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Response Of Mungbean to Gibberellic Acid (GA_3) And Nitrogen Application with Reference to Yield and Protein Content

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Abstract

An experiment was carried out in the field of Sher-e-Bangla Agricultural University, Dhaka to study the impact of GA_3 and nitrogen on growth, yield attributes and protein content of mungbean. The experiment was conducted using as treatments three levels of GA_3 (0, 50 and 100 ppm) combined with four nitrogen doses (0, 22, 44 and 66 kg ha^{-1} of urea), distributed in RCBD with three replications. Yield and quality parameters were largely affected by GA_3 treatment. 50 ppm GA_3 application generated maximum number of pods per plant (107.52), seeds pod^{-1} (9.97), chlorophyll content (52.75%), seed yield (2.16 t ha^{-1}), stover yield (1.05 t ha^{-1}), nitrogen content (4.11%) and protein content (25.72%) while minimum values were recorded in control treatment. Nitrogen was also effective in enhancing plant growth and yield. Plots receiving 44 kg urea ha^{-1} gave significantly the maximum pods per plant (108.94), seeds per pod (10.14), 1000- seed weight (47.22 g), seed yield (2.16 t ha^{-1}) and stover yield (1.08 t ha^{-1}) while minimum value was recorded in control plots followed by all other treatments for these attributes in between the range of highest and lowest values respectively of these characters among the treatment combinations applied under study.. The application of 50 ppm GA_3 in combination with 44 kg urea ha^{-1} (G_1N_2) showed the best effect (i.e., significantly superior), which produced the maximum number of pods per plant (132.27), seed per pod (11.30), thousand-seed weight (47.92 g), seed yield (2.38 t ha^{-1}), stover yield (1..28 t ha^{-1}) and both nitrogen content of seeds (4.20%) and protein content (26..25%). Hence it is recommended that 50 ppm GA_3 along with 44 kg urea ha^{-1} is the most effective treatment for obtaining higher mungbean yield and protein content.

Keywords: Nitrogen fertilization, Growth performance, Yield attributes, Seed yield, Protein content, Urea application.

Introduction

Mungbean (Vigna radiata L.) is a short - duration high-protein leguminous pulse crop commonly grown in Bangladesh and also known as green gram or golden gram, it is a member of the family Leguminosae and is native to India but widely cultivated in India,China,Thailand,Philippines,Indonesia,Myanmar,Bangladesh,Laos and Combodia. It is cultvated also in some hot, dry parts of Europe and the United States. Mungbean is nutritionally superior and easily digestible while serving as a rich source of protein, as well as enhancing the fertility status of the soil through biological nitrogen fixation (BNF) [1]. The seeds are rich in proteins (24%), fat (1–3%), carbohydrates (50.4%), fiber (3.5–4.5%) and ash (4.5–5.5%) as well, with relatively high mineral content (132 mg/100 g of calcium and 367 mg/100 g of phosphorus) [2]. Mungbean has more acceptability and is less

flatulence-free compared to other pulses [3]. Pulses Partially Cooked pulses are an integral part of the Bangladeshi diet frequently consumed as dal and in deep fried or curry form, but at just two-thirds (14.3 g) of WHO receommended 45 g daily per capita intake capacity is limited due to inadequate domestic production [4]. Mungbean production's benefit itself spreads to supply of livestock feed and improvement of soil physical, chemical and biological attributes. For instance, in Bangladesh the area under pulses is only 2.8% of the total cropped area which is dominated by rice [5]. Within pulses, compared to all other UFs, lentil covers the highest area (40.17%) whereas mungbean has 6.34%. Although a small acreage, mungbean production has begun to expand (54–68 thousand acres from 2008 to 2011) with average yields of 279 kg $acre^{-1}$[6]. The brief growth period, resistance to high temperature (30–35°C of the optima, >40°C of tolerant), drought tolerance and possibility of summer cultivation make it potential into pulse production in Bangladesh [7,8,9]. But yields are still low (farmers' field yield <1 t ha^{-1}) compared to potential yields of 2–4 t ha^{-1} [10], which makes it less competitive. Increasing productivity of mungbean is attributed to the high- yielding varieties, improved nutrient management and bring in of modern cultivation practices including summer sowing adopted. Although pulses trap atmospheric N2, application of nitrogen (N), especially at flowering, can improve growth and yield. Nitrogen starvation restricts plant growth, branching and pod length and node number. Hormones such as gibberellic acid (GA3) are also beneficial in the development of crops [11,12]. As a natural plant hormone, GA_3 can also stimulate seed cytokonsis, cell division of apple fruit and nitrogen utilization, the synthesis of photosynthetic pigments increasing leaf size and so on [13,14,15]. Exogenous application of this substance at optimal concentrations and growth stages can help the crops to enhance physiological state and crop productivity. Considering current agricultural policy and in order to meet the requirement on yield increase, early maturity, and seed quality, this study was conducted through an experimental trial to investigate the effects of GA_3 (different concentrations) combined with nitrogen application treatments (plants) on growth characters, yield components and quality of mungbean at different levels:

- To assess the impact of exogenous application of gibberellic acid (GA_3) on growth parameters, yield attributes, yield and protein content in mungbean.
- To assess the impact of exogenously applied nitrogen on growth parameters, yield attributes, yield and protein contents in mungbean.
- To study the interactive effect of GA_3 and nitrogen on growth, yield and production parameters in mungbean.

Materials and Methods

The current chapter describes the materials and methods used for the development of the experiment. The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka from March to June 2025. The experimental farm is situated geographically at 23°46′ N latitude and 90°22′ E longitude with an elevation of 8.24 m above the sea level [16]. The study area has a subtropical climate with most of the rainfall falling during March to September, but limited rain in all other months [17]. The soil of the experimental field was silty clay loam in texture and classified as Madhupur Tract series. The region is situated in XII Madhupur Tract (AEZ No. 28), the soil pH of which varies from 5.8 to 6.5 [18]. The analytical values of experimental field soil samples were determined at the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka. The mungbean genotypes were 'BARI Mung-6' which is high yielding variety used in the experiment. The Seeds were obtained from Pulse Research Centre of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. BARI Mung-6, a high yielding mungbean variety developed by the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur was released in 2003. The variety is photo-insensitive and has a short growth period of 55–58 days. It has large seeds and matures almost all at once. BARI Mung-6: BARI Mung-6 was bred from the NM-92 line and released by AVRDC in 1992. Yield potential for this cultivar is 1.5 to 2.0 t ha^{-1}. Further more it is resistant to yellow mosaic virus and tolerant to all the important insect-pests [19].

The experiment was laid out with two treatment factors, as detailed below:

Factor A: Three levels of GA_3 (Gibberellic acid)

G_0 = 0 ppm GA_3
G_1 = 50 ppm GA_3
G_2 = 100 ppm GA_3

Factor B: Four levels of Nitrogen

N_0 = Control (no urea)
N_1 = 22 kg urea ha^{-1} (10.12 kg N ha^{-1})

N_2 = 44 kg urea ha^{-1} (20.24 kg N ha^{-1})

N_3 = 66 kg urea ha^{-1} (30.36 kg N ha^{-1})

There were altogether 12 treatment combinations used in each block which were as follows:
G_0N_0, G_0N_1, G_0N_2, G_0N_3, G_1N_0, G_1N_1, G_1N_2, G_1N_3, G_2N_0, G_2N_1, G_2N_2, G_2N_3.

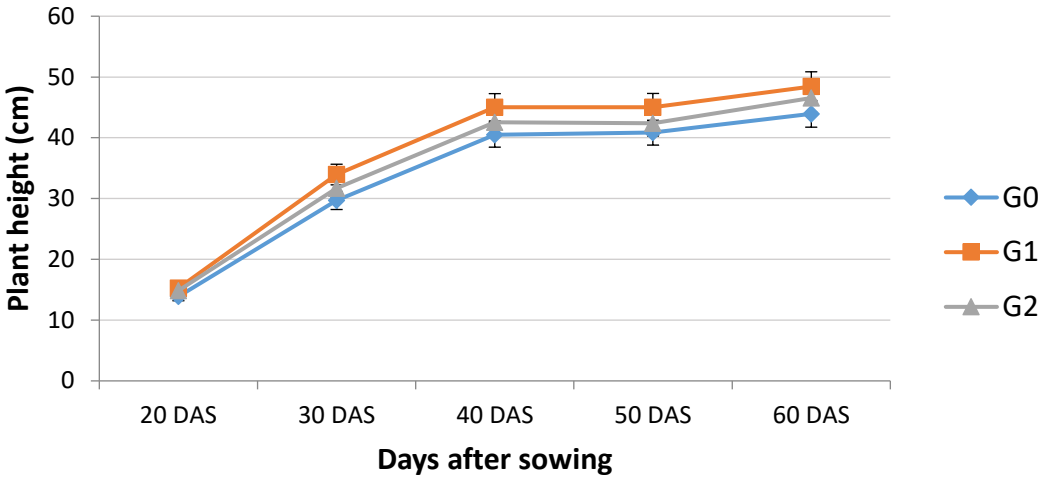
The experiment was designed as Randomized Complete Block Design (RCBD) with two factors and three replications making a total area of 19.5 m × 10 m which was divided in to three blocks having 12 plots (2 m ×1m) in each block for planting. Experiments were conducted at spacing between plots of 0.5 m and blocks as well as plots spaced one meter apart during the crop production season of March-early 2025, soils for which experimentation had been done. laddering and spading weed free residue free land. Fertilizers such as urea (50 kg ha^{-1} in three splits), Triple Super Phosphate (80 kg ha^{-1}) and Muriate of Potash (35 kg ha^{-1}) applied and mixed with the soil before final leveling. 50 and 100 ppm GA_3 solutions made from a stock of 1000 ppm were sprayed at 24 and 39 DAS. The Bavistin treated seeds were sown on 16th March, 2016 at spacing of 30 cm ×10 cm and depth of 2-3 cm. Thinning and weeding were carried out at 20 DAS and another thinning was done at 35 DAS. Irrigation was performed at 15 and 30 DAS, with Dimecron 50 EC (1 L ha^{-1}) for pest control. The pods were harvested at the state when about 90% of them changed brown to black. The plant height, branches, leaves and flowers were all recorded at 10-day intervals based on 10 sampled plants per plot. Number of pods per plant, pod length, number of seeds per pod, 1000-seed weight and nodules per plant were recorded at maturity. Dry matter was estimated by oven-drying plant samples at 80.2°C for 48h. The chlorophyll content of ten tagged plants was measured using a SPAD meter at 60 DAS. Seeds and stover were weighed in a 1 m^2 central mass and reported as t ha^{-1}. Nitrogen was analysed by the semi-micro Kjeldahl method, and N content was multiplied by 6.25 to obtain protein content. The data was statistically analyzed by MSTAT-C software and the treatment means were compared through ANOVA followed by LSD test at 0.05 level of significance [20,21].

Results and Discussion

The purpose of the present investigation is to assess the impact of GA_3 and nitrogen on growth, yield, and protein content in mungbean. Information on several growing and yield-related traits has been obtained and analysed. ANOVA for variation between growth and yield characters. The results have been thoughtfully formulated and discussed according to tables, graphs and are depicted with suitable interpretations as indicated below.

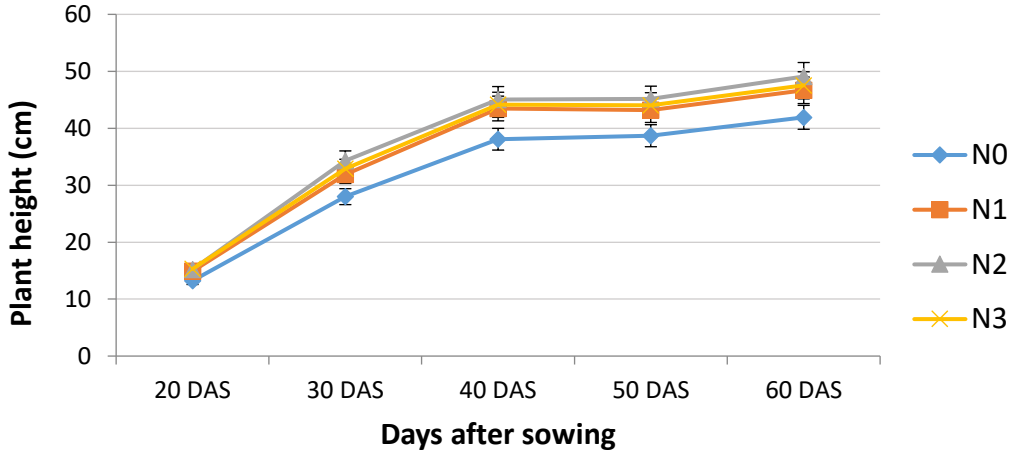
Plant height

BARI Mung-6: At 20 DAS, application of GA_3 (at 30, 40, 50 and 60 DAS) significantly affected the plant height of BARI Mung-6; at rest period no significant difference was observed. The maximum plant height (15.26, 33.95, 45.01, 45.04 and 48.43 cm) was observed in G_{x1} treatment (50 ppm GA_3) at 20,30,40,50 and 60 DAS., respectively. On the other hand, the lowest values of plant height at all growth stages (13.88, 29.68, 40.48, 40.84 and 43.94 cm) were recorded in G_0 (control) (Figure 1). The results are similar to those of studies by Azadi et al. (2013) and Mainul et al. (2014) [22,23]. Nitrogen application : For Nitrogen levels, variations among different plant heights were significant at 30, 40, 50 and 60 DAS but non-significant at 20 DAS. The greatest plant height at 20, 30, 40, 50 and 60 DAS (15.21; 34.30; 45.07; 45.14 e 48.09 cm) was reflected in N_2 soil treatment (44 kg ha^{-1} de urea). On the other hand, the lowest plant heights (13.23, 27.99, 38.08, 38.69 and 41.92 cm) were obtained from N_0 (untreated) treatment (Figure 2). The interaction of GA_3 and nitrogen had a significant effect on the plant height at 30, 40, 50 and 60 DAS whereas it was not effective at 20 DAS. Maximum plant height at 20, 30, 40, 50 and 60 DAS (16.74,38.17 ,48.25,49.02 and52.80 cm) was recorded with the treatment combination G_1N_2(50 ppm GA_3 +44kg urea ha^{-1}). Whereas the lowest plant height at these stages (12.96, 27.08, 37.11, 38.42 and 41.27 cm) was observed under control treatment combination G_0N_0.



G_0: 0 ppm GA_3, G_1: 50 ppm GA_3, G_2: 100 ppm GA_3

Figure 1. Effect of GA_3 on plant height of mungbean at different days after sowing (DAS)



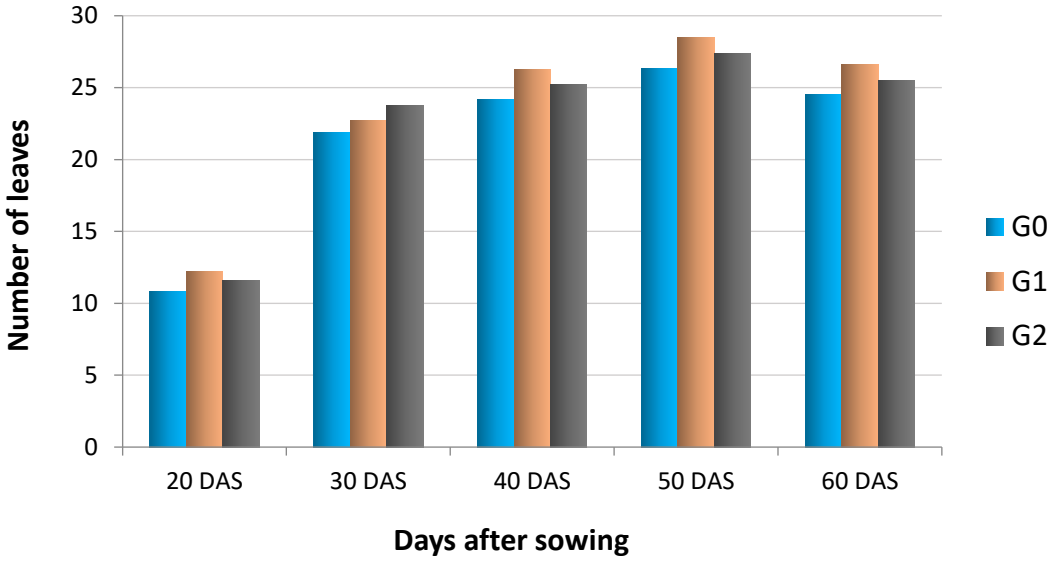
N_0: Control, N_1: 22 kg urea ha^{-1}, N_2: 44 kg urea ha^{-1}, N_3: 66 kg urea ha^{-1}

Figure 2. Effect of nitrogen on plant height of mungbean at different days after sowing (DAS)

Number of leaves

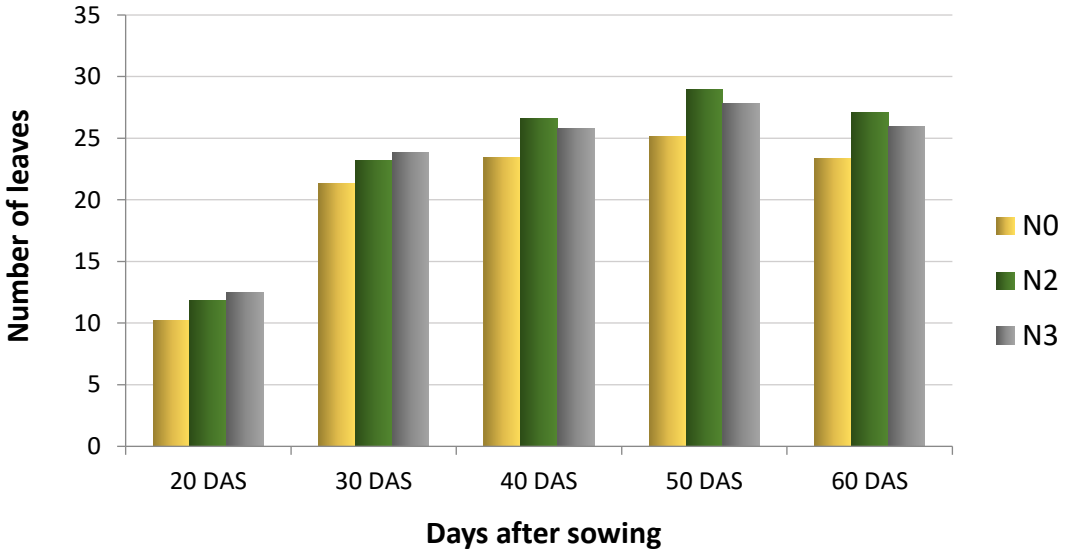
The number of leaves per plant differed significantly at 30, 40, 50, and 60 DAS because of GA_3 application but not at 20 DAS. Thirty days after sowing (DAS), the maximum number of leaves per plant (23.77) was recorded from G_2 treatment (100 ppm GA_3). Plants treated at 20, 40, 50 and 60 DAS also produced the highest peak number of leaves per plant under the G_1 treatment (50 ppm GA_3), which totaled on average with maximum of 12.20; and plants for number ±4 leaves abundance per plant was maxima among treatments they were found in control organically beside about to weight productive parts (leaf weigh). In contrast, the minimum values of leaves per plant at all growth stages (10.85, 21.86, 24.20, 26.33 and 24.50 at 20, 30,40 DAS respectively) were recorded in G_0 (control) treatment (Figure 3). These data are consistent with those of Mainul *et al.* (2014) [23]. The number of leaves per plant at 30, 40, 50 and 60 DAS differed significantly due to the N application; however, no significant effect was observed in the number of leaves per plant at 20 DAS. The greatest number of leaves per plant at 20 and 30 DAS (12.48 and 23.83, respectively) was noted in the N_3 treatment (66 kg urea ha^{-1}). At 40, 50 and 60 DAS the maximum number of leaves per plant (26.60, 28) and (27.11 respectively) was found in N_2 treatment (44 kg urea ha^{-1}). On the contrary, the lowest number of leaves per plant was observed in all observation times (10.21, 21.36, 23.40, 25.18 and 23.37 at 20, 30, 40, 50 and DAS-60 respectively) under applying N_0 (control) treatment (Figure 4). Mean interaction effect of GA_3 with nitrogen application was significant for number of leaves per plant at 30,40,50 and 60 DAS except on 20 DAS. At 20 and 30 DAS, the maximum leaves per plant (13.74 and 25.84) was recorded in G_1N_3 treatment combination (50 ppm GA_3 + 66 kg urea ha^{-1}). However, at 40; 50 and 60 DAS the highest number of leaves $plant^{-1}$ (28.77; 31.06 and 29.12 respectively) was observed in G_1N_2

(50 ppm GA_3 + urea-44 kg ha^{-1} combination treatmant). In contrast, the minimum number of leaves per plant at all the stages of observation (9.79, 21.51, 23.00, 24.49 and 22.96 at 20, 30, 40, 50 and 60 DAS respectively) were noted for G_0N_0 (control) treatment combination.



G_0: 0 ppm GA_3, G_1: 50 ppm GA_3, G_2: 100 ppm GA_3

Figure 3. Effect of GA_3 on number of leaves per plant of mungbean at different days after sowing (DAS)



N_0: Control, N_1: 22 kg urea ha^{-1}, N_2: 44 kg urea ha^{-1}, N_3: 66 kg urea ha^{-1}

Figure 4. Effect of nitrogen on number of leaves per plant of mungbean at different days after sowing (DAS)

Number of branches

The number of branches per plant varied significantly in response to GA_3 application. The highest number of branches per plant (2.75) was recorded in the G_2 treatment (100 ppm GA_3), which was statistically similar to the G_1 treatment (50 ppm GA_3) that produced 2.70 branches per plant. In contrast, the lowest number of branches per plant (2.31) was observed under the G_0 (control) treatment (Table 1). These findings are consistent with the results reported by Mainul *et al*. (2014) [23]. Within each column, treatment means sharing the same letter(s) did not differ significantly as determined by the LSD test at the 5% level of significance. The treatment codes were as follows: G_0 = 0 ppm GA_3, G_1 = 50 ppm GA_3, G_2 = 100 ppm GA_3; N_0 = control (no urea), N_1 = 22 kg urea ha^{-1}, N_2

= 44 kg urea ha^{-1}, and N_3 = 66 kg urea ha^{-1}. With respect to nitrogen application, a significant variation in the number of branches per plant was observed. The highest number of branches per plant (2.81) was recorded in the N_2 treatment (44 kg urea ha^{-1}), which was statistically similar to the N_1 and N_3 treatments. In contrast, the lowest number of branches per plant (2.11) was obtained from the N_0 (control) treatment (Table 2). A significant interaction effect between GA_3 and nitrogen application on the number of branches per plant was also evident. The maximum number of branches per plant (3.02) was recorded under the G_1N_2 treatment combination (50 ppm GA_3 + 44 kg urea ha^{-1}), which was statistically comparable to the G_1N_3 treatment combination. Conversely, the minimum number of branches per plant (1.88) was observed in the G_0N_0 (control) treatment combination.

Number of inflorescence

A significant variation in the number of inflorescences per plant was observed in response to GA_3 application. The highest number of inflorescences per plant (8.63) was recorded under the G_1 treatment (50 ppm GA_3), followed by the G_2 treatment (100 ppm GA_3) with 7.75 inflorescences per plant. In contrast, the lowest number of inflorescences per plant (7.02) was obtained from the G_0 (control) treatment (Table 1). With respect to nitrogen application, a significant difference in the number of inflorescences per plant was also evident. The maximum number of inflorescences per plant (8.48) was recorded in the N_2 treatment (44 kg urea ha^{-1}), followed by the N_3 treatment (66 kg urea ha^{-1}) with 8.19 inflorescences per plant. Conversely, the minimum number of inflorescences per plant (6.62) was observed under the N_0 (control) treatment (Table 2). The interaction effect between GA_3 and nitrogen application exerted a significant influence on the number of inflorescences per plant. The highest number of inflorescences per plant (9.59) was obtained from the G_1N_2 treatment combination (50 ppm GA_3 + 44 kg urea ha^{-1}). In contrast, the lowest number of inflorescences per plant (6.09) was recorded in the G_0N_0 (control) treatment combination (Table 3).

Number of flowers

The number of flowers per inflorescence varied significantly in response to GA_3 application. The highest number of flowers per inflorescence (9.02) was recorded under the G_1 treatment (50 ppm GA_3), followed by the G_2 treatment (100 ppm GA_3) with 7.44 flowers per inflorescence. In contrast, the lowest number of flowers per inflorescence (5.85) was observed in the G_0 (control) treatment (Table 1). With respect to nitrogen application, a significant variation in the number of flowers per inflorescence was observed. The highest number of flowers per inflorescence (9.19) was recorded in the N_2 treatment (44 kg urea ha^{-1}), followed by the N_3 treatment (66 kg urea ha^{-1}) with 7.85 flowers, which was statistically similar to the N_1 treatment (22 kg urea ha^{-1}). In contrast, the lowest number of flowers per inflorescence (5.19) was observed in the N_0 (control) treatment (Table 2). The interaction effect between GA_3 and nitrogen application also showed a significant influence on this parameter (Appendix V). The maximum number of flowers per inflorescence (11.52) was recorded in the G_1N_2 treatment combination (50 ppm GA_3 + 44 kg urea ha^{-1}), whereas the minimum (4.52) was observed in the G_0N_0 (control) treatment combination (Table 3).

Table 1. Effect of GA_3 on number of branches plant^{-1}, number of inflorescence plant^{-1} and number of flowers inflorescence^{-1} of mungbean

Treatment	Number of branches plant^{-1}	Number of inflorescence plant^{-1}	Number of flowers inflorescence^{-1}
G_0	2.31 b	7.02 c	5.85 c
G_1	2.70 a	8.63 a	9.02 a
G_2	2.75 a	7.75 b	7.44 b
LSD $_{(0.05)}$	0.20	0.22	0.59
CV %	9.54	6.44	9.43

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.
G_0:0 ppm GA_3, G_1:50 ppm GA_3, G_2:100 ppm GA_3

Table 2. Effect of nitrogen on number of branches plant^{-1}, number of inflorescence plant^{-1} and number of flowers inflorescence^{-1} of mungbean

Treatment	Number of branches plant^{-1}	Number of inflorescence plant^{-1}	Number of flowers inflorescence^{-1}
N_0	2.11 b	6.62 d	5.19 c
N_1	2.67 a	7.91 c	7.52 b
N_2	2.81 a	8.48 a	9.19 a

N_3	2.68 a	8.19 b	7.85 b
LSD $_{(0.05)}$	0.23	0.26	0.68
CV %	9.54	6.44	9.43

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance. N_0:Control (no urea), N_1:22 kg urea ha^{-1}, N_2 44 kg urea ha^{-1}, N_3:66 kg urea ha^{-1}

Table 3. Combined effect of GA_3 and nitrogen on number of branches plant^{-1}, number of inflorescence plant^{-1} and number of flowers inflorescence^{-1} of mungbean

Treatment	Number of branches plant^{-1}	Number of inflorescence plant^{-1}	Number of flowers inflorescence^{-1}
G_0N_0	1.88 f	6.09 h	4.52 f
G_0N_1	2.38 cde	7.09fg	5.85 de
G_0N_2	2.63 a-d	7.56 e	6.85 cd
G_0N_3	2.363 de	7.36 ef	6.19 de
G_1N_0	2.01 ef	6.82 g	5.52 ef
G_1N_1	2.81ab	8.96 b	9.19 b
G_1N_2	3.02 a	9.59 a	11.52 a
G_1N_3	2.99 a	9.16 ab	9.85 b
G_2N_0	2.45bcd	6.96fg	5.52ef
G_2N_1	2.83 ab	7.69 de	7.52 c
G_2N_2	2.78 abc	8.29 c	9.19 b
G_2N_3	2.70 a-d	8.06 cd	7.52 c
LSD $_{(0.05)}$	0.41	0.45	1.18
CV %	9.54	6.44	9.43

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance. G_0:0 ppm GA_3, G_1:50 ppm GA_3, G_2:100 ppm GA_3, N_0:Control (no urea), N_1:22 kg urea ha^{-1}, N_2:44 kg urea ha^{-1}, N_3:66 kg urea ha^{-1}

Number of pods

The number of pods per plant varied significantly in response to GA_3 application. The highest number of pods per plant (107.52) was recorded in the G_1 treatment (50 ppm GA_3), followed by the G_2 treatment (100 ppm GA_3) with 93.27 pods per plant. In contrast, the lowest number of pods per plant (77.02) was observed in the G_0 (control) treatment (Table 4). These results are in agreement with the findings of Hossen *et al*. (2015) [24]. With respect to nitrogen application, a significant effect on the number of pods per plant was also observed. The maximum number of pods per plant (108.94) was recorded in the N_2 treatment (44 kg urea ha^{-1}), which was statistically similar to the N_3 treatment (66 kg urea ha^{-1}), followed by the N_1 treatment (22 kg urea ha^{-1}) with 92.38 pods per plant. The minimum number of pods per plant (65.49) was observed in the N_0 (control) treatment (Table 5). The interaction effect of GA_3 and nitrogen application significantly influenced the number of pods per plant . The highest pod number (132.27) was obtained in the G_1N_2 treatment combination (50 ppm GA_3 + 44 kg urea ha^{-1}), which was statistically similar to the G_1N_3 treatment combination. In contrast, the lowest number of pods per plant (56.27) was recorded in the G_0N_0 (control) treatment combination (Table 6).

Number of seeds

The number of seeds per pod varied significantly in response to GA_3 application. The highest number of seeds per pod (9.97) was recorded in the G_1 treatment (50 ppm GA_3), followed by the G_2 treatment (100 ppm GA_3) with 9.42 seeds per pod. In contrast, the lowest number of seeds per pod (9.07) was observed in the G_0 (control) treatment (Table 4). These findings are consistent with the results reported by Hossen *et al*. (2015) and Mainul *et al*. (2014) [23,24]. Significant variation in the number of seeds per pod was also observed due to nitrogen application. The maximum number of seeds per pod (10.14) was obtained in the N_2 treatment (44 kg urea ha^{-1}), followed by the N_3 treatment (66 kg urea ha^{-1}) with 9.75 seeds, which was statistically similar to the N_1 treatment (22 kg urea ha^{-1}). Conversely, the minimum number of seeds per pod (8.50) was recorded in the N_0 (control)

treatment (Table 5). The interaction effect of GA_3 and nitrogen application significantly influenced the number of seeds per pod. The highest number of seeds per pod (11.30) was obtained from the G_1N_2 treatment combination (50 ppm GA_3 + 44 kg urea ha^{-1}), whereas the lowest number (8.27) was recorded in the G_0N_0 (control) treatment combination (Table 6).

Pod length

Pod length varied significantly in response to GA_3 application. The longest pods (8.24 cm) were recorded in the G_2 treatment (100 ppm GA_3), followed by the G_1 treatment (50 ppm GA_3) with 8.09 cm. In contrast, the shortest pods (7.87 cm) were observed in the G_0 (control) treatment (Table 4). These results are consistent with the findings of Hossen *et al*. (2015) and Mainul *et al*. (2014) [23,24]. Significant differences in pod length were also observed due to nitrogen application. The maximum pod length (8.33 cm) was obtained in the N_3 treatment (66 kg urea ha^{-1}), followed by the N_2 treatment (44 kg urea ha^{-1}) with 8.21 cm, which was statistically similar to the N_1 treatment (22 kg urea ha^{-1}). The shortest pod length (7.58 cm) was recorded in the N_0 (control) treatment (Table 5). The interaction effect of GA_3 and nitrogen application significantly influenced pod length . The longest pods (8.58 cm) were recorded in the G_2N_3 treatment combination (100 ppm GA_3 + 66 kg urea ha^{-1}), whereas the shortest pods (7.48 cm) were observed in the G_0N_0 (control) treatment combination (Table 6).

Table 4. Effect of GA_3 on number pods $plant^{-1}$, number of seeds pod^{-1} and pod length of mungbean

Treatment	Number pods $plant^{-1}$	Number of seeds pod^{-1}	Pod length (cm)
G_0	77.02 c	9.07 c	7.87 c
G_1	107.52 a	9.97 a	8.09 b
G_2	93.27 b	9.42 b	8.24 a
LSD $_{(0.05)}$	7.38	0.25	0.08
CV %	9.42	6.23	7.20

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.
G_0:0 ppm GA_3, G_1:50 ppm GA_3, G_2:100 ppm GA_3

Table 5. Effect of nitrogen on number pods $plant^{-1}$, number of seeds pod^{-1} and pod length of mungbean

Treatment	Number pods $plant^{-1}$	Number of seeds pod^{-1}	Pod length (cm)
N_0	65.49 c	8.50 c	7.58 c
N_1	92.38 b	9.54 b	8.14 b
N_2	108.94 a	10.14 a	8.21 b
N_3	103.60 a	9.75 b	8.33 a
LSD $_{(0.05)}$	8.53	0.29	0.09
CV %	9.42	6.23	7.20

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.
N_0:Control (no urea), N_1:22 kg urea ha^{-1}, N_2:44 kg urea ha^{-1}, N_3:66 kg urea ha^{-1}

Table 6. Combined effect of GA_3 and nitrogen on number pods $plant^{-1}$, number of seeds pod^{-1} and pod length of mungbean

Treatment	Number pods $plant^{-1}$	Number of seeds pod^{-1}	Pod length (cm)
G_0N_0	56.27 g	8.27 g	7.48 h
G_0N_1	75.60ef	9.23 de	7.87 f
G_0N_2	90.60 cd	9.43 cd	8.16 de
G_0N_3	85.60 de	9.33 de	7.99ef
G_1N_0	66.60fg	8.40fg	7.60gh
G_1N_1	107.60 b	9.90bc	8.38bc
G_1N_2	132.27 a	11.30 a	8.23 cd
G_1N_3	123.60 a	10.30 b	8.42 ab
G_2N_0	73.60ef	8.83ef	7.67 g
G_2N_1	93.94 bcd	9.50 cd	8.18 d

G_2N_2	103.94 bc	9.70 cd	8.27bcd
G_2N_3	101.60bc	9.63 cd	8.58 a
LSD $_{(0.05)}$	14.77	0.51	0.16
CV %	9.42	6.23	7.20

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance. G_0:0 ppm GA_3, G_1:50 ppm GA_3, G_2:100 ppm GA_3, N_0:Control (no urea), N_1:22 kg urea ha^{-1}, N_2:44 kg urea ha^{-1}, N_3:66 kg urea ha^{-1}

1000-seed weight

GA_3 application significantly influenced 1000-seed weight. The highest weight (47.04 g) was recorded in G_2 (100 ppm GA_3), statistically similar to G_1, while the lowest (45.37 g) was observed in G_0 (control) (Table 7), consistent with Hossen *et al*. (2015) and Mainul *et al*. (2014) [23,24]. Nitrogen application also showed a significant effect. The maximum 1000-seed weight (47.22 g) was obtained in N_2 (44 kg urea ha^{-1}), statistically similar to N_3, whereas the minimum (44.34 g) occurred in N_0, similar to N_1 (Table 8). The interaction of GA_3 and nitrogen significantly affected 1000-seed weight. The highest weight (47.92 g) was recorded in G_1N_2 (50 ppm GA_3 + 44 kg urea ha^{-1}), statistically comparable to several other combinations, while the lowest (43.25 g) was observed in G_0N_0 (control) (Table 9).

Number of nodule

GA_3 application significantly influenced the number of nodules per plant. The highest number (6.17) was recorded in G_2 (100 ppm GA_3), followed by G_1 (5.67), while the lowest (5.17) occurred in G_0 (control) (Table 7), in agreement with Amin *et al*. (2015) [25]. Nitrogen application also had a significant effect. The maximum number of nodules per plant (6.22) was observed in N_2 (44 kg urea ha^{-1}), statistically similar to N_1 and N_3, whereas the minimum (4.89) was found in N_0 (control) (Table 8). The interaction of GA_3 and nitrogen significantly affected nodule number. The highest number (6.67) was recorded in G_1N_2 (50 ppm GA_3 + 44 kg urea ha^{-1}), comparable to G_1N_1 and G_1N_3, while the lowest (4.67) occurred in G_0N_0 (control) (Table 9).

Dry matter content of plant

Dry matter content (%) of the plants varied significantly with GA_3 application. The highest dry matter content (11.90%) was recorded in G_0 (0 ppm GA_3), followed by G_2 (10.51%), while the lowest (9.31%) occurred in G_1 (control) (Table 7), consistent with Razzaque *et al*. (2017) [26]. Nitrogen application also showed a significant effect. The maximum dry matter content (12.24%) was observed in N_3 (66 kg urea ha^{-1}), followed by N_2 (10.91%), statistically similar to N_1, whereas the minimum (8.61%) was recorded in N_0 (control) (Table 8). The interaction between GA_3 and nitrogen significantly influenced plant dry matter. The highest content (14.94%) was obtained in G_0N_3 (0 ppm GA_3 + 66 kg urea ha^{-1}), while the lowest (8.17%) occurred in G_0N_0 (control) (Table 9).

Chlorophyll content

Chlorophyll content varied significantly in response to GA_3 application. The highest chlorophyll content (52.75%) was recorded in G_1 (50 ppm GA_3), followed by G_2 (51.57%), while the lowest (48.73%) occurred in G_0 (control) (Table 7). Nitrogen application also showed a significant effect. The maximum chlorophyll content (53.47%) was obtained in N_3 (66 kg urea ha^{-1}), followed by N_2 (52.32%), whereas the minimum (46.74%) was recorded in N_0 (control) (Table 8). The interaction of GA_3 and nitrogen significantly influenced chlorophyll content. The highest value (56.13%) was observed in G_1N_3 (50 ppm GA_3 + 66 kg urea ha^{-1}), while the lowest (44.46%) was recorded in G_0N_0 (control) (Table 9).

Table 7. Effect of GA_3 on 1000-seed weight, number of nodule $plant^{-1}$, dry matter content of plant and chlorophyll content of mungbean

Treatment	1000-seed weight (g)	Number of nodule $plant^{-1}$	Dry matter content of plant (%)	Chlorophyll content (%)
G_0	45.37 b	5.17 c	11.90 a	48.73 c
G_1	46.66 a	5.67 b	9.31 c	52.75 a
G_2	47.04 a	6.17 a	10.51 b	51.57 b
LSD $_{(0.05)}$	0.94	0.41	0.41	0.61
CV %	7.41	8.68	4.60	9.41

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance. G_0:0 ppm GA_3, G_1:50 ppm GA_3, G_2:100 ppm GA_3

Table 8. Effect of nitrogen on 1000-seed weight, number of nodule plant^{-1}, dry matter content of plant and chlorophyll content of mungbean

Treatment	1000-seed weight (g)	Number of nodule plant^{-1}	Dry matter content of plant (%)	Chlorophyll content (%)
N_0	44.34 b	4.89 b	8.61 c	46.74 d
N_1	45.87 b	5.78 a	10.54 b	51.53 c
N_2	47.22 a	6.22 a	10.91 b	52.32 b
N_3	47.00 a	5.78 a	12.24 a	53.47 a
LSD $_{(0.05)}$	1.09	0.48	0.47	0.70
CV %	7.41	8.68	4.60	9.41

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance. N_0:Control (no urea), N_1:22 kg urea ha^{-1}, N_2:44 kg urea ha^{-1}, N_3:66 kg urea ha^{-1}

Table 9. Combined effect of GA_3 and nitrogen on 1000-seed weight, number of nodule plant^{-1}, dry matter content of plant and chlorophyll content of mungbean

Treatment	1000-seed weight (g)	Number of nodule plant^{-1}	Dry matter content of plant (%)	Chlorophyll content (%)
G_0N_0	43.25 c	4.67 d	8.17 g	44.46 i
G_0N_1	45.80 b	5.00 cd	9.34 f	49.14 fg
G_0N_2	46.29 ab	5.67 bc	10.30 e	51.27 e
G_0N_3	46.17 ab	5.33 cd	14.94 a	50.05 f
G_1N_0	43.81 c	4.67 d	8.71fg	46.99 h
G_1N_1	47.49 ab	6.67 a	11.84bc	53.63bc
G_1N_2	47.92 a	6.67 a	11.49 bc	54.24 b
G_1N_3	47.42 ab	6.67 a	12.13 b	56.13 a
G_2N_0	45.96 b	5.33 cd	8.95fg	48.76 g
G_2N_1	47.33ab	5.67 bc	10.44 de	51.83 de
G_2N_2	47.45 ab	6.33ab	9.42 f	53.01 cd
G_2N_3	47.41 ab	5.33 cd	11.18 cd	52.69 cd
LSD $_{(0.05)}$	1.89	0.83	0.82	1.22
CV %	7.41	8.68	4.60	9.41

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance. G_0:0 ppm GA_3, G_1:50 ppm GA_3, G_2:100 ppm GA_3, N_0:Control (no urea), N_1:22 kg urea ha^{-1}, N_2:44 kg urea ha^{-1}, N_3:66 kg urea ha^{-1}

Seed yield

GA_3 application significantly influenced seed yield (t ha^{-1}). The highest yield (2.16 t ha^{-1}) was recorded in G_1 (50 ppm GA_3), followed by G_2 (2.02 t ha^{-1}), while the lowest (1.92 t ha^{-1}) occurred in G_0 (control) (Table 10), consistent with Hossain *et al*. (2014) [27]. Nitrogen application also showed a significant effect on seed yield. The maximum yield (2.16 t ha^{-1}) was obtained in N_2 (44 kg urea ha^{-1}), followed by N_3 (2.08 t ha^{-1}), whereas the minimum (1.86 t ha^{-1}) was recorded in N_0 (control) (Table 11). The interaction of GA_3 and nitrogen significantly affected seed yield. The highest yield (2.38 t ha^{-1}) was observed in G_1N_2 (50 ppm GA_3 + 44 kg urea ha^{-1}), while the lowest (1.83 t ha^{-1}) occurred in G_0N_0 (control) (Table 12).

Stover yield

Stover yield varied significantly in response to GA_3 application. The highest stover yield (1.05 t ha^{-1}) was recorded in G_1 (50 ppm GA_3), followed by G_2 (0.94 t ha^{-1}), while the lowest (0.85 t ha^{-1}) occurred in G_0 (control) (Table

10), consistent with Hossain *et al*. (2014) [27]. Nitrogen application also showed a significant effect. The maximum stover yield (1.08 t ha^{-1}) was obtained in N_2 (44 kg urea ha^{-1}), followed by N_3 (0.97 t ha^{-1}), statistically similar to N_1, whereas the minimum (0.78 t ha^{-1}) was recorded in N_0 (control) (Table 11). The interaction of GA_3 and nitrogen significantly influenced stover yield. The highest yield (1.28 t ha^{-1}) was observed in G_1N_2 (50 ppm GA_3 + 44 kg urea ha^{-1}), while the lowest (0.71 t ha^{-1}) occurred in G_0N_0 (control) (Table 12).

Nitrogen content

Nitrogen content (%) varied significantly with GA_3 application. The highest nitrogen content (4.11%) was recorded in G_1 (50 ppm GA_3), while the lowest (4.04%) occurred in G_0 (control), statistically similar to G_2 (Table 10), in agreement with Kumar and Tomar (2013) [28]. Nitrogen application also showed a significant effect. The maximum nitrogen content (4.16%) was observed in N_2 (44 kg urea ha^{-1}), whereas the minimum (4.01%) occurred in N_0 (control) (Table 11). The interaction of GA_3 and nitrogen significantly influenced nitrogen content. The highest value (4.20%) was obtained in G_1N_2 (50 ppm GA_3 + 44 kg urea ha^{-1}), while the lowest (3.90%) was recorded in G_0N_0 (control) (Table 12).

Protein content

Protein content (%) varied significantly with GA_3 application. The highest protein content (25.72%) was recorded in G_1 (50 ppm GA_3), while the lowest (25.26%) occurred in G_0 (control) (Table 10), consistent with the findings of Kumar and Tomar (2013) [28]. Protein content (%) varied significantly with nitrogen application. The highest protein content (26.00%) was observed in N_2 (44 kg urea ha^{-1}), whereas the lowest (25.06%) occurred in N_0 (control) (Table 11), consistent with Azadi *et al*. (2013) [22]. The interaction of GA_3 and nitrogen also significantly affected protein content. The maximum value (26.25%) was recorded in G_1N_2 (50 ppm GA_3 + 44 kg urea ha^{-1}), while the minimum (24.37%) occurred in G_0N_0 (control) (Table 12).

Table 10. Effect of GA_3 on seed yield, stover yield, nitrogen content and protein content of mungbean

Treatment	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Nitrogen content (%)	Protein content (%)
G_0	1.92 c	0.85 c	4.04 b	25.26 c
G_1	2.16 a	1.05 a	4.11 a	25.72 a
G_2	2.02 b	0.94 b	4.06 b	25.37 b
LSD $_{(0.05)}$	0.011	0.031	0.001	0.009
CV %	10.31	7.03	7.23	6.25

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.
G_0:0 ppm GA_3, G_1:50 ppm GA_3, G_2:100 ppm GA_3

Table 11. Effect of nitrogen on seed yield, stover yield, nitrogen contentand protein content of mungbean

Treatment	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Nitrogen content (%)	Protein content (%)
N_0	1.86 d	0.78 c	4.01 c	25.06 c
N_1	2.04 c	0.96 b	4.06 b	25.37 b
N_2	2.16 a	1.08 a	4.16 a	26.00 a
N_3	2.08 b	0.97 b	4.06 b	25.37 b
LSD $_{(0.05)}$	0.013	0.023	0.002	0.011
CV %	10.31	7.03	7.23	6.25

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.
N_0:Control (no urea), N_1:22 kg urea ha^{-1}, N_2:44 kg urea ha^{-1}, N_3:66 kg urea ha^{-1}

Table 12. Combined effect of GA_3 and nitrogen on seed yield, stover yield, nitrogen content and protein content of mungbean

Treatment	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Nitrogen content (%)	Protein content (%)
G_0N_0	1.83 j	0.71 h	3.90 f	24.37 j
G_0N_1	1.93 h	0.88 f	4.00 e	25.00 i

G_0N_2	1.97 g	0.94 e	4.13 bc	25.81 d
G_0N_3	1.97 g	0.89 f	4.02 e	25.12 h
G_1N_0	1.88 i	0.81 g	4.15 ab	26.00 c
G_1N_1	2.18 c	1.04 c	4.00 e	25.00 i
G_1N_2	2.38 a	1.28 a	4.20 a	26.25 a
G_1N_3	2.22 b	1.08 b	4.19 a	26.18 b
G_2N_0	1.89 i	0.82 g	4.09 cd	25.56 f
G_2N_1	2.03 f	0.97 d	4.05 de	25.31 g
G_2N_2	2.13 d	1.04 c	4.11 bc	25.68 e
G_2N_3	2.06 e	0.96 de	4.02 e	25.12 h
LSD $_{(0.05)}$	0.022	0.025	0.002	0.019
CV %	10.31	7.03	7.23	6.25

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance. G_0:0 ppm GA_3, G_1:50 ppm GA_3, G_2:100 ppm GA_3, N_0:Control (no urea), N_1:22 kg urea ha^{-1}, N_2:44 kg urea ha^{-1}, N_3:66 kg urea ha^{-1}

CONCLUSIONS

The present study revealed that the combined application of 50 ppm GA_3 and 44 kg urea ha^{-1} was the most effective for enhancing seed yield (2.38 t ha^{-1}), nitrogen content (4.20%), and protein content (26.25%) in mungbean. Further research is recommended with additional GA_3 and nitrogen treatments to identify optimal growth, yield, and protein content of mungbean across different regions of Bangladesh.

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