was observed in control where no application of BAP was done.

Among different treatment combination, maximum ratio (25.45) was observed in Kataribhog × 30 ppm BAP which was statistically similar to that of Kataribhog × 60 ppm BAP (25.11) and Kalijira × 90 ppm BAP (25.22). The minimum ratio (22.05) was observed in Chinigura × control which was statistically at par with that of Chinigura × 90 ppm BAP (22.89). Different length breadth ratio of flag leaf in aromatic rice was also reported by Ashrafuzzaman*et al.* [14] which was consistent with the output of the present study.

3.7 Panicle Length

The individual effect and the interaction effect of cultivar and concentration of BAP significantly influenced the panicle length of aromatic rice (Tables 9 & 10). The cultivarKalijira produced the longest panicle (23.41 cm) among the three cultivars, whereas the shortest (20.44 cm) panicle was found in the cultivarChinigura. The shortest panicle (21.14 cm) was found in control treatment where no BAP was applied, while other three concentrations of BAP produced statistically similar panicle length where 90 ppm BAP produced the longest (24.10 cm) one.

Table 9. Effect of cultivar and concentration of BAP on yield components and grain yield of aromatic rice

Treatments	Panicle length (cm)	500-grain weight (g)	Grain yield (t ha^{-1})
Rice cultivars			
V_1	20.44c	6.72	3.45c
V_2	22.31b	6.83	3.64b
V_3	23.41a	6.76	3.77a
Level of significance	0.05	NS	0.05
Concentration of BAP			
B_0	21.14b	5.96c	3.22c
B_1	23.72a	6.56b	3.67b
B_2	23.84a	6.90b	3.71b
B_3	24.10a	7.44a	3.88a
Level of significance	0.05	0.05	0.01
CV%	3.31	8.27	6.54

In a column, means sharing common letters did not differ significantly from each other at 5% probability level by DMRT. V_1 = Chinigura, V_2 = Kataribhog and V_3 = Kalijira. B_0 = Control, B_1 = 30 ppm BAP, B_2 = 60 ppm BAP and B_3 = 90 ppm BAP.

Among the interactions, the longest panicle (24.65 cm) was recorded in Kalijira × 90 ppm BAP followed by panicle length recorded in Kalijira × 30 ppm BAP (24.39 cm) and Kalijira × 60 ppm BAP (24.47 cm). The shortest panicle (20.60 cm) was recorded in Kataribhog × control. The increased panicle length in aromatic rice under foliar application of BAP possibly due to stimulatory effect of BAP on reproductive growth of rice plant as BAP accelerates cell elongation and cell division during both vegetative and reproductive growth of plant. The results of the present study are in parallel with the previous investigations (Bakhsh *et al.* [15] and Tiwari *et al.* [16]), where they also reported that plant growth regulator increased panicle length in paddy.

3.8 500-Grain Weight

The individual effect of cultivar was not significant on 500-grain weight but the individual effect of BAP concentration and their interaction effect significantly influenced the 500-grain weight (Tables 9 & 10). The Kataribhogcultivar gave the highest 500-grain weight (6.83 g), while the lowest weight (6.72 g) was found in Chiniguracultivar. Lowest 500-grain weight (5.96 g) was recorded in control where no BAP was applied and the highest 500-grain weight (7.44 g) was recorded from application of 90 ppm BAP.

The treatment combination Chinigura × 90 ppm BAP gave the maximum 500-grain weight (7.63 g) which was statistically at par with that of Kataribhog × 90 ppm (7.36 g) and Kalijira × 90 ppm BAP (7.35 g), whereas the minimum grain weight (5.81 g) was recorded in Chinigura × control which was statistically similar to that of Kalijira × control (5.96 g). Plant growth regulator BAP increases acceleration of reserve mobilization in grain which might be the reason of increased grain weight under foliar application of BAP. Khan *et al*. [17] studied effect of naphthalene acetic acid on rice cultivars and observed application of growth regulator at panicle initiation stage resulted in increased 1000-grain weight which was consistent with our findings. Increasing 1000-grain weight in Sri lankan traditional rice varieties under different cytokinin (BAP and kinetin) was also observed by Dahanayaka*et al.* [18] which supports the present outputs.

Table 10. Interaction effect of cultivar and concentration of BAP on yield components and grain yield of aromatic rice

Interaction	Panicle length (cm)	500-grain weight (g)	Grain yield (t ha^{-1})
V_1B_0	21.42d	5.81d	3.08d
V_1B_1	22.07cd	6.57bc	3.35c
V_1B_2	21.90cd	6.88ab	3.74b
V_1B_3	23.97abc	7.63a	3.63bc
V_2B_0	20.60e	6.20cd	3.23cd
V_2B_1	21.80d	6.72ab	3.90ab
V_2B_2	23.18bcd	6.90ab	4.02a
V_2B_3	23.67abc	7.36a	3.40c
V_3B_0	21.18 cd	5.96d	3.35c
V_3B_1	24.39ab	6.40cd	3.76b
V_3B_2	24.47ab	6.91ab	3.88ab
V_3B_3	24.65a	7.35a	4.10a
Level of significance	0.01	0.01	0.01
CV%	3.31	8.27	6.54

In a column, means sharing common letters did not differ significantly from each other at 5% probability level by DMRT. V_1 *= Chinigura,* V_2 *= Kataribhog and* V_3 *= Kalijira.* B_0 *= Control,* B_1 *= 30 ppm BAP,* B_2 *= 60 ppm BAP and* B_3 *= 90 ppm BAP.*

3.9 Grain Yield

The individual effect and the interaction effect of cultivar and concentration of BAP significantly influenced the grain yield of aromatic rice (Tables 9 & 10). Among the three cultivars the Kalijiracultivar was best yielder regarding grain yield (3.77 t ha^{-1}), while the Chiniguracultivar produced lowest grain yield (3.45 t ha^{-1}). Among the four concentrations of

BAP, 90 ppm BAP produced the highest grain yield (3.88 t ha^{-1}), whereas lowest grain yield (3.22 t ha^{-1}) was found in control where no application of BAP was done.

Among different treatment combinations, the highest grain yield (4.10 t ha^{-1}) was recorded from Kalijira × 90 ppm BAP which was statistically at par with grain yield (4.02 t ha^{-1}) recorded from Kataribhog × 60 ppm BAP, whereas the lowest grain yield (3.08 t ha^{-1}) was recorded from Chinigura × control. Differential degree of grain yieldamong the rice cultivars might be due to genetic variability of aromatic rice cultivars. High yield is determined by physiological process leading to a high net accumulation of photosynthates and their partitioning (Miah *et al.* [19]. Foliar application of plant growth regulator positively affected leaf characteristics as BAP has a positive regulatory effect on vegetative growth of plant. Improved leaf characteristics increased rate of photosynthesis activity, accelerated translocation and efficiency of utilization of photosynthase, thus resulted in the increased grain yield. The results of the present study are in parallel with the results observed by Bakhsh *et al.* [15], where they also found that plant growth regulator (NAA) increased grain yield in paddy. Different degree of grain yield due to genetic variability in aromatic rice cultivar was also reported by Ashrafuzzaman*et al.*[14] which was consistent with the output of the present study. Increasing grain yield in Sri lankan traditional rice varieties under different cytokinin (BAP and kinetin) was also observed by Dahanayaka*et al.* [18] which supports the present outputs.Tiwari *et al*. [16] studied effect of different plant growth regulators on hybrid rice and observed application of growth regulator resulted in increased grain yield which was consistent with our findings.

4. CONCLUSION

Foliar application of BAP, ~~a plant growth regulator~~ might be usedas an environment-friendly approach for the improvement of leaf characteristics as well as the production of aromatic rice.Among different treatment combinations the highest grain yield was recorded from Kalijira under 90 ppm BAP, whereas the lowest grain yieldwas recorded from Chinigura under control.From the findings of the present study, 90 ppm of BAP can be recommended at farmer's level to increase the yield and production of aromatic rice which may help to meet up the increasing demand for aromatic rice.

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