

Influence of gibberellic acid (GA₃) on growth, chlorophyll and seed yield of summer mungbean cultivars in Northwest of Bangladesh

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ABSTRACT

Mungbean is an important pulse crop and its productivity is highly sensitive to application of plant growth regulators. The experiment was carried out to investigate the effects of gibberellic acid (GA₃) on growth, leaf chlorophyll and yield of summer mungbean cultivars viz., V₁-Binamoog-5, V₂-BARI mung 6 and V₃-Binamoog-8 along with four treatments of H₁-control (without GA₃), H₂-50 ppm GA₃, H₃-100 ppm GA₃ and H₄-150 ppm GA₃ applied 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, chlorophyll content, proline content and seed yield. 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 GA₃. The highest plant height, number of leaves plant⁻¹, leaf area plant⁻¹ and seed yield were obtained by applying 100 ppm GA₃. The interaction effect of cultivars and different concentrations of GA₃ were statistically significant on plant height, number of leaves plant⁻¹, leaf area plant⁻¹ and seed yield. The highest plant height, number of leaves plant⁻¹, leaf area plant⁻¹ and seed yield were obtained in Binamoog-8 by spraying 100 ppm GA₃. Therefore, it infers that foliar application of GA₃ at the rate of 100 ppm and Binamoog-8 had the best yield potentiality in Northwest of Bangladesh for profitable summer mungbean cultivation.

Keywords: Chlorophyll, GA₃, growth, mungbean, seed yield

INTRODUCTION

Mungbean (*Vigna radiata* (L) Wilczek) is one of the most important pulse crops of global economic importance. It originated in the South and Southeast Asia and widely grown in Bangladesh, India, Pakistan, Myanmar, Thailand, Philippines, China and Indonesia. Mungbean has special important as an accommodative crop with short growing period along with N₂ fixation in soil (Ferdous et al., 2012). Plant growth regulators (PGRs) are being used as an aid to enhance yield of different crops (Nickell 1982, Sarker et al. 2009, Bakhsh et al. 2011). Gibberellins are plant

hormones with a wide range of activities including seed germination and cell elongation (Miransari and Smith 2009, Hayashi et al. 2014). Hussain et al. (2018) stated that growth parameters showed increment with foliar spray with gibberellic acid. It breaks seed dormancy, stems elongation, enhances germination, internodal length, hypocotyls growth and cell division in cambial zone and increases the size of leaves, flowers and pods (Deotale et al. 1998). It is well established that gibberellic acid causes a dramatic increase in growth of mungbean. It increases dry weight (Hore et al. 1988) as well as seed yield (Maske et al. 1998). So, favorable conditions may be induced by applying growth regulator like GA₃ exogenously in proper concentration at a

proper time in a specific crop. Considering the above fact, the present study was undertaken with the response of mungbean to GA₃ in relation to growth, yield and quality at Northwest in Dinajpur region of Bangladesh for profitable cultivation.

MATERIALS AND METHODS

The experiment was conducted at the Agricultural Farm of Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during the period from March to June 2011. The research site was located in Northwest of Bangladesh, an agriculturally important region. It is between 25.13° N' latitude and 88.23° E' longitude and at an elevation of 34.5 m above the mean 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 (V₁-Binamoog-5, V₂-BARI mung 6 and V₃-Binamoog-8) while factor B were four treatments *viz.* H₁-control (without GA₃), H₂-50 ppm GA₃, H₃-100 ppm GA₃ and H₄-150 ppm GA₃. The experiment was laid out in Randomized Complete Block Design (RCBD) with 2 factors. Twenty combined treatments were V₁H₁, V₁H₂, V₁H₃, V₁H₄, V₂H₁, V₂H₂, V₂H₃, V₂H₄, V₃H₁, V₃H₂, V₃H₃ and V₃H₄, 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 (Ferdous 2016) for better germination, second irrigation was done after weeding and thinning, and third irrigation was done at flowering stage. Specific concentration of GA₃ for experimental treatments was prepared and applied in the form of foliar sprays at 25 and 45 DAS.

Yield and yield contributing characteristics: 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. Plant heights of selected plants were taken 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 mature stage. 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 65°C 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.

Chlorophyll content: 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 = $12.21 A_{663} - 2.81 A_{646}$ (mg g⁻¹ FW)

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

Total carotenoid = $(1000 A_{470} - 2.05 \times \text{Chl-a} - 114.8 \times \text{Chl-b}) / 245$ (mg g⁻¹ FW) by Porra (2002).

Proline content: 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.

Seed yield: 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.

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: Plant height increased gradually with the advancement of the growth stages (15 -60 DAS) of the plants in all the cultivars (Table 1). Significant variations ($P < 0.05$) were observed on plant height among the cultivars. The highest plant heights (10.36, 21.60, 43.59 and 66.29 cm) were observed in V₃ (Binamoog-8) and the lowest plant height were observed in 9.30, 19.92, 39.70 and 61.50 cm in V₂ (BARI mung-6) at 15, 30, 45 and 60 DAS, respectively. Plant height was significantly influenced by different concentrations of GA₃ at all growth stages of mungbean (Table 1). Applying 100 ppm GA₃ had the significant effect to stimulate more cell divisions in increasing height at 30, 45, 60 DAS and at maturity stages except 15 DAS, and the lowest dry root weight was observed in control. The interaction effect of cultivars and different concentrations of GA₃ were also

statistically significant at different days after sowing (Table 1). The highest (10.73, 24.87, 45.93 and 70.68 cm) and the lowest (8.91, 17.75, 36.78 and 57.12 cm) plant heights were obtained in V₃H₃ (Binamoog-8 × 100 ppm GA₃) and V₂H₁ (BARI mung 6 × with no GA₃ application) treatments at 15, 30, 45 and 60 DAS,

respectively. From the above observation, it was found that plant height was increased with the 100ppm GA₃ in Binamoog-8 variety. It is observed that GA₃ caused remarkably increase of plant height of BARI mung 2 (Haque 2001). He reported that 100 mg L⁻¹ of GA₃ was more effective in stem elongation in mungbean.

Table 1. Effect of GA₃ on plant height of summer mungbean and their interactions

Treatments	Plant height (cm)			
Cultivars	15 DAS	30 DAS	45 DAS	60 DAS
V ₁	10.12a	20.89a	41.91b	64.62a
V ₂	9.30b	19.92b	39.70c	61.51b
V ₃	10.36a	21.60a	43.59a	66.29a
LSD (0.05)	0.36	0.87	0.92	1.76
GA ₃	-	-	-	-
H ₁	9.66b	18.68c	39.48c	60.29c
H ₂	9.94ab	20.81b	42.03b	64.84b
H ₃	10.30a	23.60a	44.18a	68.45a
H ₄	9.82b	20.17b	41.27b	62.98b
LSD (0.05)	0.41	1.01	1.07	2.03
Cultivars × GA ₃	-	-	-	-
V ₁ H ₁	9.98bc	18.85ef	39.63a	60.83e
V ₁ H ₂	10.18ab	21.03cd	42.12cd	65.26bc
V ₁ H ₃	10.32ab	23.77ab	44.08ab	69.93a
V ₁ H ₄	10.03ab	19.94de	41.78de	62.48c-e
V ₂ H ₁	8.91e	17.75f	36.78g	57.12f
V ₂ H ₂	9.26c-e	20.33de	40.18ef	62.88b-e
V ₂ H ₃	9.84b-d	22.17bc	42.52b-d	64.79b-d
V ₂ H ₄	9.19de	19.43d-f	39.34f	61.26de
V ₃ H ₁	10.08ab	19.45d-f	41.98c-e	62.94b-e
V ₃ H ₂	10.39ab	21.08cd	43.78bc	66.39b
V ₃ H ₃	10.73a	24.87a	45.93a	70.64a
V ₃ H ₄	10.25ab	20.98cd	42.68b-d	65.21bc
LSD (0.05)	0.72	1.74	1.85	3.53

In column, means followed by same letters are not significantly different; V₁-Binamoog-5, V₂-BARI mung 6 and V₃-Binamoog-8, H₁-0 ppm (control), H₂-50 ppm, H₃-100 ppm and H₄-150 ppm

Number of leaves per plant: Number of leaves plant⁻¹ differed significantly ($P < 0.05$) among the cultivars at different days after sowing. The highest number of leaves plant⁻¹ (4.17, 5.51, 8.19, 10.49 and 9.42) was recorded in the Binamoog-8 (V₃) which were statistically different among the cultivars and the lowest number of leaves plant⁻¹ (3.32, 4.84, 6.37, 7.78 and 7.4) were in BARI mung 6 (V₂) variety at all stages, respectively (Table 2). Significantly the highest number of leaves (3.96, 5.62, 7.90, 9.95 and 9.00) was found spraying 100 ppm (H₃) GA₃ due to its biochemical activities. The lowest number of leaves (4.78, 6.48, 8.34 and 7.51) was observed in control plants at 30, 45, 60 DAS and mature stages, respectively except 15 DAS. Interaction effect of cultivars and different concentrations of GA₃ was found in Table 2. A significance different was found with the interaction

effect among the cultivars and different concentrations of GA₃. The highest number of leaves plant⁻¹ was observed in V₃H₃ during the entire growth stages. The lowest number of leaves plant⁻¹ (3.16) was recorded in V₂H₄ at 15 DAS but the lowest number of leaves plant⁻¹ was found during whole growing period. Similar results was observed in Sarkar et al. (2002), who found that GA₃ using 100 ppm in soybean plants produced higher number of leaves at the later stages of 60 and 80 DAS. Noor et al. (2017) found that GA₃ at 50 ppm concentration in treated french bean plants produced higher number of leaves at the later stages of 48 and 58 DAS. It might be due to GA₃ that stimulates cell enlargement and cell division and enhances plant height, number of branches and number of leaves in the present studies.



Table 2. Effect of GA₃ on number of leaves plant⁻¹ of summer mungbean and their interactions

Treatments	Number of leaves plant ⁻¹				
Cultivars	15 DAS	30 DAS	45 DAS	60 DAS	At mature
V ₁	3.97a	5.11b	7.51b	9.23b	8.26b
V ₂	3.32 b	4.85b	6.37c	7.78c	7.45c
V ₃	4.17a	5.51a	8.19a	10.49a	9.42a
LSD (0.05)	0.45	0.31	0.51	0.44	0.51
GA ₃	-	-	-	-	-
H ₁	3.77	4.78c	6.48b	8.34c	7.51c
H ₂	3.79	5.14b	7.62a	9.35b	8.81a
H ₃	3.96	5.62a	7.90a	9.95a	9.00a
H ₄	3.75	5.07bc	7.41a	9.05b	8.21b
LSD (0.05)	0.52	0.35	0.59	0.51	0.59
Cultivars × GA ₃	-	-	-	-	-
V ₁ H ₁	3.86a-c	4.78bc	6.26ef	8.63de	7.38f-h
V ₁ H ₂	3.99a-c	5.18b	7.95a-c	9.24cd	8.72c-e
V ₁ H ₃	4.06a-c	5.33b	8.14a-c	9.98bc	8.91b-d
V ₁ H ₄	3.97a-c	5.13b	7.66b-d	9.09d	8.06d-g
V ₂ H ₁	3.39bc	4.31c	5.93f	7.23g	6.93h
V ₂ H ₂	3.26bc	4.92bc	6.56ef	8.09e-g	7.84e-h
V ₂ H ₃	3.48a-c	5.36b	6.71d-f	8.18ef	7.98d-g
V ₂ H ₄	3.16c	4.81bc	6.28ef	7.63fg	7.04gh
V ₃ H ₁	4.07ab	5.26b	7.25c-e	9.17cd	8.23d-f
V ₃ H ₂	4.14ab	5.33b	8.36ab	10.71b	9.86ab
V ₃ H ₃	4.35a	6.18a	8.86a	11.68a	10.11a
V ₃ H ₄	4.12ab	5.27b	8.29ab	10.43b	9.51a-c
LSD (0.05)	0.90	0.61	1.02	1.88	1.03

In column, means followed by same letters are not significantly different; V₁- Binamoog-5, V₂- BARI mung 6 and V₃ - Binamoog-8, H₁- 0 ppm (control), H₂- 50 ppm, H₃-100 ppm and H₄-150 ppm

Leaf area per plant: Effects of GA₃ of different cultivars of mungbean was significantly differed on leaf area plant⁻¹ at 15, 30, 45, 60 DAS and mature stage (Table 3). The highest leaf area plant⁻¹ was found in V₃ plants and the lowest was observed in V₂ plants at 15 DAS. Leaf area plant⁻¹ was significantly influenced by the application of different concentrations of GA₃ at all growth stages of mungbean (Table 3). Significantly the maximum leaf area plant⁻¹ was observed while spraying 100 ppm GA₃ at 30, 45, 60 DAS and mature stage, respectively. The lowest leaf area plant⁻¹ was found spraying H₁ at 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 stages by the interaction effect between cultivars and different concentrations of GA₃ (Table 3). Significant maximum leaf area plant⁻¹ was observed by applying V₃H₃ at 30 DAS to mature stage except at 15 DAS. Similarly, the lowest leaf area plant⁻¹ was obtained in V₂H₁ at 30 DAS from mature stage. GA₃ induced higher leaf areas were reported in mungbean plant by Rahman et al. (2018), in rice plants (Liu et al. 2012) and tomato plants (Khan et al. 2006).

Dry root weight per plant: There was a significant variation of dry root weight plant⁻¹ was observed except 15 DAS (Table 4). Dry root weight was the maximum in Binamoog-8 and BARI mung 6 during the whole growth stages using different levels of GA₃. Spraying 100 ppm GA₃ had the significant effect to produce more biomass in root at all stages except 15 DAS and the lowest dry root weight was observed in control. Dry root weight showed significant difference among the interaction effect between cultivars and different concentrations of GA₃ at 30 DAS to mature stage except 15 DAS (Table 4). Among the interaction effect, the highest dry root weight was observed in V₃H₃ (Binamoog-8 × 100 ppm GA₃) of 0.14, 0.53, 1.08 and 0.86 g at 30, 45, 60 DAS and mature stage, respectively. Similarly, significantly the lowest dry root weight was observed in V₂H₁ (BARI mung 6 × without GA₃) treatment of 0.05, 0.15, 0.36 and 0.32 g at 30, 45, 60 DAS and mature stages, respectively. Root dry weight was increased with increasing with NAA concentration (Ferdous et al. 2012) in mungbean plant and similar result was observed in Wang and Deng (1992) in rice plant.

Table 3. Effect of GA₃ on leaf area plant⁻¹ of summer mungbean and their interactions

Treatments		Leaf area plant ⁻¹ (cm ²)				
Cultivars	15DAS	30DAS	45DAS	60DAS	At mature	
V ₁	35.67a	220.84a	737.97b	1489.60b	1319.20b	
V ₂	29.64b	193.55b	606.57c	1116.40c	1016.10c	
V ₃	36.39a	221.46a	821.41a	1655.80a	1518.60a	
LSD (0.05)	1.69	5.91	11.13	20.22	16.40	
GA ₃	-	-	-	-	-	
H ₁	33.63	186.06d	632.01d	1302.20d	1142.10d	
H ₂	33.70	218.36b	738.62b	1444.20b	1308.60b	
H ₃	34.19	234.86a	820.27a	1517.60a	1417.30a	
H ₄	34.08	208.52c	697.05c	1418.30c	1270.10c	
LSD (0.05)	1.95	6.82	12.85	23.35	18.93	
Cultivars × GA ₃	-	-	-	-	-	
V ₁ H ₁	35.83	186.51ef	663.78f	1368.21f	1096.35h	
V ₁ H ₂	35.42	228.92b	730.69e	1492.79e	1397.64e	
V ₁ H ₃	35.78	243.63a	831.95c	1594.35c	1463.51cd	
V ₁ H ₄	35.63	224.29bc	725.48e	1503.13e	1318.37f	
V ₂ H ₁	29.68	178.96f	563.92i	992.63j	896.75j	
V ₂ H ₂	29.42	195.33e	628.71g	1161.19h	1013.68i	
V ₂ H ₃	29.75	212.29d	636.23g	1201.74f	1154.83g	
V ₂ H ₄	29.71	187.63ef	597.44h	1109.92h	998.92i	
V ₃ H ₁	35.38	192.72e	668.32f	1545.89c	1433.24d	
V ₃ H ₂	36.26	230.83b	856.45b	1678.76b	1514.62b	
V ₃ H ₃	37.03	248.67a	992.63a	1756.68a	1633.49a	
V ₃ H ₄	36.92	213.64 cd	768.24d	1641.92b	1493.15bc	
LSD (0.05)	3.38	11.82	22.27	40.45	32.80	

In column, means followed by same letters are not significantly different; V₁- Binamoog-5, V₂- BARI mung 6 and V₃- Binamoog-8, H₁- 0 ppm (control), H₂- 50 ppm, H₃-100 ppm and H₄-150 ppm

Table 4. Effect of GA₃ on dry root weight of summer mungbean and their interactions

Treatments		Dry root weight plant ⁻¹ (g)				
Cultivars	15 DAS	30 DAS	45 DAS	60 DAS	At mature	
V ₁	0.01	0.08b	0.34a	0.54b	0.41b	
V ₂	0.01	0.07b	0.24b	0.51b	0.40b	
V ₃	0.01	0.11a	0.40a	0.90a	0.56a	
LSD (0.05)	-	0.03	0.08	0.17	0.04	
GA ₃	-	-	-	-	-	
H ₁	0.01	0.06a	0.19c	0.48b	0.34c	
H ₂	0.01	0.09ab	0.35b	0.69a	0.44b	
H ₃	0.01	0.12a	0.46a	0.80a	0.64a	
H ₄	0.01	0.08ab	0.32b	0.63ab	0.41b	
LSD (0.05)	-	0.04	0.09	0.19	0.05	
Cultivars × GA ₃	-	-	-	-	-	
V ₁ H ₁	0.01	0.06b	0.23c-f	0.45a	0.34d	
V ₁ H ₂	0.02	0.09ab	0.36b-d	0.58c	0.41cd	
V ₁ H ₃	0.01	0.11ab	0.47ab	0.66bc	0.52b	
V ₁ H ₄	0.01	0.08ab	0.33b-d	0.47c	0.39cd	
V ₂ H ₁	0.02	0.05b	0.15f	0.36c	0.32d	
V ₂ H ₂	0.01	0.08ab	0.24c-f	0.53c	0.39cd	
V ₂ H ₃	0.01	0.11ab	0.39a-c	0.67bc	0.56b	
V ₂ H ₄	0.01	0.07ab	0.21d-f	0.49c	0.35d	
V ₃ H ₁	0.01	0.09ab	0.19ef	0.63bc	0.38d	
V ₃ H ₂	0.01	0.11ab	0.46ab	0.96ab	0.53b	
V ₃ H ₃	0.01	0.14a	0.53a	1.08a	0.86a	
V ₃ H ₄	0.01	0.10ab	0.42ab	0.94ab	0.48bc	
LSD (0.05)	-	0.07	0.16	0.34	0.09	

In column, means followed by same letters are not significantly different; V₁- Binamoog-5, V₂- BARI mung 6 and V₃- Binamoog-8, H₁- 0 ppm (control), H₂- 50 ppm, H₃-100 ppm and H₄-150 ppm



Number of root nodule: The giberellins are also able to regulate the legume nodules production indicated recently. Hayashi et al., (2014) reported that the GA₃ is important at two different growth stages of nodulation including the early stage of root colonization and the late stage of nodule production and maturity. A significant difference in number of root nodule was observed at all growth stages among three cultivars of summer mungbean (Table 5). Number of root nodule was the maximum (25.03, 49.69, 94.46 and 63.64) in V₃ (Binamoog-8) and minimum (20.81, 35.50, 79.14 and 49.53) was observed in V₂ (BARI mungbean) at 30 to 60 DAS and mature stage, respectively (Table 5). Number of nodule plant⁻¹ differed significantly among four concentrations of GA₃ at different days after sowing (Table 5). GA₃ at 100 ppm had significant effect on Binamoog-8 producing of root nodule at 30 to 60 DAS and at mature stage while the lowest number of nodule was observed in control. The interaction effect of cultivars and different concentrations of GA₃ were also statistically significant at different days after sowing (Table 5). Developments of root nodule are mainly

dependent on phosphorous availability and the function of root nodule forming bacteria. Growth regulators cause increase in activity of root system and enhances biotic activities in the rhizosphere. Similar findings were reported, who stated that the 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 (Raut et al. 2017, Ketki and Thakare 2006).

Foliar application of GA₃ induced this effect at all the concentration applied. The present finding was in good agreement with Uddin (2009). The greater numbers of root nodule are beneficial for fixing atmospheric N₂ by rhizobium bacteria resulted in N supply in soil. The present study indicated that the higher root nodulation produced by foliar spraying of GA₃ might nourish N requirement for the mungbean plants, which might have supported N nutrition. Higher nodule formation in summer mungbean roots applying NAA application was reported by Ferrdous et al. (2012).

Table 5. Effect of GA₃ on number of root nodule of summer mungbean and their interactions

Treatments	Number of root nodule plant ⁻¹			
Cultivars	30 DAS	45 DAS	60 DAS	At mature
V ₁	24.73a	38.41b	82.98b	55.56b
V ₂	20.81b	35.36c	79.14b	49.53c
V ₃	25.03a	49.69a	94.46a	63.64a
LSD (0.05)	2.21	0.67	5.24	3.85
GA ₃	-	-	-	-
H ₁	19.25c	33.63d	68.16d	34.79c
H ₂	22.42b	41.48b	89.00b	60.06b
H ₃	31.27a	50.54a	104.00a	72.65a
H ₄	21.16bc	38.960c	80.98c	57.47b
LSD (0.05)	2.54	4.78	6.05	4.45
Cultivars × GA ₃	-	-	-	-
V ₁ H ₁	18.31fg	33.28g	65.98ef	32.65h
V ₁ H ₂	24.45cd	38.86d	89.76c	59.38d-f
V ₁ H ₃	31.55ab	46.57c	103.54ab	72.92b
V ₁ H ₄	22.66d-f	34.92f	72.67d-f	57.31ef
V ₂ H ₁	16.66g	30.84h	65.84f	34.41h
V ₂ H ₂	19.48e-g	36.66e	78.49d	52.86fg
V ₂ H ₃	28.74bc	39.83d	95.83bc	61.47c-e
V ₂ H ₄	18.35fg	34.14fg	76.43de	49.38g
V ₃ H ₁	22.79de	36.77e	72.65d-f	37.32h
V ₃ H ₂	23.33de	48.94b	98.76bc	67.96bc
V ₃ H ₃	33.53a	65.23a	112.63a	83.58a
V ₃ H ₄	22.46d-f	47.82bc	93.83bc	65.73b-d
LSD (0.05)	4.41	1.34	10.48	7.70

In column, means followed by same letters are not significantly different; V₁- Binamoog-5, V₂ - BARI mung 6 and V₃ - Binamoog-8, H₁- 0 ppm (control), H₂- 50 ppm, H₃-100 ppm and H₄-150 ppm



Root volume: Root volume was recorded from 15 to 60 DAS. Significant maximum root volume was observed in V₃ (Binamoog-8) treatment at 45 and 60 DAS (5.88 and 8.47cm³). Significant the lowest root volume was observed in V₂ (BARI mung 6) at 15to 60 DAS (1.18, 2.34, 4.57 and 7.12 cm³) treatment (Table 6). The highest root volume was observed in H₃ (1.16, 3.58, 5.83 and 8.52 cm³) at all growth stages and the lowest root volume was observed in control at 15 to 60 DAS(0.94, 1.93, 4.55

and 6.43cm³), respectively. The interaction effect of cultivar and different concentrations of GA₃ for root volume was significant at 15 to 60 DAS. It is clear from the results that the highest root volume was observed in V₃H₃ treatment and the lowest was observed in V₂H₁ at 15 DAS and 60 DAS. Ferdous et al.(2012) revealed that NAA induced higher root volume in mungbean plants, which conformed the present study.

Table 6. Effect of GA₃ on root volume of summer mungbean and their interactions

Treatments	Root volume plant ⁻¹ (cm ³)			
	15DAS	30DAS	45DAS	60DAS
Cultivars				
V ₁	1.02b	3.15a	4.75b	7.55ab
V ₂	0.93c	2.34b	4.57b	7.12b
V ₃	1.18a	2.58b	5.88a	8.47a
LSD (0.05)	0.03	0.33	0.45	0.92
GA ₃	-	-	-	-
H ₁	0.94d	1.93c	4.55b	6.43b
H ₂	1.06b	2.67b	5.03b	8.01a
H ₃	1.16a	3.58a	5.83a	8.52a
H ₄	1.01c	2.58b	4.87b	7.89a
LSD (0.05)	0.04	0.38	0.52	1.06
Cultivars × GA ₃				
V ₁ H ₁	0.98e	1.78	4.41ef	6.21bc
V ₁ H ₂	1.01c-e	2.33	4.68c-f	7.86ab
V ₁ H ₃	1.08c	2.83	5.42b-d	8.53a
V ₁ H ₄	0.99de	2.26	4.51d-f	7.61ab
V ₂ H ₁	0.83f	1.75	3.85f	5.13c
V ₂ H ₂	0.98e	2.38	4.71c-f	7.83ab
V ₂ H ₃	1.06cd	2.92	5.09b-e	8.06a
V ₂ H ₄	0.86f	2.24	4.65	7.46ab
V ₃ H ₁	1.01c-e	2.18	5.39b-d	7.96ab
V ₃ H ₂	1.21b	2.67	5.71b	8.34a
V ₃ H ₃	1.35a	2.98	6.98a	8.98a
V ₃ H ₄	1.18b	2.52	5.47bc	8.62a
LSD (0.05)	0.07	0.66	0.91	1.84

In column, means followed by same letters are not significantly different; V₁- Binamoog-5, V₂ - BARI mung 6 and V₃ - Binamoog-8, H₁- 0 ppm (control), H₂- 50 ppm, H₃-100 ppm and H₄-150 ppm

Chlorophyll content: There was no significant effect on chlorophyll-a content in leaves among the cultivars but levels of GA₃ (Table 7). It is noted that a significant effect was observed in the interaction among the cultivars and levels. The highest chlorophyll-a (1.37 mg g⁻¹FW) was found in with the application of 100 ppm GA₃ and the lowest (1.14 mg g⁻¹ FW) was observed in control (H₁) treatment. The highest amount of chlorophyll-a was obtained (1.39 mg g⁻¹ FW) in V₂H₃ leaves and the lowest chlorophyll-a (1.13 mg g⁻¹ FW) was in V₂H₁ leaves. Chlorophyll-b was maximum in V₃but minimum in V₂ treatment. Considering levels of GA₃, the highest chlorophyll-b content (0.54 mg g⁻¹ FW) was obtained in H₃ while the lowest content was 0.42 mg g⁻¹FW in H₁ (Control).The highest chlorophyll-b (0.58 mg g⁻¹ FW) was obtained in V₃H₃ and V₁H₃treatments,

while the lowest chlorophyll-b (0.38 mg g⁻¹ FW) was observed in V₂H₁ leaves.

Carotenoid content: Results in Table 7 showed that carotenoid content differed significantly among the cultivars. Binamoog-8 (V₃) observed the highest carotenoid content (0.35 mg g⁻¹FW), which was statistically different from other cultivars and carotenoid content (0.32 mg g⁻¹FW) was found from BARI mung 6. This variation might be due to the GA₃ effect on different physiological activities. Carotenoid content was significantly influenced by application of different concentrations of GA₃ (Table 7). The highest carotenoid content (0.38 mg g⁻¹FW) was obtained in H₃, while the lowest content (0.31 mg g⁻¹FW) was found in H₁ treatment. The interaction effect of cultivars and different concentrations of GA₃ was statistically significant on carotenoid content.



Proline content: Proline content was non-significant among the cultivars and ranged from 1.35 to 1.41 mg g⁻¹ FW but was significantly influenced by the application of different concentrations of GA₃ (Table 7). The highest proline content (1.41 mg g⁻¹ FW) was obtained in H₄ while the lowest (1.33 mg g⁻¹ FW) was obtained in H₃ (without GA₃). The interaction effect of cultivars and different concentrations of GA₃ was also statistically significant on proline content (Table 7). The highest proline content (1.45 mg g⁻¹ FW) was obtained in V₃H₄ while the lowest proline content (1.31 mg g⁻¹ FW) was observed in V₂H₁. From the present investigation, important role of GA and proline was observed when applied as foliar spraying on mungbean. Proline application results in its rapid uptake and coupled with its synthesis in plant, thereby increasing the endogenous level of proline and also plays an important role for osmotic adjustment against various stresses (Ahmed et al. 2011). In addition to the role of osmo-protection, proline protects the enzymes, protein structure, cell organelles and membranes by checking lipid peroxidation and facilitates the energy supply for plant growth, and effective quencher of ROS formed through life cycle of plant and enhanced the activity of

antioxidant enzymes. and therefore, proline increases resistance to unfavorable climatic conditions (Ashraf and Foolad 2007).

Seed yield: Seed yield differed significantly among the cultivars (Table 7). Binamoog-8 (V₃) showed the highest seed yield (1.29 t ha⁻¹), which was statistically different from other cultivars. Seed yield was significantly influenced by the application of different concentrations of GA₃ (Table 7). The highest seed yield (1.53 t ha⁻¹) was obtained in H₃ (100 ppm GA₃) while the lowest (1.02 t ha⁻¹) was obtained in H₃(without GA₃). The interaction effect of cultivars and different concentrations of GA₃ were found the highest seed yield (1.66 t ha⁻¹) in V₃H₃ followed by V₁H₃ (1.56 t ha⁻¹). The lowest seed yield (0.98 t ha⁻¹) was observed in V₂H₁. The greater seed yield by applying 100 ppm GA₃ due to increased chlorophyll production and higher leaf area which might help in enhance photosynthesis in mungbean. GA₃ with different concentrations significantly enhanced seed yield in many crops as reported by a number of researchers (Beall et al. 1996, Uddin 1999, Sarkar et al. 2002, Tiwari et al. 2011, Alam et al. 2018, Rahman et al. 2018, Sanjida et al. 2019).

Table 7. Effect of GA₃ on chlorophyll, carotenoid, proline and seed yield of summer mungbean and their interactions

Treatments	Chlorophyll-a (mg g ⁻¹)	Chlorophyll-b (mg g ⁻¹)	Carotenoid (mg g ⁻¹)	Proline (mg g ⁻¹)	Seed yield (t ha ⁻¹)
Cultivars					
V ₁	1.26	0.49a	0.34a	1.35	1.21ab
V ₂	1.24	0.43b	0.32ab	1.36	1.15b
V ₃	1.25	0.51a	0.35a	1.41	1.29a
LSD (0.05)	0.07	0.04	0.023	0.059	0.109
GA₃					
H ₁	1.14c	0.42c	0.31c	1.33b	1.02c
H ₂	1.28b	0.48b	0.35ab	1.36ab	1.08c
H ₃	1.37a	0.54a	0.38a	1.39ab	1.53a
H ₄	1.23b	0.46bc	0.32bc	1.41a	1.23b
LSD (0.05)	0.08	0.046	0.040	0.068	0.126
Cultivars × GA₃					
V ₁ H ₁	1.14de	0.43d-f	0.32b-d	1.33b	1.02e
V ₁ H ₂	1.29a-c	0.51a-d	0.35a-c	1.34ab	1.08e
V ₁ H ₃	1.36ab	0.56ab	0.38ab	1.37ab	1.56ab
V ₁ H ₄	1.24b-e	0.48b-e	0.31cd	1.39ab	1.18c-e
V ₂ H ₁	1.13e	0.38f	0.27d	1.31b	0.98e
V ₂ H ₂	1.28a-d	0.42ef	0.34a-c	1.36ab	1.06e
V ₂ H ₃	1.37ab	0.49b-e	0.38ab	1.39ab	1.39bc
V ₂ H ₄	1.23b-e	0.44c-f	0.31cd	1.41ab	1.17dc
V ₃ H ₁	1.14de	0.45c-f	0.34a-c	1.37ab	1.06e
V ₃ H ₂	1.28a-d	0.52a-c	0.37abc	1.39ab	1.11e
V ₃ H ₃	1.39a	0.58a	0.39a	1.42ab	1.66a
V ₃ H ₄	1.21c-e	0.47c-e	0.34a-c	1.45a	1.35b-d
LSD (0.05)	0.14	0.081	0.069	0.117	0.218

In column, means followed by same letters are not significantly different; V₁- Binamoog-5, V₂- BARI mung 6 and V₃ - Binamoog-8, H₁- 0 ppm (control), H₂- 50 ppm, H₃-100 ppm and H₄-150 ppm

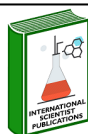


CONCLUSION

It is concluded that gibberellic acid (GA₃) had the positive stimulatory effect on growth, chlorophyll and seed yield production. The highest number of leaves plant⁻¹, leaf area plant⁻¹ along with greater amount chlorophyll production enhanced seed yield obtained applying 100 ppm GA₃. The interaction among the cultivars with different concentrations of GA₃ showed statistically significant variation on the growth and yield parameters. The highest plant height, number of leaves plant⁻¹, leaf area plant⁻¹ and seed yield were obtained in Binamoog-8 by thrice exogenous spraying 100 ppm of GA₃. It is evidently suggested that Binamoog-8, a summer mungbean cultivar in Bangladesh boosted up its yield potentiality by exogenous foliar application of GA₃ @ 100 ppm. Therefore, the findings infer that GA₃ might help in producing more summer mungbean seed yield in Old Himalayan Piedmont Plain soil especially in Northwest of Bangladesh for environment friendly management practices.

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