ABSTRACT

To explore the effects of 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 and its requirement is increasing dramatically due to the rapid growth of world population. 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, a substantial yield increase of 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 25\(^\circ\)39′ N latitude and 88\(^\circ\)41′ 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 of 50 cm and 1 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 Kalijira cultivar 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.

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 shortest leaf blade (24.26 cm) at 30 DAT. Shortest leaf blade was recorded in the cultivar Chinigura at 30 and 60 DAT (23.88 cm and 33.35, respectively), while the cultivar Kalijira 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 (24.72 cm 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.

| Treatment | Number of leaf at 30 DAT | Number of leaf at 60 DAT | Number of leaf at Harvest |
|-----------|--------------------------|--------------------------|---------------------------|
| Rice cultivars | V₁ | 3.60 | 7.84b | 10.84b |
| | V₂ | 3.28 | 7.07c | 12.45a |
| | V₃ | 3.54 | 8.20a | 11.99a |
| Level of significance | NS | 0.05 | 0.05 |
| Concentration of BAP | B₀ | 2.56c | 6.81d | 10.49c |
| | B₁ | 3.27bc | 7.34cd | 11.49b |
| | B₂ | 3.63ab | 8.00b | 12.30a |
| | B₃ | 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. V₁ = Chinigura, V₂ = Kataribhog and V₃ = Kalijira. B₀ = Control, B₁ = 30 ppm BAP, B₂ = 60 ppm BAP and B₃ = 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 | Number of leaf at 60 DAT | Number of leaf at Harvest |
|-------------|--------------------------|--------------------------|---------------------------|
| V₁B₀ | 2.67b | 6.39b | 9.14d |
| V₁B₁ | 3.66ab | 7.67ab | 10.79cd |
| V₁B₂ | 3.67ab | 8.62a | 11.67bc |
| V₁B₃ | 4.39 a | 8.67a | 11.77bc |
| V₂B₀ | 2.34b | 6.44b | 11.73bc |
| V₂B₁ | 2.67b | 6.58b | 12.34ab |
| V₂B₂ | 3.67ab | 6.67b | 12.56ab |
| V₂B₃ | 4.44 a | 8.59a | 13.18a |
| V₃B₀ | 2.67b | 7.59ab | 10.60cd |
| V₃B₁ | 3.47ab | 7.78ab | 11.34bc |
| V₃B₂ | 3.54ab | 8.73a | 12.67ab |
| V₃B₃ | 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. V₁ = Chinigura, V₂ = Kataribhog and V₃ = Kalijira. B₀ = Control, B₁ = 30 ppm BAP, B₂ = 60 ppm BAP and B₃ = 90 ppm BAP. DAT = Days after transplanting
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 × 60 ppm BAP and Kalijira × 90 ppm BAP (35.24 cm). At harvest, the longest leaf blade (41.83 cm) was again observed in Kalijira × 90 ppm BAP. The shortest leaf blade (23.24 cm) was recorded from Kalijira × 30 ppm BAP at 30 DAT, 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 Chinigura cultivar (1.49 g at 60 DAT and 1.50 g at harvest), whereas the Kalijira cultivar 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.

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

| Treatments | 30 DAT | 60 DAT | Harvest |
|------------|--------|--------|---------|
| Rice cultivars | | | |
| V1 | 23.88 | 33.35 | 39.09 |
| V2 | 24.05 | 34.60 | 39.65 |
| V3 | 24.26 | 33.59 | 39.03 |
| Level of significance | NS | NS | NS |
| Concentration of BAP | | | |
| B0 | 24.07 | 31.96d | 36.88c |
| B1 | 23.28 | 33.56c | 39.07b |
| B2 | 24.17 | 34.56ab | 40.29a |
| B3 | 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. V1 = Chinigura, V2 = Kataribhog and V3 = Kalijira. B0 = Control, B1 = 30 ppm BAP, B2 = 60 ppm BAP and B3 = 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 | 30 DAT | 60 DAT | Harvest |
|-------------|--------|--------|---------|
| V1B0        | 23.44  | 31.44c | 35.78d  |
| V1B1        | 23.34  | 33.22bc| 39.42bc |
| V1B2        | 23.86  | 34.00ab| 40.93ab |
| V1B3        | 24.88  | 34.74ab| 40.23ab |
| V2B0        | 24.27  | 33.04bc| 38.00c  |
| V2B1        | 23.26  | 34.29ab| 39.69bc |
| V2B2        | 24.26  | 35.24a | 40.63ab |
| V2B3        | 24.39  | 35.84a | 40.26ab |
| V3B0        | 24.50  | 31.40c | 36.87cd |
| V3B1        | 23.24  | 33.17bc| 38.11c  |
| V3B2        | 24.40  | 34.45ab| 39.31bc |
| V3B3        | 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. V1 = Chinigura, V2 = Kataribhog and V3 = Kalijira. B0 = Control, B1 = 30 ppm BAP, B2 = 60 ppm BAP and B3 = 90 ppm BAP. DAT = Days after transplanting.

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

| Treatments | 60 DAT | Harvest |
|------------|--------|---------|
| Rice cultivars |        |         |
| V1         | 1.49a  | 1.50a   |
| V2         | 1.50a  | 1.56a   |
| V3         | 1.34b  | 1.36b   |
| Level of significance | 0.01 | 0.01 |

| Concentration of BAP | 60 DAT | Harvest |
|----------------------|--------|---------|
| B0                   | 1.22c  | 1.28c   |
| B1                   | 1.44b  | 1.36bc  |
| B2                   | 1.63a  | 1.72a   |
| B3                   | 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. V1 = Chinigura, V2 = Kataribhog and V3 = Kalijira. B0 = Control, B1 = 30 ppm BAP, B2 = 60 ppm BAP and B3 = 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 the interaction effect of cultivar and concentration of BAP (Tables 7 & 8). The longest leaf blade (42.46 cm) was observed in cultivar Kataribhog, 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).

![Image of Leaf Blade Comparison](image)

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 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 |
|-------------|------------------------|--------|---------|
| V1B0        | 1.27cd                 | 1.31bc |
| V1B1        | 1.59ab                 | 1.39c  |
| V1B2        | 1.69a                  | 1.72a  |
| V1B3        | 1.42bc                 | 1.59b  |
| V2B0        | 1.35bcd                | 1.29de |
| V2B1        | 1.54abc                | 1.39c  |
| V2B2        | 1.52abc                | 1.80a  |
| V2B3        | 1.59ab                 | 1.76a  |
| V3B0        | 1.03e                  | 1.24e  |
| V3B1        | 1.18cde                | 1.31de |
| V3B2        | 1.67a                  | 1.63b  |
| V3B3        | 1.46bc                 | 1.39c  |

In a column, means sharing common letters did not differ significantly from each other at 5% probability level by DMRT. V1 = Chinigura, V2 = Kataribhog and V3 = Kalijira. B0 = Control, B1 = 30 ppm BAP, B2 = 60 ppm BAP and B3 = 90 ppm BAP. DAT = Days after transplanting.

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 |                          |                            |                     |
| V1         | 41.90b                    | 1.82a                      | 23.02               |
| V2         | 42.46a                    | 1.70b                      | 24.98               |
| V3         | 41.84b                    | 1.73b                      | 24.18               |
| Level of significance | 0.05                    | 0.05                       | NS                  |
| Concentration of BAP |                        |                            |                     |
| B0         | 39.69c                    | 1.69b                      | 23.49               |
| B1         | 41.88b                    | 1.72b                      | 24.35               |
| B2         | 43.10a                    | 1.78a                      | 24.21               |
| B3         | 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. V1 = Chinigura, V2 = Kataribhog and V3 = Kalijira. B0 = Control, B1 = 30 ppm BAP, B2 = 60 ppm BAP and B3 = 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 |
|-------------|---------------------------|---------------------------|---------------------|
| V1 B0       | 38.59d                    | 1.75b                     | 22.05c              |
| V1 B1       | 42.23bc                   | 1.79b                     | 23.59bc             |
| V1 B2       | 43.74ab                   | 1.86a                     | 23.52bc             |
| V1 B3       | 43.04ab                   | 1.88a                     | 22.89c              |
| V2 B0       | 40.81c                    | 1.64c                     | 24.88ab             |
| V2 B1       | 42.50bc                   | 1.67c                     | 25.45a              |
| V2 B2       | 43.44ab                   | 1.73bc                    | 25.11a              |
| V2 B3       | 43.07ab                   | 1.75bc                    | 24.61b              |
| V3 B0       | 39.68cd                   | 1.68c                     | 23.62bc             |
| V3 B1       | 40.92c                    | 1.71bc                    | 23.93bc             |
| V3 B2       | 42.12bc                   | 1.76b                     | 23.93bc             |
| V3 B3       | 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. V1 = Chinigura, V2 = Kataribhog and V3 = Kalijira. B0 = Control, B1 = 30 ppm BAP, B2 = 60 ppm BAP and B3 = 90 ppm BAP.

Growth regulator like BAP increases rate of photosynthesis activity, accelerates translocation and efficiency of utilization of photosynase, 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 Kataribhog cultivar and minimum ratio (23.02) was observed in Chinigura cultivar. 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 cultivar Kalijira produced the longest panicle (23.41 cm) among the three cultivars, whereas the shortest (20.44 cm) panicle was found in the cultivar Chinigura. 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.

Among the interactions, the longest panicle (24.65 cm) was recorded in Kataribhog × 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 Kataribhog cultivar gave the highest 500-grain weight (6.83 g), while the lowest weight (6.72 g) was found in Chinigura cultivar. 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.

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 Kalijira cultivar was best yielder regarding grain yield (3.77 t ha⁻¹), while the Chinigura cultivar 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

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 |                      |                      |                     |
| V₁         | 20.44c              | 6.72                 | 3.45c               |
| V₂         | 22.31b              | 6.83                 | 3.64b               |
| V₃         | 23.41a              | 6.76                 | 3.77a               |
| Level of significance | 0.05 | NS                   | 0.05                |
| Concentration of BAP |                      |                      |                     |
| B₀         | 21.14b              | 5.96c                | 3.22c               |
| B₁         | 23.72a              | 6.56b                | 3.67b               |
| B₂         | 23.84a              | 6.90b                | 3.71b               |
| B₃         | 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. V₁ = Chinigura, V₂ = Kataribhog and V₃ = Kalijira. B₀ = Control, B₁ = 30 ppm BAP, B₂ = 60 ppm BAP and B₃ = 90 ppm BAP.
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 (tha⁻¹) |
|------------|--------------------|---------------------|---------------------|
| V₁B₀       | 21.42d             | 5.81d               | 3.08d               |
| V₁B₁       | 22.07cd            | 6.57bc              | 3.35c               |
| V₂B₀       | 21.90cd            | 6.88ab              | 3.74b               |
| V₂B₁       | 23.97abc           | 7.63a               | 3.63bc              |
| V₂B₂       | 20.60e             | 6.20cd              | 3.23cd              |
| V₂B₃       | 21.80d             | 6.72ab              | 3.90ab              |
| V₃B₀       | 23.18bcd           | 6.90ab              | 4.02a               |
| V₃B₁       | 23.67abc           | 7.36a               | 3.40c               |
| V₃B₂       | 21.18 cd           | 5.96d               | 3.35c               |
| V₃B₃       | 24.39ab            | 6.40cd              | 3.76b               |
| V₄B₂       | 24.47ab            | 6.91ab              | 3.88ab              |
| V₄B₃       | 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. V₁ = Chinigura, V₂ = Kataribhog and V₃ = Kalijira. B₀ = Control, B₁ = 30 ppm BAP, B₂ = 60 ppm BAP and B₃ = 90 ppm BAP

degree of grain yield among 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, might be used as 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 yield was 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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