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Response of Different Bio-stimulants on Growth, Phenology, Soil and Yield Attributes of Summer Moongbean (*Vigna radiata*)

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ABSTRACT

The present field work was conducted to evaluate the effect of different bio-stimulants on the growth, soil and yield attributes of summer moongbean (*Vigna radiata*). The experiment was laid out in randomized block design with three replications at the farm of the Department of Agronomy, Lovely Professional University. A total of seven treatments were utilized with varying levels of RDF and bio-stimulants on moongbean growth, soil and yield attributes. With an increase in the concentration of bio-stimulants (humic, fulvic and tryptophan), the growth characteristics including plant height, plant population, fresh weight, dry weight, leaf area index, crop, relative growth rate and net assimilation rate were significantly improved. Among the various treatments T_5 (RDF+5 g/l FA) showed maximum plant height (49.61 cm), plant population (91.67), fresh weight (7.87 g), dry weight (2.17 g), leaf area index (84.72), crop growth rate (89.57), relative crop rate (178.62) and net assimilation rate (94.49). The phenological and plant attributes of moongbean were maximum at T_5 (RDF+5 g/l FA) followed by T_7 and T_4 treatments. Soil analysis of moongbean had significant impact of bio-stimulants on pH, EC, organic carbon, nitrogen, potassium and phosphorus elements. Furthermore, yield attributes improved with an increase in bio-stimulants (humic, fulvic and tryptophan) and treatment T_5 (RDF+5 g/l FA) had maximum number of pods/plant, pod length, pod dry weight, number of seeds/pod, 1000-seed weight, seed yield, biological yield and harvest index followed by T_7 (RDF+1 g/l tryptophan) and T_4 (RDF+2.5 g/l FA) treatments. Among the various treatments, the application of T_5 (RDF+5 g/l FA) had a significant impact on various growth, phenological, soil, plant and yield attributes. Fulvic acid and tryptophan significantly increased seed yield, biological yield and harvest index demonstrating its positive impact on the overall crop production of moongbean.

Key words: Bio-stimulants, fulvic acid, growth, humic acid, moongbean, plant, soil, yield attributes, sustainability

INTRODUCTION

Moongbean (*Vigna radiata*) belongs to the Leguminosae family and is the third most important pulse crop in India after pigeonpea and chickpea. Moongbean is also known as green gram, mung, or monggo (Mahajan *et al.*, 2023). Moongbean requires less time to mature, can be grown in the summer, winter, or rainy season (*kharif*), and works well with the nation's current cropping plan. Grown occasionally as a catch crop in between the *rabi* and *kharif* seasons, it exhibits a higher daily yield (Kaur and Sharma, 2017). One of the most significant vegetable crops grown in Egypt is moongbean. Dry bean production was 39665 metric tonnes on an area total of 39665 hectares under cultivation. With each harvested hectare of dry beans yielding up to 125 kg of protein, common beans are considered a nearly perfect food by nutritionists since they provide low-income customers with an inexpensive amount of micronutrients and 22-37% protein (Navya *et al.*, 2021; Mahajan *et al.*, 2023). Moogbean offers a fair number of vitamins and other important elements, as well as nutritional value and digestibility. Several factors have contributed to the decline in green gram output throughout time. When the first rains arrive, farmers typically begin planting without applying the recommended basal amount of nutrients (Mota *et al.*, 2021). It is necessary to check balanced nutrition given to the crop at the appropriate period because of this, which results in unrealized potential productivity. Furthermore, especially for short-duration crops like green gram, the amount of nutrients applied to the soil is sometimes insufficient to meet the crop need (Dineshkumar *et al.*, 2020). Fertilizer is one of the many inputs used in agriculture; to increase crop output while replenishing the nutrients that crops have taken from the soil. The fertilizer application technique is a non-financial input that affects yield by growing the crop. Foliar spraying concentrates on the above-ground areas, where nutrients are required and fast absorption is aided (Kumawat *et al.*, 2021; Mahajan *et al.,* 2023). Foliar fertilization may be a more effective method of making up for the decrease in root activity and nutrient uptake, particularly during the reproductive phases. This short-term strategy maintains crop productivity while having minimal negative effects on the environment and raises the quality of produce by immediately reaching the location of food synthesis (Bilal *et al.*, 2021). Foliar spraying is more cost-effective in terms of yielding larger financial returns than soil treatment since it requires fewer nutrients. It has been discovered that the overuse of mineral nitrogen fertilizers in intensive agricultural systems seriously affects soil fertility, human health, food security and air pollution (Yousefi *et al.,* 2020). Throughout the last 60 years, the use of nitrogen fertilizers has expanded seven-fold worldwide. By 2050, it is anticipated that the use of nitrogen fertilizer will have tripled. New strategies must be introduced to solve such issues (Kumawat *et al.,* 2021).

One such method is the use of plant bio-stimulants, which are often combinations of amino acids and peptides. Additionally, they are rich in bio-active compounds that can enhance a variety of physiological processes that promote plant development and boost nutrient utilization efficiency without negatively impacting crop productivity or the quality of the final product, all while lowering the need for chemical fertilizers. The effects of bio- stimulants, however, might vary from species to species and are highly dependent on the application time and dose as well as environmental conditions both before and after. Different bio-stimulants used for growth and development are humic, fulvic acid and tryptophan. Humic acid has a significant impact on plant root development (Paradikovic *et al.,* 2019). Humic acids given to the soil improved root initiation and boosted root development. Humic compounds' stimulatory effects have been linked to increased uptake of macronutrients. It is also considered a plant hormone like chemical that minimizes soil erosion and enhances soil water holding capacity, hence, improving crop drought tolerance (Bilal *et al.*, 2021). The second significant humus material is fulvic acid (FA), which is regarded as an effective biostimulant for improved plant development and output. Fulvic acids influence the pathways in plants that control development, which in turn promotes resilience to stress and the general health of the plant (Baltazar *et al.,* 2021). The retention of water in the soil is increased by fulvic acid. Additionally, they improve the health of the plant and its products by aiding in the filtering out of heavy metals and poisons. Because fulvic acid may supply these elements directly to plants, it readily binds or chelates minerals including iron, calcium, copper, zinc, and magnesium (Rouphael and Colla, 2020). Tryptophan, the precursor to IAA, is found naturally in plant root exudates. It is also produced by the hydrolysis of dead cell proteins and is turned into indole acetic acid by plant growth promoting rhizo-bacteria (Parihar *et al.,* 2022). The application of tryptophan in soil has proven very beneficial in improving crop growth. Tryptophan is the physiological precursor to the phytohormone and is used by bacteria to produce indole acetic acid. Exogenous application of tryptophan to soil improves crop development and yield because it is transformed into auxin by soil bacteria (Elkhatib *et al.*, 2020). Thus, the present study was utilized to evaluate the effect of different bio-stimulants on the growth, soil and yield attributes of summer moongbean.

MATERIALS AND METHODS

The present work was conducted at the field of School of Agriculture, Lovely Professional University, Phagwara, Punjab during the summer season of 2023. Moongbean variety SML-668 was procured from the local market of Punjab.

The randomized block design (RBD) was composed of eight treatments in three replications. The different treatments included T_0–Control, T_1–100% RDF, T_2–RDF + 1 g/l HA, T_3–RDF+2 g/l HA, T_4–RDF+2.5 g/l FA, T_5–RDF+5 g/l FA, T_6–RDF+0.5 g/l tryptophan and T_7–RDF+1g/l tryptophan. The area for the plot was 360 m^2 with a size of 20.16 m^2 and 24 plots. The seeds were sown on April 7th, 2023 at a spacing of 30 x 10 cm. Three irrigations were given after sowing. The foliar spray of the stimulators was applied in two equal doses: at 24 days after sowing and at the beginning of the blooming stage. Nitrogen, phosphorus and potassium fertilizers were applied in doses of 25, 50 and 25 kg/ha, respectively. The harvesting was done 61 days after sowing (June 17th, 2023). The other agricultural practices followed for moongbean were applied as for the recommendations of commercial production.

The data for growth, soil and yield attributes of the moongbean crop were recorded using three randomly chosen plants from each treatment after seed sowing. For growth characters' plant height (cm), plant population, fresh weight (g), dry weight (g), leaf area index, crop growth rate ($g/m^2/day$), relative growth rate (g/g/day) and net assimilation rate ($g/cm^2/day$) were estimated (Di Filippo-Herrera *et al.,* 2019). The growth parameters were recorded at 15 days interval. For phenological parameters days to emergence, days to 50% flowering, days to pod initiation and days to physiological maturity were evaluated. For plant analysis of mooongbean, N uptake of seed and stalk (kg/ha), P uptake of seed and stalk (kg/ha) and K uptake of seed and stalk (kg/ha) were studied. For soil analysis soil pH, EC, organic carbon, N, P and K were identified at the initial and maturity stage. Soil pH was done with the help of pH meter (Razzaque *et al.,* 2016), electrical conductivity meter was used for EC (Khan *et al.*, 2020), organic carbon was measured by total organic carbon analyzer (Baltazar *et al.*, 2021) and NPK elements were measured by NPK sensors (Parveen *et al.,* 2023).

The yield attributes recorded for the moongbean crop were the number of pods/plant, pod length, pod dry weight (g), number of seeds/pod, 1000-seed weight, seed yield (kg/ha), biological yield (kg/ha) and harvest index (%) following Parveen *et al.* (2023).

The analysis of the data was done statistically by RBD sheet in SPSS software. Results were presented in the form of the mean for different growth, soil and yield attributes. A significant difference ($P<0.05$) among treatments was indicated by SPSS software version 24.

RESULTS AND DISCUSSION

Growth parameters including plant height, plant population, fresh weight, dry weight, leaf area index, crop growth rate ($g/m^2/day$), relative growth rate (g/g/day) and net assimilation rate ($g/cm^2/day$) were significantly influenced by the effect of different bio-stimulants on growth attributes at 15 days intervals. Growth characters increased successively with increasing the foliar application of the concentrations of bio-stimulants significantly (Table 1). Plant height had a significant effect of humic, fulvic acid and tryptophan on moongbean. Plant height was found highest in T_5 (RDF+5 g/l FA) as 49.61 followed by T_7 (RDF+1 g/l tryptophan and T_4 (RDF+2.5 g/l FA) and the lowest was observed in T_0 (control) as 43.46 cm. Foliar applications of humic, fulvic acid and tryptophan revealed significant increments in plant height over the control treatment. The application of fulvic acid caused the best growth

Table 1. Growth attributes of moongbean crop as influenced by different treatments of bio-stimulants

Treatment	Plant height (cm)	Plant population	Fresh weight (g)	Dry weight (g)	Leaf area index	Crop growth rate ($g/m^2/day$)	Relative growth rate (g/g/day)	Net assimilation rate ($g/cm^2/day$)
T_0–Control	43.46^h	38.33^g	6.74^f	1.54^f	51.69^e	84.33^f	173.68^h	88.54^g
T_1–100% RDF	45.73^g	42.33^f	6.84^f	1.61^e	56.03^e	85.58^e	174.49^g	89.52^f
T_2–RDF+1 g/l HA	46.18^f	48.33^f	6.93^f	1.69^e	58.82^e	85.62^e	175.19^f	91.22^e
T_3–RDF+2 g/l HA	47.21^e	56.33^e	7.14^e	1.78^d	62.11^d	86.50^d	175.64^e	91.69^e
T_4–RDF+2.5 g/l FA	48.14^c	73.67^c	7.56^c	1.98^c	71.31^c	87.47^c	176.54^c	92.74^c
T_5–RDF+5 g/l FA	49.61^a	91.67^a	7.87^a	2.17^a	84.72^a	89.57^a	178.62^a	94.49^a
T_6–RDF+0.5 g/l tryptophan	47.57^d	64.67^d	7.33^d	1.87^d	68.63^d	87.33^c	177.29^d	92.14^d
T_7–RDF+1 g/l tryptophan	48.69^b	83.33^b	7.78^b	2.08^b	78.35^b	88.65^b	177.57^b	93.69^b
C. D.	0.13	4.24	0.07	0.03	0.68	0.35	0.18	0.30
C. V.	0.23	5.50	0.84	1.50	0.83	0.32	0.08	0.27
SE (d±)	0.06	2.03	0.03	0.01	0.32	0.16	0.08	0.14
SE (m±)	0.04	1.43	0.02	0.01	0.23	0.12	0.06	0.10

HA–Humic acid, FA–Fulvic acid, C. D.–Critical difference, C. V.–Critical variance and SE–Standard error. Different superscripts in the same column are significantly different ($P<0.05$).

performance followed by tryptophan and humic acid treatments. Bio-stimulants have a direct role in absorption by plants either through cuticle or stomata and have a significant role in photosynthesis activity in plant leaves which improves the plant height. The results are in agreement with the findings of Ali *et al.* (2019) in the moongbean crop to improve growth and yield.

Plant population had a significant effect of humic, fulvic acid and tryptophan on moongbean (Table 1). The plant population increased with an increase in the concentration of bio-stimulants. Plant population was found highest in T_5 (RDF+5 g/l FA) as 91.67 followed by T_7 (RDF+1 g/l tryptophan) and T_4 (RDF+2.5 g/l FA) and the lowest was observed in T_0 (Control) as 38.33 cm. As these bio-stimulants are effective for enhancing cell division and differentiation, hence, they are known as growth stimulators and improve the plant population of the moongbean crop. Similar results were found by Elkhatib *et al.* (2020) in the moongbean crop.

The maximum fresh weight was recorded as 7.87 g in T_5 (RDF+5 g/l FA) followed by T_7 (RDF+1 g/l tryptophan) and T_4 (RDF + 2.5 g/l FA) and the lowest was observed as 6.74 g in T_0 (Control). A foliar spray of fulvic acid and tryptophan resulted in the supply of the optimum quantity of nutrients to the plant and their subsequent absorption by moongbean leaves resulting in better assimilation and translocation of nutrients and improved fresh weight. These results are in conformity with those of Yousefi *et al.* (2020) in moongbean. The dry weight of the moongbean crop improved significantly by the foliar application of humic, fulvic acid and tryptophan. The highest dry weight was observed as 2.17 g in T_5 (RDF+5 g/l FA) and the lowest was recorded in T_1 (Control) as 1.54 g. Overall, the application of fulvic acid and tryptophan resulted in an improvement in growth performance and enhanced the dry weight of moongbean. The results are in accordance with the findings of Parveen *et al.* (2023).

The maximum leaf area index was recorded as 84.72 in T_5 (RDF+5 g/l FA) followed by T_7 (RDF+1 g/l tryptophan) and T_4 (RDF+2.5 g/l FA) and the lowest was observed as 51.69 in T_0 (Control). The more leaf area was recorded under higher concentrations of these growth eliciting substances. The application of fulvic acid and tryptophan resulted in growth improvement and improved the leaf area index of the moongbean. Such findings were confirmed in moongbean by Ali *et al.* (2019). The pattern of crop and relative growth rate was enhanced by the application of different bio-stimulants including humic, fulvic and tryptophan. Treatment T_5 (RDF+5 g/l FA) had maximum crop and relative crop rate of 89.57 and 178.62, respectively. The addition of bio-stimulants improved the crop and relative growth rate of the moongbean crop. The pattern of net assimilation rate had a maximum value at T_5 (RDF + 5 g/l FA) as 94.49 followed by T_7 (RDF+ 1 g/l tryptophan) and T_4 (RDF + 2.5 g/l FA). The lowest was observed as 88.54 in T_0 (Control). The net assimilation rate had no direct influence on yield but had a direct improvement in the growth of moongbean. Similar results were studied by Elkhatib *et al.* (2020) in the moongbean crop under growth parameters.

The days to emergence were recorded more in T_5 (RDF+5 g/l FA) as 22.47 followed by T_7 (RDF+1 g/l tryptophan) and T_4 (RDF+2.5 g/l FA) treatments (Table 2). The days to 50% flowering were maximum in T_5 (RDF+5g/l FA) at 34.57 and lowest in T_0 (Control) at 24.33. A similar trend was followed for the days to pod initiation and days to physiological maturity in moongbean crop. The days to pod initiation and days to physiological maturity were recorded maximum in T_5 (RDF+5 g/l FA) as 18.63 and 74.65 followed by T_7 (RDF+1 g/l tryptophan) and T_4 (RDF+2.5 g/l FA) treatments. The lowest was observed in T_0 (Control) as 14.27 and 69.21, respectively. A significant positive relation was observed by foliar applications of humic, fulvic acid and tryptophan on phonological parameters in the moongbean crop. The application of fulvic acid improved phenological parameters followed by tryptophan and humic acid treatments. The phenological parameters had a positive relation with seed yield in moongbean and it improved the yield attributes of moongbean. Similar findings were revealed by Ali *et al.* (2019) and Elkhatib *et al.* (2020) in the moongbean crop.

The nitrogen uptake by seed and stalk was recorded maximum in T_5 (RDF+5 g/l FA) as 38.62 and 33.38 kg/ha, respectively (Table 3). The lowest nitrogen uptake by seed and stalk was observed in T_0 (Control) as 35.61 and 28.43 kg/ha. These findings suggest a strong

Table 2. Phenological attributes of moongbean crop as influenced by different treatments of biostimulants

Treatment	Days to emergence	Days to 50% flowering	Days to pod initiation	Days to physiological maturity
T_0–Control	15.85^g	24.33^h	14.27^g	69.21^e
T_1–100% RDF	16.63^f	25.34^g	14.62^f	69.48^e
T_2–RDF+1 g/l HA	17.47^e	26.50^f	15.23^e	71.47^d
T_3–RDF+2 g/l HA	18.62^d	27.62^e	15.59^d	72.19^c
T_4–RDF+2.5 g/l FA	21.27^b	29.50^c	17.23^b	73.23^b
T_5–RDF+5 g/l FA	22.47^a	34.57^a	18.63^a	74.65^a
T_6–RDF+0.5 g/l tryptophan	19.50^c	28.29^d	16.62^c	72.41^c
T_7–RDF+1 g/l tryptophan	21.55^b	32.60^b	17.48^b	73.63^b
C. D.	0.29	0.22	0.16	0.20
C. V.	1.23	0.62	0.79	0.23
SE (d±)	0.14	0.10	0.07	0.09
SE (m±)	0.09	0.07	0.05	0.06

HA–Humic acid, FA–Fulvic acid, C. D. = Critical difference, C. V. = Critical variance and SE = Standard error. Different superscripts in the same column are significantly different ($P<0.05$).

Table 3. Plant analysis of moongbean crop as influenced by different treatments of bio-stimulants

Treatment	N uptake of seed (kg/ha)	N uptake of stalk (kg/ha)	P uptake of seed (kg/ha)	P uptake of stalk (kg/ha)	K uptake of seed (kg/ha)	K uptake of stalk (kg/ha)
T_0–Control	35.61^f	28.43^e	6.76^g	3.65^h	3.83^f	23.53^e
T_1–100% RDF	36.65^e	29.59^d	6.81^f	3.75^g	3.90^e	24.14^d
T_2–RDF+1 g/l HA	36.32^e	31.15^c	6.88^f	3.86^f	3.95^e	24.31^d
T_3–RDF+2 g/l HA	37.12^d	31.52^c	6.96^e	3.95^e	4.05^d	24.58^d
T_4–RDF+2.5 g/l FA	38.15^c	32.62^b	7.16^c	4.16^c	4.28^c	25.59^c
T_5–RDF+5 g/l FA	38.62^a	33.38^a	7.59^a	4.45^a	4.67^a	26.69^a
T_6–RDF+0.5 g/l tryptophan	37.52^d	32.24^b	7.05^d	4.07^d	4.15^d	25.18^c
T_7–RDF+1 g/l tryptophan	38.49^b	33.14^a	7.37^b	4.27^b	4.40^b	26.40^b
C. D.	0.10	0.12	0.04	0.07	0.08	0.18
C. V.	0.23	0.31	0.47	1.47	1.61	0.59
SE (d±)	0.05	0.05	0.01	0.03	0.03	0.08
SE (m±)	0.03	0.04	0.01	0.02	0.02	0.06

HA–Humic acid, FA–Fulvic acid, CD–Critical difference, C. V. = Critical variance and SE–Standard error. Different superscripts in the same column are significantly different ($P<0.05$).

synergistic relationship between potassium and phosphorus, which may led to a rise in the creation of dry matter. It is a well-established fact that N uptake rises as dry matter production increases. The phosphorus uptake by seed and stalk was recorded maximum in T_5 (RDF+ 5 g/l FA) as 7.59 and 4.45 kg/ha, respectively. The lowest phosphorus uptake by seed and stalk was observed in T_0 (Control) as 6.76 and 3.65 kg/ha. Similar trend was followed for potassium uptake of seed and stalk in moongbean. The potassium uptake by seed and stalk was recorded maximum in T_5 (RDF+5 g/l FA) as 4.67 and 26.69 kg/ha, respectively. The lowest phosphorus uptake by seed and stalk was observed in T_0 (Control) as 3.83 and 25.53 kg/ha. Nitrogen uptake due to phosphorus and potassium application increased due to N-fixation as a result of increased number of nodules. Foliar applications of humic, fulvic acid and tryptophan significantly improved the plant analysis. The results are in agreement with the findings of Di Filippo-Herrera *et al.* (2019) and Parveen *et al.* (2023) in the moongbean crop.

pH value was recorded maximum in T_5 (RDF+5 g/l FA) as 7.97 at an initial stage and 7.96 at the final stage (Table 4). The EC value was maximum in T_5 (RDF + 5 g/l FA) as 1.81 at the initial stage and 1.82 at the final stage. A similar trend was followed for the organic carbon and showed a maximum in T_5 (RDF + 5 g/l FA) as 0.23 at the initial stage and 0.45 at the final stage. The N, P and K values in soil analysis of moongbean were more in T_5 (RDF+5 g/l FA) and lowest in T_0 (Control). Foliar applications of humic, fulvic acid and

Table 4. Soil analysis of moongbean crop as influenced by different treatments of bio-stimulants

Treatment	pH		EC (d/Sm)		Organic carbon		N (ppm)		P (ppm)		K (ppm)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
T_0–Control	7.74^d	7.72^c	1.65^c	1.64^c	0.16^b	0.36^b	169.29^c	173.07^b	23.17^d	21.20^d	187.29^b	181.70^b
T_1–100% RDF	7.78^d	7.76^c	1.68^c	1.67^c	0.17^b	0.38^b	179.16^b	190.47^a	23.60^d	21.73^d	188.14^b	182.60^b
T_2–RDF+1 g/l HA	7.83^c	7.79^c	1.71^b	1.71^b	0.18^b	0.38^b	179.45^b	192.53^a	24.33^c	22.10^c	189.46^b	182.80^b
T_3–RDF+2 g/l HA	7.84^c	7.81^b	1.73^b	1.72^b	0.20^a	0.39^b	180.80^a	194.43^a	24.65^c	22.53^c	189.35^b	184.27^a
T_4–RDF+2.5 g/l FA	7.91^b	7.93^a	1.77^b	1.76^b	0.21^a	0.41^a	182.21^a	195.23^a	25.65^b	23.40^b	192.09^a	185.73^a
T_5–RDF+5 g/l FA	7.97^a	7.96^a	1.81^a	1.82^a	0.23^a	0.45^a	183.67^a	199.10^a	26.52^a	24.07^a	192.20^a	186.83^a
T_6–RDF+0.5 g/l tryptophan	7.87^{cb}	7.89^b	1.75^b	1.76^b	0.21^a	0.39^b	181.20^a	194.87^a	25.12^b	22.73^c	190.58^a	184.90^a
T_7–RDF+1 g/l tryptophan	7.96^a	7.94^a	1.79^b	1.78^b	0.22^a	0.42^a	182.83^a	198.33^a	26.09^a	23.93^b	192.17^a	186.20^a
C. D.	0.05	0.05	0.04	0.04	0.02	0.03	0.53	2.24	0.51	0.72	0.27	0.89
C. V.	0.03	0.04	0.02	0.02	0.01	0.01	0.24	0.94	1.68	2.56	0.11	0.39
SE (d±)	0.02	0.03	0.03	0.03	0.01	0.01	0.25	1.07	0.24	0.34	0.13	0.42
SE (m±)	0.01	0.01	0.01	0.01	0.01	0.01	0.25	1.07	0.17	0.24	0.09	0.30

HA–Humic acid, FA–Fulvic acid, C. D. = Critical difference, C. V. = Critical variance and SE–Standard error.
Different superscripts in the same column are significantly different (P<0.05).

tryptophan revealed significant improvement in soil. The application of fulvic acid improved soil performance followed by tryptophan and humic acid treatments. As bio-stimulants have a direct role in the absorption of nutrients, root growth and soil water holding capacity led to increased nutrient availability to soil. The results are in agreement with the findings of Di Filippo-Herrera *et al.* (2019) and Parveen *et al.* (2023) in the mungbean crop.

The maximum number of pods/plant was recorded in T_5 (RDF + 5 g/l FA) as 18.57 and lowest as 11.47 in control T_0 (Table 5). The pod length and pod dry weight were also reported maximum in T_5 (RDF+5 g/l FA) as 8.62 cm and 4.29 g, respectively. The number of seeds/pod and 1000-seed weight were depicted maximum in T_5 (RDF+5 g/l FA) as 12.27 and 30.10 and minimum in T_0 (Control). This could be a result of foliar spraying of fertilizers and bio-stimulants, which are effective in achieving greater yield qualities. Results are according to the findings of AgüEro-Esparza *et al.* (2022) who utilized foliar applications on green gram crops to improve productivity. The seed and biological yield were also significantly influenced by fulvic acid and tryptophan and reported more in T_5 (RDF+5 g/l FA) as 1688 and 2680 kg/ha. The improved seed yield could be attributed to the increased availability of practically all-important plant nutrients through the transfer of photosynthates accumulated under the effect of foliar nutrient sprays combined with bio-stimulants. Furthermore, the translocation and accumulation of photosynthates in economic sinks boosted yield characteristics, which led to increased seed production. The enhanced

Table 5. Yield attributes of moongbean crop as influenced by different treatments of bio-stimulants

Treatment	No. of pods/ plant	Pod length (cm)	Pod dry weight (g)	No. of seeds/ pod	1000-seed weight (g)	Seed yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
				At harvest				
T_0–Control	11.47^g	6.78^f	3.44^g	6.43^h	26.90^d	979^f	1348^h	21.33^d
T_1–100% RDF	13.49^f	7.12^e	3.63^f	7.62^g	27.10^c	1274^e	1469^g	21.92^d
T_2–RDF+1 g/l HA	14.30^e	7.14^e	3.74^e	8.41^f	27.33^c	1367^d	1646^f	22.61^c
T_3–RDF+2 g/l HA	15.37^d	7.30^d	3.84^d	9.37^e	27.80^c	1460^c	1872^e	22.72^c
T_4–RDF+2.5 g/l FA	16.13^c	7.67^c	4.10^b	10.44^c	28.77^b	1526^b	2157^c	23.85^b
T_5–RDF+5 g/l FA	18.57^a	8.62^a	4.29^a	12.27^a	30.10^a	1688^a	2680^a	24.47^a
T_6–RDF+0.5 g/l tryptophan	15.53^d	7.38^d	3.93^c	10.26^d	28.23^b	1473^c	1993^d	23.26^b
T_7–RDF+1 g/l tryptophan	17.47^b	7.75^b	4.16^b	11.57^b	28.76^b	1552^b	2348^b	24.42^a
C. D.	0.47	0.08	0.04	0.38	0.36	14.93	23.88	0.12
C. V.	2.49	0.97	0.97	3.24	1.05	0.85	0.99	0.42
SE (d±)	0.22	0.04	0.02	0.18	0.17	7.16	11.44	0.05
SE (m±)	0.16	0.03	0.01	0.13	0.12	5.06	8.09	0.04

HA–Humic acid, FA–Fulvic acid, C. D.–Critical difference, C. V.–Critical variance and SE–Standard error.
Different superscripts in the same column are significantly different (P<0.05).

seed yield could be attributed to the constant supply of nutrients, which increased leaf area and dry matter, resulting in a greater yield. Results are in accordance with the findings of Ali *et al.* (2019) in green gram who utilized humic acid and nitrogen levels to improve productivity.

The harvest index was significantly influenced by fulvic acid and tryptophan and reported more in T_5 (RDF+5 g/l FA) as 24.47%. A higher value of harvest index was recorded with the foliar sprays of fulvic acid and tryptophan. Higher values of the harvest index were achieved due to the optimum availability of nutrients and bio-stimulants leading to efficient translocation of assimilates partitioning to reproductive parts which is reflected in the harvest index. Bio-stimulants are a rich source of multiple main nutrients such as K, P and secondary nutrients, and they promote several elements of harvest index growth and development. These findings are in agreement with Elkhatib *et al.* (2020) who utilized humic acid, fulvic acid and tryptophan on the growth and productivity of common bean.

CONCLUSION

The application of T_5 treatment (RDF+5 g/l FA) followed by T_7 (RDF+1 g/l tryptophan) and T_4 (RDF + 2.5 g/l FA) improved the growth, phenological, soil, plant and yield components in moongbean. Bio-stimulants had a considerable effect on growth, phenological, soil, plant and yield characteristics. This enhancing impact may be linked to the nutrient's beneficial influence on metabolism and biological activity, as well as its stimulatory effect on photosynthetic pigments and enzymatic activity, which increased plant vegetative growth, phenological, soil, plant and yield. They are abundant in bioactive compounds that can improve many physiological processes that support plant growth, phenology and increase the efficiency with which nutrients are utilized by plants, all while reducing the requirement for chemical fertilizers and having no detrimental effects on crop productivity or product quality. Thus, it is recommended that bio-stimulants such as humic, fulvic acid and tryptophan be used to boost the growth, plant, soil and yield components in the moongbean crop.

REFERENCES

AgüEro-Esparza, M., Villalobos-Cano, O., Sanchez, E., Perez-Alvarez, S., Sida-Arreola, J. P., Palacio-MáRquez, A. and RamíRez-Estrada, C. A. (2022). Effectiveness of foliar application of biostimulants and nanoparticles on growth, nitrogen assimilation and nutritional content in greenbean. *Notulae Scientia Biologicae* **14**: 11261.

Ali, I., Khan, A. A., Imran, Inamullah, Khan, A., Asim, M. and Iqbal, B. (2019). Humic acid and nitrogen levels optimizing productivity of green gram (*Vigna radiata* L.). *Rus. Agric. Sci.* **45**: 43-47.

Baltazar, M., Correia, S., Guinan, K. J., Sujeeth, N., Bragança, R. and Gonçalves, B. (2021). Recent advances in the molecular effects of biostimulants in plants: An overview. *Biomolecules* **11**: 1096. *https://doi.org/10.3390/biom11081096.*

Bilal, S., Hazafa, A., Ashraf, I., Alamri, S., Siddiqui, M. H., Ramzan, A. and Naeem, M. (2021). Comparative effect of inoculation of phosphorus-solubilizing bacteria and phosphorus as sustainable fertilizer on yield and quality of mungbean (*Vigna radiata* L.). *Plants* **10**: 2079. *https://doi.org/10.3390/plants10102079.*

Di Filippo-Herrera, D. A., Muñoz-Ochoa, M., Hernández-Herrera, R. M. and Hernández-Carmona, G. (2019). Biostimulant activity of individual and blended seaweed extracts on the germination and growth of the mungbean. *J. App. Phyc.* **31**: 2025-2037.

Dineshkumar, R., Duraimurugan, M., Sharmiladevi, N., Lakshmi, L. P., Rasheeq, A. A., Arumugam, A. and Sampathkumar, P. (2020). Microalgal liquid biofertilizer and biostimulant effect on green gram (*Vigna radiata* L.)–An experimental cultivation. *Biomass Conversion and Biorefinery* **12**: 3007-3027.

Elkhatib, H. A., Gabr, S. M., Roshdy, A. H. and Kasi, R. S. (2020). Effects of different nitrogen fertilization rates and foliar application of humic acid, fulvic acid and tryptophan on growth, productivity and chemical composition of common bean plants (*Phaseolus vulgaris* L.). *Alex. Sci. Exchange J.* **41**: 191-204.

Kaur, J. and Sharma, P. (2017). Response of summer mungbean (*Vigna radiata* L.) to Rhizobium and PGPR inoculation under different planting methods. *Ann. Agric. Res.* **37**: 87-90.

Khan, S., Ismail, M., Ibrar, M. and Ali, Z. (2020). The effect of biochar on soil organic matter, total N in soil and plant, nodules, grain yield and biomass of mungbean. *Soil Environ.* **39**: 87-94.

Kumawat, K. C., Sharma, P., Nair, R. M. and Bindumadhava, H. (2021). Dual microbial inoculation, a game changer? bacterial biostimulants with multifunctional growth promoting traits to mitigate salinity stress in spring mungbean. *Front. Microbiol.* **11**: 600576. *https://doi.org/10.3389/fmicb.2020.600576.*

Mahajan, G., Wenham, K. and Chauhan, B. S. (2023). Mungbean (*Vigna radiata*) growth and yield response in relation to water stress and elevated day/night temperature conditions. *Agronomy* **13**: 2546. *https://doi.org/10.3390/agronomy13102546.*

Mota, F. M., Balla, D. S. and Doda, M. B. (2021). Response of mung bean varieties (*Vigna radiata* L.) to application rates and methods of blended NPs fertilizer at humbo. *Int. J. Agron.* **2021**: 01-10.

Navya, P. P., Akhila, M. and Dawson, J. (2021). Effect of plant growth regulators on growth and yield of Zaid mungbean (*Vigna radiata* L.). *J. Pharm. Phytochem.* **10**: 1228-1230.

Paradikovic, N., Teklic, T., Zeljkovic, S., Lisjak, M. and Špoljarevic, M. (2019). Biostimulants research in some horticultural plant species–A review. *Food Energy Security* **8**: e00162.

Parihar, P., Singh, P. and Patidar, J. K. (2022). Biostimulants for improving nutritional quality in legumes. In: *New and Future Developments in Microbial Biotechnology and Bioengineering.* pp. 261-275. Elsevier. *https://doi.org/10.1016/B978-0-323-85579-2.00011-3.*

Parveen, A., Aslam, M. M., Iqbal, R., Ali, M., Kamran, M., Alwahibi, M. S. and Elshikh, M. S. (2023). Effect of natural phytohormones on growth, nutritional status and yield of mungbean (*Vigna radiata* L.) and N availability in sandy-loam soil of sub-tropics. *Soil Systems* **7**: 34. *https://doi.org/10.3390/soilsystems7020034.*

Razzaque, M. A., Haque, M. M., Rahman, M. M., Bazzaz, M. M. and Khan, M. S. A. (2016). Screening of mungbean [*Vigna radiata* (L.) Wilczek] genotypes under nutrient stress in soil. *Bangladesh J. Agric. Res.* **41**: 377-386.

Rouphael, Y. and Colla, G. (2020). Biostimulants in agriculture. *Front. Plant Sci.* **11**: *https://doi.org/10.3389/fpls.2020.00040.*

Yousefi, A., Mirzaeitalarposhti, R., Nabati, J. and Soufizadeh, S. (2020). Evaluation radiation use efficiency and growth indicators on two mungbean (*Vigna radiata* L.) genotypes under the influence of biological fertilizers. *J. Plant Nut.* **44**: 1095-1106.