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Effects of benzyl aminopurine (BAP) on growth, yield and biochemical characteristics of summer mungbean cultivars

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ABSTRACT

A field experiment was conducted to study the effect of benzyl aminopurine (BAP) on growth, yield and biochemical characteristicsof three summer mungbean cultivars, cv. Binamoog-5, BARI mung 6 and Binamoog-8 along with four treatments *viz*., H_1-control (without BAP), H_2-50 ppm BAP, H_3-100 ppm BAP and H_4-150 ppm BAPapplied at 15, 30, 45 and 60 days after sowing (DAS). Data were recorded on plant height, number of leaves plant^{-1}, leaf area plant^{-1}, dry root weight, root volume, number of root nodule, seed yield, chlorophyll, carotenoid and proline contents. Plant height, number of leaves plant^{-1}, leaf area plant^{-1} and seed yield were statistically different among the cultivars and also significantly influenced by the application of different concentrations of BAP. The highest plant height (68.59 cm), number of leaves plant^{-1} (10.89), leaf area plant^{-1} (1677.8 cm^2) and seed yield (1.69 t ha^{-1}) were obtained by applying 100 ppm BAP. The interaction effect of cultivars and different concentrations of BAPwere statistically significant on plant height, number of leaves plant^{-1}, leaf area plant^{-1} and seed yield. The highest plant height (71.88 cm), number of leaves plant^{-1} (12.46), leaf area plant^{-1} (1863.26 cm^2) and seed yield (1.87 t ha^{-1}) were obtained in Binamoog-8 by spraying 100 ppm BAP. Chlorophyll, carotenoid and proline contents were significantly influenced by the application of different concentrations of BAP. The study infers that BAP enhanced growth and yield of summer mungbean cv. Binamoog-8, which might be an alternative eco-friendly management practices.

Keywords:BAP, carotenoid, chlorophyll, growth, mungbean, proline, seed yield.

INTRODUCTION

Mungbean (*Vigna radiate* (L) Wilczek) is one of the most important pulse crops of global economic importance. Economically it is the most important crop of the Vigna group, being rich in quality protein, minerals and vitamins and is alsoused as animal fodder and greenmanure. It contains flavonoids havingantioxidant activities. It originated in the South and Southeast Asia and widely grown in Bangladesh, India, Pakistan, Mayannmar, Thailand, Philippinnes, China and Indonesia. Mungbean has special important as an accommodative crop with short growing period along with N_2 fixation in soil (Noor-E-Ferdous et al. 2012). Plant growth regulators (PGRs) are being used as an aid to enhance yield of different crops (Noor-E-Ferdous et al. 2020, Noor et al. 2018, Hussain et al. 2018, Bakhsh et al. 2011, Sarker et al. 2009, Nickell 1982).

PGR is 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 (Sarker et al. 2020). Similar PGRs are active in different stages of the same plant in different ways. An exogenous application of plant growth regulators affects the endogenous hormonal pattern of the plant,

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either by supplementation of sub-optimal levels or by interaction with their synthesis, translocation or inactivation of existing hormone levels. Plant hormones regulate physiological process and synthetic growth regulators may also stimulate growth and development of field crops thereby enhanced total dry mass and yield. (Sanjida et al. 2019, Cho et al. 2008, Chibu et al. 2000, Das and Das 1996). Application of 6-BAP found to increase plant height, number of leaves plant^{-1}, natural product measure with resulting upgrade in seed yield in various plants (Sarker et al. 2020). The uses of growth substances such as 6-benzyl aminopurine (6-BAP), NAA, GA_3 and some others at different concentrations increased aromatic rice grain production (Sarker et al. 2020). It is 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 summer mungbean cultivars were released by Bangladesh Agricultural Research Institute (BARI) and Bangladesh Institute of Nuclear Agriculture (BINA), summer mungbean cultivars were given less attention and their yielding ability was not studied well by using plant growth regulators. Research on summer mungbean using BAP is limited in Bangladesh. Findings in using different PGRs for increasing summer mungbean yield in some countries certainly provide valuable information; those can't be prescribed without preliminary field trial in Bangladesh. Therefore, more researches are necessary to investigate the efficacy of BAP on summer mungbean production. Thus, the objective is to study the growth characteristics, -yield potentials and biochemical attributes of three selected summer mungbean cultivars in response to BAP.

MATERIALS AND METHODS

Experimental sites and treatments: A field study was conducted at the research field of the Department of Agricultural Chemistry, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, Bangladesh. The research site was located in Northwest of Bangladesh, an agriculturally important region. It is between 25.13º N′ latitude and 88.23º E′ longitude and at an elevation of 34.5 m above the sea level. The experimental land belongs to the Himalayan Piedmont Plain, Agro-ecological Zone (AEZ-1) and Ranishankail soil series classified by FAO (1988). The experimental field was a medium high land having sandy loam soil with pH 5.60. The experiment using three summer mungbean cultivars was considered as factor A (V_1-Binamoog-5, V_2-BARI mung 6 and V_3-Binamoog-8) while factor B were fourtreatments *viz*,. H_1-control (without BAP), H_2-50 ppm BAP, H_3-100 ppm BAP and H_4-150 ppm BAP. The experiment was laid out in Randomized Complete Block Design (RCBD) with 2 factors. Twelve combined treatments were V_1H_1, V1H2, V_1H_3, V_1H_4, V_2H_1, V_2H_2, V_2H_3, V_2H_4, V_3H_1, V_3H_2, V_3H_3 and V_3H_4, respectively for the purposes. Crop management practices like fertilizer, irrigation and pest management were done properly as and when necessary. Three irrigations were applied where the first pre-sowing irrigation was done at the time of lime application @ 1.0 t ha^{-1} and were mixed with soil before two week of seed sowing (Noor-E-Ferdous 2016) for better germination, second irrigation was done after weeding and thinning, and third irrigation was done at flowering stage. Specific concentration of BAPfor experimental treatments was prepared and applied in the form of foliar sprays at 25 and 45 DAS.

Growth and yield contributing characters: Three plants were selected randomly from each plot and plant height was measured from base of the plant up to the tip of the main stem at 15, 30, 45 and 60 days after sowing (DAS). Leaves (trifoliate) were counted on each sampled plant at 15, 30, 45, 60 DAS and at mature stage. For root volume measures, three plants from each plot were collected carefully at 15, 30, 45, 60 DAS and at mature stage so that no root damage occurred. Root volume was measured by water displacing methods using 20 mL measuring cylinder followed by oven dried at 65ºC for 72 hours. The average dry root weight was calculated. The number of nodules in the root of each collected plants were counted and noted at 30, 45, 60 DAS and at mature stage. Seeds obtained from each unit plot were sun-dried and weighed carefully. The pod was collected by handpicking when full maturity came turning brown to black in color. Seed weights of sample plants were added to the respective unit plot yield to record the final seed yield per plot. Seed yield was expressed as kg ha^{-1} after adjusting at 10% moisture level.

Biochemical analysis: Fresh leaf samples from mungbean plants at the flowering stage were collected for chlorophyll estimation. Chlorophyll content of mungbean leaves was determined by following the method described by Arnon (1949).

Chl-a=12.21 A_{663}-2.81A_{646} (mg g^{-1} FW)

Chl-b=20.13 A_{646}-6.03A_{663} (mg g^{-1} FW)

Total carotenoid = (1000A_{470} - 2.05×Chl-a - 114.8×Chl-b) / 245 (mg g^{-1} FW) by Porra (2002).

Free proline content of leaves was estimated using the acid ninhydrin method described by Bates et al. (1973). Approximately 50 mg of fresh leaf sample (same leaf sample for chlorophyll estimation) at flowering stage was collected in a 2 mL Eppendorf tube and extract was prepared using 3% sulfosalicylic acid. The optical density of solutions (sample solutions and standard solution) was measured at 520 nm wavelength using UV-visible spectrophotometer with the help of standard curve using proline standard series solution.

Statistical analyses: The obtained data on different parameters were statistically analyzed using the MSTAT-C program. The treatment means were compared by Least Significant Difference (LSD) followed by Duncan's Multiple Range (DMRT) Test (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Plant height: The height of summer mungbean plants of different cultivars at different growth stages was markedly influenced by the application of BAP (Table 1). Result showed that significantly (P<0.05) highest plant height (10.28, 22.06, 42.4 and 67.93 cm) were observed in V_3 (Binamoog-8) from 15 to 60 DAS with 15 days interval while the lowest plant height (9.62, 20.97, 40.54 and 63.60 cm) were observed in V_2 (BARI mung 6) at 15, 30, 45 and 60 DAS, respectively. The variation in plant height might be attributed to the varietal characters of mungbean. Plant height was significantly influenced by the application of different concentrations of BAP at all growth stages of mungbean (Table 1). The concentration of 100 ppm BAP produced the highest plant height (10.08, 24.04, 44.31 and 68.59 cm) at different DAS. The lowest plant heights (9.65, 18.91, 36.78 and 61.75 cm) were observed in control (H_1) treatment in respective DAS. The interaction effect of varieties and different concentrations of BAP were statistically significant at different days after sowing (Table 1). The highest plant height (10.36, 24.97, 45.08, and 71.88 cm) was obtained in V_3H_3 (with Binamoog-8×100 ppm BAP) treatment at 15, 30, 45 and 60 DAS, respectively. The lowest plant height (8.92, 18.24, 35.99 and 61.07 cm) was observed in V_2H_1 (BARI mung 6×with no BAP application) treatment at 15, 30, 45 and 60 DAS, respectively. From the above observation, it was found that the plant height was increased with the increasing doses of BAP along with Binamoog-8. Khanam (2016) reported that application of 6-BAP showed better performance on plant height of two rice cultivars studied at both vegetative and harvesting stages.

Table 1. Effect of BAP on plant height of three cultivars of summer mungbean with their interactions

Treatments	Plant height (cm)			
Varieties	15 DAS	30 DAS	45 DAS	60 DAS
V_1	9.76b	21.12ab	41.22b	65.26b
V_2	9.62b	20.97b	40.54b	63.60c
V_3	10.28a	22.06a	42.40a	67.93a
LSD (0.05)	0.37	0.98	0.68	1.43
BAP	-	-	-	
H_1	9.65b	18.91d	36.78d	61.75c
H_2	9.94ab	20.50c	41.39c	66.19b
H_3	10.08a	24.04a	44.31a	68.59a
H_4	9.81ab	22.07b	43.04b	65.81b
LSD (0.05)	0.43	1.13	0.78	1.66
Varieties × BAP	-	-	-	-
V_1H_1	9.87ab	18.65g	36.03h	61.34fg
V_1H_2	9.68ab	20.04fg	41.17ef	65.54c-e
V_1H_3	9.98ab	23.47abc	44.13ab	68.02bc
V_1H_4	9.52bc	21.72c-f	43.53bc	66.04cd
V_2H_1	8.92c	18.24g	35.99h	61.07g
V_2H_2	9.87ab	20.13efg	40.36f	64.01d-f
V_2H_3	9.91ab	23.69abc	43.74a-c	65.88cd
V_2H_4	9.79ab	22.43bcd	42.08de	63.44d-g
V_3H_1	10.15ab	19.85fg	38.33g	62.86e-g
V_3H_2	10.27a	21.34def	42.66cd	69.03ab
V_3H_3	10.36a	24.97a	45.08a	71.88a
V_3H_4	10.13ab	22.07b-e	43.53bc	67.97bc
LSD (0.05)	0.74	1.96	1.36	2.87

Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability. V_1= Binamoog-5, V_2 = BARI mung 6 and V_3 = Binamoog-8, H_1 = 0 ppm (control), H_2 = 50 ppm, H_3 = 100 ppm and H_4 =150 ppm

Number of leaves plant^{-1}: Number of leaves plant^{-1} differed significantly (P<0.05) among the varieties at different days after sowing (Table 2). Binamoog-8 (V_3) had the highest number of leaves plant^{-1} *i.e*., 4.11, 6.92, 8.52, 11.58 and 10.64 at 15, 30, 45, 60 and at mature stage, which were statistically different among other varieties and the lowest number of leaves plant^{-1} were 3.73, 5.28, 6.93, 8.19, and 7.42 from BARI mung 6(V_2) cultivar (Table 2). Effect of BAP significantly influenced on number of leaves plant^{-1} at 30, 45, 60 DAS and mature stage. The highest number of leaves was found in 100 ppm BAP application (H_3) treatment at 30, 45 and 60 DAS, respectively. But at the mature stage, the highest number of leaves was observed in 150 ppm BAP (H_4) treatment. The lowest number of leaves was observed in control treatment. A significant variation was found with the interaction effect between varieties and different concentrations of BAP in respect of number of leaves plant^{-1} of mungbean at DAS (Table 2). The highest number of leaves plant^{-1} (4.65, 7.43, 9.13, 12.46 and 11.66) at 15, 30, 45, 60 DAS and mature stage was observed in V_3H_3 (Binamoog-8 × 100 ppm of BAP) treatment. The lowest number of leaves plant^{-1} (3.41) was observed in V_1H_3 (Binamoog-5 × 100 ppm of BAP) treatment at 15 DAS but the lowest number (5.01, 6.78, 7.66 and 6.98) was observed in V_2H_1 (BARI mung 6 × without BAP) treatment at 30, 45, 60 DAS and mature stages, respectively. Number of leaf plant^{-1} in BAP sprayed plants was significantly different from the controls and there was a trend that it was higher than the controls though contrasting result was also in aromatic rice plants revealed by Sarker et al. (2020).

Table 2. Effect of BAP on number of leaves plant^{-1} of three cultivars of summer mungbean with their interactions

Treatments	Number of leaves plant^{-1}				
Varieties	15 DAS	30 DAS	45 DAS	60 DAS	At mature
V_1	3.74ab	6.60a	7.81b	10.69a	9.55b
V_2	3.73b	5.28b	6.93c	8.19b	7.42c
V_3	4.11a	6.92a	8.52a	11.58a	10.64a
LSD (0.05)	0.38	0.82	0.57	1.31	0.83
BAP					
H_1	3.80a	5.72b	7.21b	9.27b	8.57b
H_2	3.81a	6.28ab	7.73ab	10.24ab	9.14ab
H_3	4.01a	6.72a	8.18a	10.89a	9.27ab
H_4	3.82a	6.35ab	7.89a	10.21ab	9.84a
LSD (0.05)	0.44	0.94	0.66	1.51	0.96
Varieties × BAP					
V_1H_1	3.98ab	5.98a-d	7.18def	9.89abc	8.94cde
V_1H_2	3.75b	6.76abc	7.94b-e	10.71ab	9.46bcd
V_1H_3	3.41b	7.01ab	8.23a-d	11.56a	10.01abc
V_1H_4	3.81b	6.66abc	7.88b-f	10.58ab	9.79bc
V_2H_1	3.54b	5.01d	6.78f	7.66c	6.98f
V_2H_2	3.66b	5.22cd	6.81ef	8.27bc	7.64ef
V_2H_3	3.97ab	5.72bcd	7.18def	8.66bc	7.84def
V_2H_4	3.73b	5.18cd	6.96ef	8.18bc	7.22f
V_3H_1	3.88b	6.17a-d	7.66c-f	10.26abc	9.79bc
V_3H_2	4.01ab	6.86ab	8.43abc	11.73a	10.33abc
V_3H_3	4.65a	7.43a	9.13a	12.46a	11.66a
V_3H_4	3.91ab	7.21ab	8.85ab	11.86a	10.79ab
LSD (0.05)	0.76	1.64	1.31	2.61	1.67

Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability.

Leaf area plant^{-1}: Effects of varieties was significant in leaf area plant^{-1} at 15, 30, 45, 60 DAS and at mature stage (Table 3). The highest leaf area plant^{-1} (35.56, 236.68, 887.31, 1689.6 and 1565.4 cm^2) was observed in V_3 (Binamoog-8) at 15, 30, 45, 60 DAS and mature stage, respectively. The lowest leaf area plant^{-1} (28.98, 225.43, 668.58, 1252.8 and 1099.6 cm^2) was observed in V_1 (BARI moog 5) treatment at 15, 30, 45, 60 DAS and mature stage, respectively. Leaf area plant^{-1}was significantly influenced by the application of different concentrations of BAP at all growth stages of mungbean (Table 3). The treatment H_4 (150 ppm BAP) produced the highest leaf area plant^{-1} (35.24 cm^2) at 15 DAS but the highest leaf area plant^{-1} (247.87, 879.63, 1677.8 and 1551.7 cm^2) was observed in H_3 (100 ppm BAP) at 30, 45, 60 DAS and mature stage, respectively. The lowest leaf area plant^{-1} (29.53, 201.56, 689.78, 1367.4 and 1189.2 cm^2) was found in H_1 (control) treatment at 15, 30, 45, 60 DAS and mature stage, respectively. A significant variation was found on leaf area plant^{-1} at 15, 30, 45, 60 DAS and at mature stage by the interaction effect of varieties and different concentrations of BAP (Table 3).The highest leaf area plant^{-1} (40.11, 257.63, 1028.91, 1863.26 and 1734.82 cm^2) was observed in V_3H_3 (Binamoog-8×100 ppm BAP) treatment and the lowest leaf area plant^{-1} (197.34, 592.64, 1027.35, 922.84 cm^2) was obtained in V_2H_1 (BARI mung 6×without BAP) treatment at 30, 45, 60 DAS and at mature stage, respectively except the lowest one (27.91 cm) was obtained in V_2H_3 (BARI mung 6×100 ppm BAP) at 15 DAS. GA_3 induced higher leaf areas as reported in mungbean plant by Rahman et al. (2018), in rice plants (Liu et al. 2012), tomato plants (Khan et al. 2006) and summer mungbean plants (Noor-E-Ferdous et al. 2020).

Table 3. Effect of BAP on leaf area plant^{-1} of three cultivars of summer mungbean with their interactions

Treatments	Leaf area plant^{-1} (cm^2)				
Varieties	15 DAS	30 DAS	45 DAS	60 DAS	At mature
V_1	33.54a	228.31ab	791.33b	1613.3b	1456.0b
V_2	28.96b	225.43b	664.58c	1252.8c	1099.6c
V_3	35.86a	236.68a	887.31a	1689.6a	1565.4a
LSD (0.05)	2.76	11.13	10.17	18.55	13.44
BAP					
H_1	29.53c	201.56c	689.78d	1367.4d	1189.2d
H_2	31.96bc	238.92ab	797.80b	1540.7b	1401.8b
H_3	34.39ab	247.87a	879.63a	1677.8a	1551.7a
H_4	35.24a	232.20b	757.09c	1488.5c	1352.0c
LSD (0.05)	3.19	12.85	11.75	21.42	15.52
Varieties × BAP	-	-	-	-	-
V_1H_1	28.77ef	198.23d	711.81g	1478.84f	1192.29g
V_1H_2	32.93c-f	237.91ab	796.75e	1655.72cd	1538.61c
V_1H_3	35.16a-d	243.66ab	891.64c	1703.28b	1601.93b
V_1H_4	37.28abc	233.44b	765.13f	1615.36e	1491.17d
V_2H_1	28.87ef	197.34d	592.64i	1027.35i	922.84j
V_2H_2	29.33ef	237.62ab	683.27h	1289.61g	1103.44h
V_2H_3	27.91f	242.33ab	718.35g	1466.73f	1318.36f
V_2H_4	29.72def	224.44bc	664.08h	1227.65h	1053.65i
V_3H_1	30.96def	209.12cd	764.88f	1596.15e	1452.33e
V_3H_2	33.63b-e	241.24ab	913.39b	1676.65bc	1563.26c
V_3H_3	40.11a	257.63a	1028.91a	1863.26a	1734.82a
V_3H_4	38.72ab	238.72ab	842.07d	1622.39de	1511.21d
LSD (0.05)	5.52	22.25	20.35	37.10	26.88

Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability.

Dry root weight plant^{-1}: Dry root weight plant^{-1} was recorded from 15 DAS to mature stage. Significant variation was observed on dry root weight plant^{-1} except 15 DAS and mature stage (Table 4). Maximum dry root weight (0.152, 0.497 and 1.15 g plant^{-1}) was recorded in V_3 (Binamoog-8) at 30, 45 and 60 DAS. The lowest dry root weight plant^{-1} (0.112, 0.373 and 1.018 g plant^{-1}) was observed in V_2 (BARI mung 6) at 30, 45 and 60 DAS, respectively. BAP treatment of H_3 (100 ppm of BAP) showed the highest weight of dry root at all stages except 15 DAS and the lowest dry root weight was observed in control treatment except 15 DAS. Dry root weight showed significant difference among the interactions effect between varieties and different concentrations of BAP at 15 to 60 DAS and at mature stage (Table 4). Among the interaction effect, the highest dry root weight (0.02 g) was observed in V_1H_I treatment and similar result were observed in V_2H_2, V_3H_1 and V_3H_4 treatments and others treatments were 0.01 g. On the other hand, significantly highest dry weight of root was observed in V_3H_3 treatment while the lowest root weight was observed in V_2H_1 treatment in all the growth stages. Similar result was observed in root dry weight where root dry weight was increased with increasing GA_3 concentration (Noor-E-Ferdous et al. 2020) and NAA concentration (Noor-E-Ferdous et al. 2012) in mungbean plant.

Number of root nodule plant^{-1}: A significant difference in number of root nodule was also observed at all growth stages among the three cultivars of summer mungbean (Table 5). Results revealed that the number of root nodule was maximum in V_3 (Binamoog-8) and minimum number of root nodule was observed in V_2 (BARI mungbeen 6) at 30 to 60 DAS and at mature stage. Number of nodule plant $^{-1}$ differed significantly spraying with BAP at different days after sowing. The treatment H_3 (100 ppm BAP) produced the highest number of root nodule at 30 to 60 DAS and at mature stage and the lowest number of nodule was observed in H_1 (control) treatment. The interaction effect of varieties and different concentrations of BAP were statistically significant at different days after sowing (Table 5). The highest number of root nodule plant^{-1} was observed in V_3H_3 (Binamoog-8×100 ppm BAP) treatment and the lowest number was observed in V_2H_2 (BARI mung 6×BAP) treatment at 30 DAS to mature stage. The result was in agreement with that of foliar application of nutrients and growth regulators found to increase in the morpho-physiological parameters, number of root nodules plant^{-1} and dry weight of nodule in soybean by the foliar application of hormones and nutrients (Ketki and Thakare 2006, Noor-E-Ferdous et al. 2012, Raut et al. 2017).

Table 4. Effect of BAP on dry root weight of three cultivars of summer mungbean with their interactions

Treatments	Dry root weight plant^{-1} (g)				
Varieties	15 DAS	30 DAS	45 DAS	60 DAS	At mature
V_1	0.012a	0.150ab	0.440a	1.098ab	0.850a
V_2	0.012a	0.112b	0.373b	1.018b	0.855a
V_3	0.015a	0.152a	0.493a	1.150a	0.880a
LSD (0.05)	4.33	0.04	0.06	0.13	0.18
BAP	-	-	-	-	-
H_1	0.017a	0.090c	0.247c	0.663c	0.523b
H_2	0.013ab	0.140b	0.490b	1.203ab	0.963a
H_3	0.010b	0.187a	0.573a	1.333a	1.050a
H_4	0.0133ab	0.137b	0.430b	1.153b	0.910a
LSD (0.05)	5.00	0.05	0.07	0.15	2.01
Varieties × BAP	-	-	-	-	-
V_1H_1	0.02a	0.11cde	0.29d	0.63d	0.51cd
V_1H_2	0.01b	0.13b-e	0.43c	1.24abc	0.98a
V_1H_3	0.01b	0.20ab	0.58ab	1.33ab	1.05a
V_1H_4	0.01b	0.16a-d	0.46c	1.19abc	0.86abc
V_2H_1	0.01b	0.07e	0.21d	0.61d	0.49d
V_2H_2	0.02a	0.12cde	0.46c	1.11bc	0.93a
V_2H_3	0.01b	0.15a-d	0.51bc	1.29abc	1.02a
V_2H_4	0.01b	0.11cde	0.31d	1.06c	0.98a
V_3H_1	0.02a	0.09de	0.24d	0.75d	0.57bcd
V_3H_2	0.01b	0.17abc	0.58ab	1.26abc	0.98a
V_3H_3	0.01b	0.21a	0.63a	1.38a	1.08a
V_3H_4	0.02a	0.14a-e	0.52abc	1.21abc	0.89ab
LSD (0.05)	8.66	0.08	0.12	0.26	0.36

Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability.

Root volume: The root volume was recorded from 15 to 60 DAS. Significant variation was observed in V_3 (Binamoog-8) cultivar in respect of root volume at 30 to 45 DAS due to cultivar except 15 and 60 DAS (Table 6). Effect of different concentrations of BAP also significantly influenced on root volume at 15 to 60 DAS. The highest root volume was observed in H_3 (100 ppm BAP) treatment at all growth stages. The lowest root volume was observed in H_1 (0 ppm BAP) treatment at 15 to 60 DAS. The interaction effect of cultivar and different concentrations of BAP for root volume was significant at 15 to 45 DAS except 60 DAS (Table 6). Results revealed that the highest root volume was observed in V_1H_3 (Binamoog-5×100 ppm BAP) treatment and the lowest root volume was observed in V_2H_1 (BARI mung 6×without BAP) at 15 and 30 DAS. At 45 DAS, the highest root volume (7.01cm^3) was found in V_3H_3 followed by V_1H_3 treatment. The V_2H_1 (BARI mung 6×without BAP) treatment showed the lowest root volume at 45 DAS. Finally, the interaction effect of cultivar and different concentrations of BAP on root volume at 60 DAS was non-significant effect (Table 6). Similarly, the present findings was in well agreement with Noor-E-Ferdous et al. (2012) regarding NAA

Table 5. Effect of BAP on number of root nodule of three cultivars of summer mungbean with their interactions

Treatments	Number of root nodule plant^{-1}			
Varieties	30 DAS	45 DAS	60 DAS	At mature
V_1	29.09ab	62.62a	108.25a	76.09a
V_2	27.25b	51.69b	98.82b	71.89b
V_3	30.73a	61.54a	110.68a	78.73a
LSD (0.05)	2.64	3.99	4.77	4.13
BAP	-	-	-	-
H_1	21.77c	39.68c	81.57d	46.01d
H_2	30.08b	59.87b	112.06b	84.98b
H_3	35.80a	75.80a	125.56a	91.66a
H_4	28.46b	59.10b	104.48c	79.64c
LSD (0.05)	3.05	4.60	5.51	4.77
Varieties × BAP				
V_1H_1	22.14fg	40.22e	80.97e	47.83ef
V_1H_2	30.27bcd	62.84bc	113.63b	86.36bcd
V_1H_3	35.29ab	80.07a	128.74a	90.87ab
V_1H_4	28.66cd	67.33bc	109.67bcd	79.29d
V_2H_1	20.05g	37.08e	78.37e	39.93f
V_2H_2	28.36de	49.84d	103.95cd	80.62cd
V_2H_3	33.66abc	69.51b	112.33bc	87.38bcd
V_2H_4	26.94def	50.31d	100.62d	79.66d
V_3H_1	23.08efg	41.74e	85.36e	50.26e
V_3H_2	31.61bcd	66.94bc	118.59b	87.95bc
V_3H_3	38.45a	77.81a	135.62a	96.74a
V_3H_4	29.78cd	59.66c	103.14cd	79.98cd
LSD (0.05)	5.28	7.97	9.54	8.26

Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability.

sprayed summer mungbean plants that NAA induced higher root volume in mungbean plants resulted in absorption of more soil water and nutrients.

Chlorophyll content: Chlorophyll-a content was observed non significant effect among the varieties and ranged from 1.39-1.46 mg g^{-1} (Table 7). Significant influence by the application of different concentrations of BAP on chlorophyll-a content in summer mungbean was recorded. The highest chlorophyll-a content (1.51 mg g^{-1}) was found due to the application of 100 ppm BAP. The lowest chlorophyll-a content (1.34 mg g^{-1}) was observed at control (H_1) treatment. The interaction effect of cultivars and different concentrations of BAP was statistically significant on chlorophyll-a content (Table 7). The highest chlorophyll-a content (1.55 mg g^{-1}) was obtained in V_2H_3 (BARI mung 6×100 ppm BAP) treatment and the lowest chlorophyll-a content (1.26 mg g^{-1}) was observed in V_2H_1 (BARI mung 6×without BAP application) treatment. The chlorophyll-b content was non-significant effect among the varieties and ranged from 0.50-0.53 mg g^{-1}. Chlorophyll-b content was significantly influenced by the application of different concentrations of BAP. The highest chlorophyll-b content (0.60 mg g^{-1}) was obtained in H_3 (100 ppm BAP) and while the lowest content (0.43 mg g^{-1}) was obtained in H_1 (without BAP) treatment. The interaction effect of varieties and different concentrations of BAP was statistically significant on chlorophyll-b content (Table 7). The highest chlorophyll-b content (0.61 mg g^{-1}) was obtained in V_3H_3 (Binamoog-8 × 100 ppm BAP) and V_1H_3 (BARI moog 5×100 ppm BAP) treatment and while the lowest chlorophyll-b content (0.43 mg g^{-1}) was observed in V_2H_1 (BARI mung 6×without BAP application) treatment. The present result was in agreement with Noor-E-Ferdous et al. (2012) where they found that GA_3 provided the highest chlorophyll content in summer mungbean plant.

Carotenoidcontent: Carotenoid content differed significantly among the varieties (Table 7). Binamoog-8 (V_3) observed the highest carotenoid content (0.42 mg g^{-1}) which was statistically different among other varieties. This variation might be due to the different physiological and morphological characteristics of the varieties. Carotenoid content was significantly influenced by the application of different concentrations of BAP (Table 7). The highest carotenoid content (0.4.8 mg g^{-1}) was obtained in H_3 (100 ppm BAP) and the lowest content (0.35 mg g^{-1}) was obtained in H_1 (without BAP) treatment. The interaction effect of varieties and different concentrations of BAP was statistically significant on carotenoidcontent. The highest carotenoid content (0.53 mg g^{-1}) was obtained in V_3H_3 (Binamoog-8×100 ppm BAP) treatment. The lowest carotenoid content (0.32 mg g^{-1}) was observed in V_1H_2 (Binamoog 5×50 ppm BAP) treatment.

Prolinecontent: Proline content was non-significant among the varieties and ranged from 1.40-1.35 mg g^{-1} (Table 7). Proline content was significantly influenced by the application of different concentrations of BAP (Table 7). The highest proline content (1.47 mg g^{-1}) was obtained in H_4 (150 ppm BAP) and the lowest content (1.27 mg g^{-1}) was obtained in H_1 (without BAP) treatment. The interaction effect of varieties and different concentrations of BAP was statistically significant on proline. The highest proline content (1.54 mg g^{-1}) was obtained in V_3H_4 (Binamoog-8×150 ppm BAP) treatment and the lowest proline content (1.26 mg g^{-1}) was found in V_2H_1 (BARI mung 6×without BAP) treatment. Sarker et al. (2020) reported that the highest proline content (0.353 mg g^{-1} FW) was recorded in Chinigura rice with 20 ppm 6-BAP application.

Seed yield: Seed yield differed significantly among the varieties (Table 7). Binamoog-8 (V_3) observed the highest seed yield (1.44 t ha^{-1}), which was statistically different among other varieties. This variation might be due to the different varietal characteristics of mungbean. The seed yield was significantly influenced by the application of different concentrations of BAP. The highest seed yield (1.69 t ha^{-1}) was obtained in H_3 (100 ppm BAP) and the lowest yield (1.19 t ha^{-1}) was obtained in H_1 (without BAP) treatment. The interaction effect of varieties and the different concentrations of BAP were statistically significant on seed yield (Table 7). The highest seed yield (1.87 t ha^{-1}) was obtained in V_3H_3 (Binamoog-8×100 ppm BAP) followed by V_1H_3 (BARI moog 5×100 ppm BAP) treatment. The lowest seed yield (1.03 t ha^{-1}) was observed in V_2H_1 (BARI mung 6×without BAP) treatment. Exogenous application of BAP significantly increased yield and yield components of aromatic rice (Roxy 2016, Sarker et al. 2020).

Table 6. Effect of BAP on root volume of three cultivars of summer mungbean with their interactions

Treatments	Root volume plant^{-1} (cm^3)			
Varieties	15 DAS	30 DAS	45 DAS	60 DAS
V_1	1.01	2.97b	6.10ab	8.68
V_2	0.99	2.69b	5.72b	8.42
V_3	1.01	3.36a	6.50a	8.73
LSD (0.05)	0.05	0.35	0.64	1.02
BAP	-	-	-	-
H_1	0.95b	2.19c	5.26b	7.82b
H_2	1.01b	3.00b	6.22a	8.78ab
H_3	1.09a	3.76a	6.77a	9.10a
H_4	0.96b	3.06b	6.17a	8.73ab
LSD (0.05)	0.06	0.40	0.74	1.18
Varieties × BAP	-	-	-	-
V_1H_1	0.99b-d	1.95d	5.13de	8.01a
V_1H_2	1.01a-d	2.83c	6.08a-e	8.84a
V_1H_3	1.11a	4.08a	6.98ab	9.11a
V_1H_4	0.96de	3.01c	6.21a-e	8.76a
V_2H_1	0.86e	1.75d	4.98e	7.33a
V_2H_2	1.02a-d	2.85c	5.71b-e	8.64a
V_2H_3	1.08abc	3.23c	6.33a-d	8.98a
V_2H_4	0.98cd	2.91c	5.84a-e	8.71a
V_3H_1	1.01a-d	2.89c	5.66c-e	8.13a
V_3H_2	1.00b-d	3.33bc	6.88a-c	8.86a
V_3H_3	1.09ab	3.97ab	7.01a	9.21a
V_3H_4	0.94de	3.26c	6.46a-c	8.71a
LSD (0.05)	0.10	0.71	1.28	2.04

Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability.

Table 7. Effect of BAP on the contents of chlorophyll, carotenoid, proline and seed yield of three cultivars of summer mungbean with their interactions

Treatments / Varieties	Chlorophyll-a (mg g^{-1})	Chlorophyll-b (mg g^{-1})	Carotenoid (mg g^{-1})	Proline (mg g^{-1})	Seed yield (t ha^{-1})
V_1	1.42	0.53	0.39ab	1.37	1.31b
V_2	1.39	0.50	0.38b	1.35	1.25c
V_3	1.46	0.53	0.42a	1.40	1.44a
LSD (0.05)	0.08	0.05	0.03	0.06	0.05
BAP	-	-	-	-	-
H_1	1.34b	0.43c	0.35b	1.27c	1.08d
H_2	1.42ab	0.55ab	0.36b	1.35bc	1.19c
H_3	1.51a	0.60a	0.48a	1.41ab	1.69a
H_4	1.42ab	0.51b	0.39b	1.47a	1.38b
LSD (0.05)	0.09	0.06	0.04	0.07	0.06
Varieties × BAP	-	-	-	-	-
V_1H_1	1.37bc	0.44c	0.37c-f	1.27cd	1.07gh
V_1H_2	1.42abc	0.57ab	0.32f	1.36b-d	1.18e-g
V_1H_3	1.47ab	0.61a	0.48ab	1.41a-d	1.67b
V_1H_4	1.41abc	0.51bc	0.39c-e	1.45ab	1.32d
V_2H_1	1.26c	0.43c	0.33ef	1.26d	1.03h
V_2H_2	1.39a-c	0.51bc	0.36d-f	1.34b-d	1.14f-h
V_2H_3	1.55a	0.58ab	0.43bc	1.39a-d	1.52c
V_2H_4	1.36bc	0.49bc	0.39c-e	1.41a-d	1.29de
V_3H_1	1.38bc	0.43c	0.36d-f	1.27cd	1.13gh
V_3H_2	1.46ab	0.58ab	0.41cd	1.35b-d	1.25d-f
V_3H_3	1.51ab	0.61a	0.52a	1.43a-c	1.87a
V_3H_4	1.48ab	0.52abc	0.38c-f	1.54a	1.51c
LSD (0.05)	0.16	0.10	0.07	0.13	0.11

Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability.

CONCLUSION

It is concluded that growth, yield and biochemical characteristics of summer mungbean cv. Binamoog-8 cultivar was increased exogenous foliar application of BAP @ 100 ppm. Most of the yield and yield contributing parameters quantitatively increased by the concentration of 100 ppm BAP on Binamoog-8 summer mungbean cultivar than that of Binamoog-5 and BARI Mung 6. In regard to all parameters, application of 100 ppm BAP on Binamoog-8 cultivar performed the best regarding the growth, yield and yield components. It is concluded that summer mungbean Binamoog-8 and Binamoog-5 showed better performance at 100 ppm and may be recommended for the farmers' level to increase summer mungbean production for farm management practices.

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