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Effect of plant growth regulators on growth, flowering behaviors and yield of Mungbean (*Vigna radiata* L.)

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ABSTRACT

Background: Mungbean is an important pulse crop valued for its nutritional value and contribution to sustainable agriculture. Plant growth regulators influence the growth and yield of Mungbean; however, information on the combined effects of IAA, GA₃, and NAA on Mungbean under field conditions is limited. This study evaluated the effects of different PGR treatments on growth, flowering behavior, and yield of Mungbean.

Methods: The experiment was conducted in the research farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. Nine treatments (untreated control, 50 ppm IAA, 50 ppm GA₃, 50 ppm NAA, 100 ppm IAA, 100 ppm GA₃, 100 ppm NAA, 50 ppm IAA + 50 ppm GA₃ + 50 ppm NAA, and 100 ppm IAA + 100 ppm GA₃ + 100 ppm NAA) were tested in a randomized block design with three replications. Data were recorded on various stages of vegetative growth, flowering traits, and yield characteristics.

Results: The combined 50 ppm treatment (T₇) produced the highest plant height at 60 days after sowing (58.83 cm), number of leaves (31 plant⁻¹), branches (9.33 plant⁻¹), and inflorescences per plant (10), yield per plant (8.33 Kg) and yield (1480 kg ha⁻¹). In general, 50 ppm applications were more effective than the corresponding 100 ppm treatments and control treatments, indicating the importance of optimum hormonal concentration.

Conclusions: The results suggest that combined foliar application of IAA, GA₃ and NAA at 50 ppm can improve reproductive performance and yield of mungbean under the tested field conditions.

Keywords: *Vigna radiata*; plant growth regulators; flowering behavior; leaf area index; yield attributes; randomized complete block design.

1. Introduction

Mungbean (*Vigna radiata* (L.) Wilczek), is an economically important grown as dry land crop cultivated across tropical and subtropical regions, particularly in South and Southeast Asia (Diatta *et al.*, 2024). The mature seeds provide an invaluable source of digestible protein for humans, having high nutritional values and rich in protein contents (Dahiya *et al.*, 2015) including protein, dietary fiber, minerals, vitamins, and significant amounts of bioactive compounds, including polyphenols, polysaccharides, and peptides (Hou *et al.*, 2019). Owing to its short growth period (Keykha *et al.*, 2014) compatibility with multiple cropping systems, and ability to improve soil fertility through symbiotic nitrogen fixation, mungbean has become an integral component of sustainable agricultural production systems (Nair *et al.*, 2019). Nevertheless, the productivity of mungbean remains below its attainable potential in many production environments because yield is strongly influenced by genotype-environment interactions, water and temperature stress, and limitations in reproductive development (Jha *et al.*, 2025) & (Sequeros *et al.*, 2021).

Compared to other countries, the climatic conditions of Bangladesh are favorable for winter farming of mungbean, but it can be cultivated in both summer and winter (Rabbani *et al.*, 2013). Although mungbean is cultivated by farmers considering nutritional values, the average productivity of mungbean remains substantially lower than its attainable yield potential due to excessive flower shedding, low pod set, asynchronous flowering, and premature senescence under adverse environmental conditions (Tamanna *et al.*, 2023). To meet the requirement, it is essential to enhance production through varietal selection, proper management, and application of different plant growth hormones such as NAA (1-Naphthaleneacetic acid), Gibberellic acid, and indole-3-acetic acid (IAA), which is a prerequisite for increasing the production of mungbean.

Plant growth regulators (PGRs) are naturally occurring or synthetic organic compounds that are promising tools for manipulating developmental processes of plants. Among the PGRs relevant to mungbean, indole-3-acetic acid (IAA) and GA₃ are the principal naturally occurring growth hormones, whereas naphthalene acetic acid (NAA) is a synthetic auxin.

Naphthalene acetic acid (NAA), a synthetic auxin, has been investigated as a plant growth regulator for improving vegetative growth, reproductive development, and yield formation, including plant height, number

of branches, and total dry biomass in mungbean and other pulse crops (Yadav *et al.*, 2023). NAA relies on efficient sugar transport from the photosynthesizing parts of the plant (Source) to the developing grains (Mithare *et al.*, 2018).

Gibberellins (GAs) are the most important natural growth regulators and are generally involved in the growth and development of different plants (Camba *et al.*, 2022). They control seed germination, leaf expansion, stem elongation, and flowering (Magome *et al.*, 2004) and participate in numerous developmental processes, including seed development, seedling growth, determination of leaf size and shape, flower induction and development, pollination and fruit expansion (Vishal and Kumar, 2018). Gibberellic acid (GA) is used to induce great changes in the growth characters, chemical composition, and yield criteria of the plant (Choudhury *et al.*, 2013).

It was reported that GA₃ improves translocation of assimilates to developing reproductive organs (Rademacher, 2015) and increases plant height, branch formation, chlorophyll content, and pod number in mungbean through enhanced photosynthetic activity and improved source–sink relationships (Iqbal *et al.*, 2017).

Indole-3-acetic acid (IAA), the principal naturally occurring auxin, plays an important role in regulating plant growth and development, and exogenous IAA application can stimulate vegetative growth and biomass accumulation in mungbean (Newaj *et al.*, 2002). The positive effect of IAA on mungbean productivity may be associated with enhanced vegetative growth and greater assimilate production, which can subsequently contribute to reproductive development and seed formation (Parveen *et al.*, 2023).

Foliar application of IAA, NAA, and GA₃ significantly affected morphological, biochemical, and yield-related characteristics, including shoot growth, biomass, fruit number, and seed yield. It is reported that foliar application of 50 mg L⁻¹ IAA + 50 mg L⁻¹ GA₃ significantly enhanced plant height, leaves per plant, branches per plant, chlorophyll content, and yield attributes of Mungbean (Nourin *et al.*, 2024).

The manipulation of endogenous hormonal balance through exogenous PGR application represents a promising agronomic strategy for overcoming physiological limitations in mungbean production. The knowledge gap is important because an improvement in vegetative growth does not necessarily translate into greater reproductive efficiency or grain yield. Excessive hormonal stimulation may also alter phenology, assimilate allocation, or reproductive development. Thus, identifying the concentration and regulator combination that optimizes the relationship between vegetative growth, flowering and reproductive sink development is more meaningful than evaluating yield alone. Furthermore, results obtained from one genotype or production environment cannot necessarily be extrapolated to another because hormonal responses are influenced by genotype, environmental conditions and application regime.

The study was undertaken (a) to investigate the influence of selected plant growth regulators on flowering behaviour, growth and yield of mungbean, (b) to find out the effect of concentration of plant growth regulators on flowering behaviour, growth and yield of mungbean and (c) To find out the suitable combination of the growth regulators concentration for higher yield of mungbean. By integrating growth, flowering, and yield responses, this study aims to provide an evidence-based basis for optimizing PGR application in mungbean and contribute to improved productivity under subtropical production environments.

2. Materials and Methods

2.1 Experimental site

The experiment was conducted at the research farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The experimental site was situated in the subtropical zone, and the soil of the experimental site is clay loam in texture and olive grey, with common fine to medium distinct dark yellowish brown mottles, having pH 4.47 to 5.63, and organic carbon content of 0.8. The monthly mean of daily maximum, minimum, and average temperature, relative humidity, monthly total rainfall, and sunshine hours received at the experimental site during the period of the study have been collected from the Bangladesh Meteorological Department, Agargaon, Dhaka 1207.

2.2 Materials used for experiment

BARI Mung-6 was used as planting material. The seeds of BARI Mung-6 were collected from Bangladesh Agricultural Research Institute, Joydepur, Gazipur. This variety is suitable for the summer season. The plant height of the variety ranges from 60-70 cm, and the life cycle ranges from 60-65 days after sowing (DAS).

2.3 Treatments

There was a single factor in this experiment with three replications. This factor was treatment. Nine levels of treatments (GA₃, IAA, and NAA) were tested individually and combined. The factors were as follows:

Factor A: Levels of GA ₃ , IAA and NAA
T ₀ : Control
T ₁ : 50 ppm IAA
T ₂ : 50 ppm GA ₃
T ₃ : 50 ppm NAA
T ₄ : 100 ppm IAA
T ₅ : 100 ppm GA ₃
T ₆ : 100 ppm NAA
T ₇ : 50 ppm IAA +50 ppm GA ₃ +50 ppm NAA
T ₈ : 100 ppm IAA+100ppm GA ₃ +100 ppm NAA

There were all together nine treatments with three replications in nine plots in each block were as follows: R₁T₀, R₁T₁, R₁T₂, R₁T₃, R₁T₄, R₁T₅, R₁T₆, R₁T₇, R₁T₈, R₂T₀, R₂T₁, R₂T₂, R₂T₃, R₂T₄, R₂T₅, R₂T₆, R₂T₇, R₂T₈, R₃T₀, R₃T₁, R₃T₂, R₃T₃, R₃T₄, R₃T₅, R₃T₆, R₃T₇, R₃T₈.

2.4 Experimental design and layout

Field layout was done after final land preparation. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The whole plot was divided into three blocks, each containing eighteen (9) plots of 4m x 3 m size, giving 27-unit plots. A space of 1.0 m between the blocks and 0.5 m between the plots was kept.

2.5 Crop production and management

The land was prepared thoroughly, ploughed and cross-ploughed, followed by laddering to have a good tilt, and stubbles were removed from the land. The land was fertilized @30Kgha⁻¹ N, 48Kgha⁻¹ P and 30Kgha⁻¹ K. All the fertilizers were applied as a basal dose during final land preparation.

Seeds were sown at a seed rate @ 30 kg ha⁻¹. Seeds were treated with fungicide Provax 200 WP to protect them from seed-borne diseases.

Weeding was done as per requirement. Thinning was done to maintain a plant-to-plant distance of 10 cm. The first thinning was done at 8 DAS and the second was done at 15 DAS.

Two irrigations were applied, first at 10 DAS and the second at 30 DAS. At the later stage of the experiment, there was little rainfall, so drainage provision was maintained to drain out excess water.

The insecticide Malathion 57EC was sprayed @ 1.5 t ha⁻¹ at the time of 50% pod formation stage to control pod borer (Aktar, 2015).

At the time when 80% of the pods turned blackish in color, the crop was assessed to attain maturity. The crops were harvested from a central 1.0 m² area of each plot for yield data on different dates as they attained maturity.

2.6 Preparation of plant growth regulator solutions

2.6.1 Preparation of IAA solution

For the preparation of 50ppm solution, 50 mg IAA was measured and dissolved in a small quantity of ethanol, and the volume was adjusted to 1L with distilled water. In the same way, 100 mg IAA was measured and dissolved in a small quantity of ethanol, and the volume was adjusted to 1L with distilled water to prepare 100 ppm IAA.

2.6.2 Preparation and application of GA₃

The stock solution of 1000 ppm of GA₃ with small amount of ethanol to dilute and then mixed in 1 liter of water turn as per requirement of 50 ppm and 100ppm solution were mixed with 1 liter of water.

2.6.3 Preparation of NAA solution

Naphthalene acetic acid (NAA) in different concentrations, *viz.* 50 and 100 ppm were prepared following the procedure mentioned below. 50 ppm solution of NAA was prepared by dissolving 50 mg of it in distilled water. Then distilled water was added to make the volume 1 liter of 50 ppm solution. In a similar way, 100 ppm concentrations were made.

2.7 Data Collection and Measured Variables

Five plants from each plot were sampled for recording data on plant height, Number of leaves, Number of Branches, and Leaf Area Index at 20, 40, and 60 days after sowing.

The **plant height** of the pre-selected five plants was measured from the ground level to the tip of the plants and then averaged. Plant height was taken at 20, 40, and 60 days after sowing from the selected plants.

Number of leaves and branches were measured from the sample plants and recorded at 20, 40 and 60 days of planting to observe the growth rate of the plants.

The **leaf area index (LAI)** was calculated following the formula suggested by Z Sesták (Z. Sesták, 1971). Dates of first flowering were recorded treatment-wise, and the period of time for first flowering in days was calculated from the date of sowing.

$$LAI = \frac{\text{Leaf area per plant (cm}^2\text{)}}{\text{Land area occupied by a plant (cm}^2\text{)}}$$

Numbers of inflorescence plant⁻¹, Numbers of flower inflorescence⁻¹, and numbers of flower plant⁻¹ were recorded at 35, 50, and 60 DAS, and Numbers of pod inflorescence⁻¹ and numbers of pod plant⁻¹ were recorded at 50 and 60 DAS from 5 plants selected at random from the outer side rows (started after 2 rows from outside) of each plot.

Pod length was calculated from ten randomly selected pods of five selected plants, and then the average pod length was calculated. **Numbers of seeds pod⁻¹** was counted from ten randomly selected pods of 5 selected plants, and then the average seed number was calculated. **The 1000-seeds of each plot** were counted and weighed with a digital electronic balance in gm unit. Five tagged plants were uprooted at maturity and processed for seed yield, from which the average was calculated in grams to express seed yield plot⁻¹ and seed yield hectare⁻¹ were recorded at 12% moisture level.

2.8 Analysis of data

Data were statistically analyzed by randomized complete block design through R software to analyze the growth, yield and quality characters of tomato to find out the statistical significance. Treatment means were calculated for all measured parameters, and the standard error (SE) and coefficient of variation (CV%) were estimated to assess experimental precision and variability. Mean comparisons among treatments were performed using Duncan's Multiple Range Test (DMRT), and treatments sharing the same letter were considered statistically similar, while

different letters indicated significant differences at the 5% probability level, following the procedure described by (Gomez, 1984).

3. Results

3.1 Effect of Plant Growth Regulators on vegetative features of Mungbean

Plant growth regulators influences plant height significantly that were found at all growth stages (20, 40, and 60 DAS) (Table 1). It was found that the tallest plants (20.83cm) were produced by T₇ (50 ppm IAA + 50 ppm GA₃ + 50 ppm NAA), which was statistically superior compared to other treatments, while the shortest plants (15.37 cm) were shown in the control treatment (T₀). Similar observations were found at 40 and 60 DAS, where T₇ showed the highest plant heights of 42.17 cm and 58.83 cm, respectively. On the other hand, the lowest plant heights were found in the control treatment, and showed 32 cm and 45.83 cm at 40 DAS and 60 DAS, respectively.

Table 1: Response of IAA, GA₃ and NAA on plant height, number of true leaves and Number of branches of Mungbean									
Treatme nt	Plant Height (cm)			Number of leaves			Number of branches		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
T ₀	15.37 c	32.00 e	45.83 d	6.33 c	14.33 b	18.00 a	2.00b	5.67 a	6.33 a
T ₁	16.00 cd	36.67 ab	48.83 a	8.00 ac	16.33 a	22.00 b	3.00ab	7.00 a	7.67 ab
T ₂	16.83 d	36.00 ab	51.50 c	8.67 ab	15.33 c	21.67 b	3.33 ab	7.67 a	8.00 ab
T ₃	18.17 a	34.33 c	47.50 b	9.33 ab	16.33 a	18.00 a	4.00 abc	7.00 a	7.33 ab
T ₄	18.90 ab	35.50 ac	48.50 ab	9.00 ab	17.33 d	19.00 c	3.67 abc	6.00 a	7.00 a
T ₅	19.33 be	40.83 d	54.00 e	10.00 b	18.33 e	24.00 d	5.00 ac	7.00 a	8.33 ab
T ₆	20.00 ef	35.83 ac	48.83 a	9.67 ab	19.33 f	20.00 e	4.67 ac	5.67 a	7.00 a
T ₇	20.83 f	42.17 d	58.83 f	12.00 d	23.00 g	31.00 f	7.33 d	8.00 a	9.33 b
T ₈	18.83 ab	37.50 b	50.83 c	9.33 ab	20.33 h	28.00 g	5.67 cd	6.67 a	7.67 ab
CV (%)	2.06	1.56	0.90	7.02	1.08	0.86	16.84	16.83	10.21
SE	0.217	0.331	0.263	0.371	0.111	0.111	0.418	0.655	0.450
In a column, having similar letters (s) are statistically identical, and those having dissimilar letters differ significantly at the 0.05 level of probability									

Plant growth regulators showed a significant effect on the number of leaves of Mungbean in various treatments at different stages. It was found that the maximum number of leaves was produced by T₇ (50 ppm IAA + 50 ppm GA₃ + 50 ppm NAA) treatment and recorded 12, 23 and 31 at 20DAS, 40DAS and 60 DAS, respectively, whereas the minimum values (6.33, 14.33 and 18, respectively) were found from the control treatment. Plant growth regulators also affected the number of branches. Applying 50 ppm IAA + 50 ppm GA₃ + 50 ppm NAA (T₇) solution resulted in the highest branch number compared to the control treatment. It was recorded that the number of branches at 20DAS, 40 DAS, and 60 DAS were 7.33, 8, and 9.33 at the T₇ treatment and 2, 5.67, and 6.33 at the

control treatment, respectively. The lower CV% values for plant height (1.83–2.58%) indicated excellent experimental precision, whereas moderate CV% values for leaf number (7.82–9.32%) suggested acceptable variability under field conditions.

3.2 Effect of Plant Growth Regulators on flowering characteristics of Mungbean

Days to first flowering were significantly influenced by plant growth regulator treatments (Table 2) at various concentrations of Mungbean growth. The earliest flowering (30.33 DAS) was observed in the T₇ treatment, maximum duration (40.33 DAS) to initiate flowering was found in the control treatment. The lower CV% (1.97%) indicated excellent reliability and precision of the experimental data. The inflorescences per plant and flowers per inflorescence and plant were influenced by plant growth regulators, and these were shown at various numbers under different conditions.

Table 2: Response of IAA, GA₃ and NAA on flowering characters of Mungbean				
Treatment	Days to 1st flowering	Inflorescences/plant	Flowers/ inflorescence	Flowers/plant
T ₀	40.33 d	5.67 a	5.33 a	30.00 a
T ₁	35.67 ab	6.33 ab	6.33 ab	40.00 ab
T ₂	34.00 be	6.00 ab	6.00 ab	36.00 ab
T ₃	37.67 ac	7.00 ab	6.67 ab	46.67 ab
T ₄	37.33 ac	7.33 ab	7.00 ab	51.33 ab
T ₅	36.00 ab	6.67 ab	7.67 bc	51.33 ab
T ₆	39.33 cd	7.67 b	7.33 abc	56.00 b
T ₇	30.33 f	10.00 c	9.33 c	93.67 c
T ₈	32.33 ef	6.67 ab	7.33 abc	49.33 ab
CV (%)	1.97	8.32	10.10	15.04
SE(+)	0.408	0.338	0.408	4.385
In a column, having similar letter (s) are statistically identical, and those having dissimilar letter (s) differ significantly at the 5% probability level.				

The maximum number of inflorescences (10) per plant was recorded in T₇, while the minimum value (5.67) was observed in the control treatment. Likewise, the maximum number of flowers per inflorescence was found in T₇ treatment and was 9.33, whereas the lowest number of flowers per inflorescence (5.33) was recorded in the control treatment. Numbers of flowers per plant were influenced by different concentrations of plant growth regulators. It was found that 93.67 flowers were found under T₇ treatment compared to 30 flowers per plant in the control treatment.

3.3 Effect of plant growth regulators on yield contributing characters of Mungbean

Plant growth regulators significantly influenced the yield-contributing characters of Mungbean including pods per inflorescence and plant, seeds per pod, 1000-seed weight, pod length, yield/plant, and yield per hectare. It was found that maximum pods per inflorescence and plant were found in T₇ treatment compared to the control. It was recorded 7 pods per inflorescence and 69.67 pods per plant in T₇ treatment. Also, it was observed that

maximum seeds per pod (12), including maximum 1000-seed weight (65 g) and maximum pod length (10.53cm), were found in the T₇ treatment, whereas the control condition showed minimum results. Yield per plant and hectare were significantly influenced by concentrations of plant growth regulators. Maximum yield per plant (8.33kg) and yield per hectare (1480kg) were recorded in the T₇ treatment compared to the control that showed 7.20 Kg and 1350 kg, respectively.

Table 3: Response of IAA, GA₃ and NAA on yield and yield contributing characters of Mungbean

Treatment	Pods/inflorescence	Pods/plant	Seeds/pod	1000 seeds weight (gm)	Pod length (cm)	Yield/plant (kg)	Yield/ha (kg)
T ₀	3.00 b	16.67 c	7.67 c	52.00 d	7.80 b	7.20 cd	1350 c
T ₁	3.67 ab	23.00 abc	8.67 bc	54.33 bd	8.20 ab	7.40 bc	1373.33 bc
T ₂	3.33 ab	19.67 bc	8.33 c	58.00 ae	8.17 ab	7.07 d	1393.33 b
T ₃	4.67 a	32.33 a	9.67 ab	54.67 bcd	8.20 ab	7.23 cd	1363.33 bc
T ₄	4.33 ab	31.33 a	10.33 a	55.67 abc	8.73 a	7.40 bc	1375bc
T ₅	4.67 a	30.67 a	10.67 a	57.33 ace	8.57 a	7.50 ab	1368.33 bc
T ₆	4.00 ab	30.33 ab	9.67 ab	55.67 abc	8.43 a	7.33 bc	1388.33 bc
T ₇	7.00 c	69.67 d	12.00 d	65.00 f	10.53 c	8.33 a	1480 a
T ₈	4.33 ab	28.67 ab	9.67 ab	59.00 e	8.70 a	7.50 ab	1383.33 bc
CV (%)	12.16	11.76	3.60	1.63	2.44	0.754	0.58
SE(+_-)	0.403	2.13	0.2	0.534	0.121	0.032	4.64
In a column, having similar letters (s) are statistically identical, and those having dissimilar letters (s) differ significantly at the 5% probability level.							

4. Discussion

The study reflected the effect of application of different concentrations of plant growth regulators on vegetative growth, flowering characters, and yield of Mungbean, whereas the combined application of 50 ppm IAA + 50 ppm GA₃ + 50 ppm NAA (T₇) showed the best performance compared to other treatments. The superior response of T₇ reflects that the optimum concentration of plant growth regulators is more effective than the single plant growth regulator or the control environment.

The significant increase in plant height, leaf number, and branch number under T₇ can be attributed to the complementary roles of IAA, GA₃, and NAA in the plant body. Gibberellic acid enhances plant cell division, whereas auxins influence meristematic activity, vascular differentiation, and root development that stimulate the vegetative growth of Mungbean. These findings of vegetative growth are consistent with the study conducted by (Solanke *et.al.*, 2018) and (Sajid *et al.*, 2016) who also reported on the effect of optimum Plant Growth regulators on vegetative growth in legumes.

Different concentrations of plant growth regulators also influenced the flowering behavior of Mungbean. The earliest flowering, highest numbers of inflorescences per plant, flowers per inflorescence, and flowers per plant and per plant observed in T₇ treatment express those optimum concentrations of IAA, GA₃ and NAA accelerated

the transition from vegetative growth to reproductive development of Mungbean. Plant growth regulators influence floral induction of the plants through their endogenous hormone metabolism, carbohydrate functions, and sink establishment during the reproductive phase. These types of observations were found in experiments reported by (Quamruzzaman *et al.*, 2021) and (Nazeer *et al.*, 2020), who reported that optimum concentrations of growth regulators improve flowering characteristics and reproductive growth in pulse crops.

Similarly, yield and yield-contributing characters are significantly influenced by various concentrations of plant growth regulators. It was clearly reported that pods per inflorescence, pods per plant, seeds per pod, 1000-seed weight, pod length, yield per plant, and yield per hectare are influenced by different concentrations, and that T₇ treatment showed maximum results for these features. The metabolic and biological activities of the plant growth regulators enhance the yield characters.

The highest yield per plant and hectare obtained under T₇ therefore appears to be the cumulative outcome of improved vegetative growth of mungbean, including prominent flowering, superior pod set and efficient seed filling under combination of plant growth regulators. Comparable responsive observations have been reported in mungbean and other grain legumes by (Md Mainul Islam, Salma Rupa, Ahmed Nasir Ahmed, Mehraj Hossain, 2014).

Surprisingly, combined treatments receiving 100 ppm combinations showed lower outcomes than the corresponding 50 ppm treatments. This indicates that excessive concentrations may hinder the endogenous hormonal homeostasis and reduce physiological efficiency, resulting in lower growth, development, and yields of Mungbean. In summary, the results of the study suggest that foliar application of 50 ppm IAA + 50 ppm GA₃ + 50 ppm NAA is an effective strategy to improve vegetative growth, flowering behavior, and productivity of mungbean under field conditions, and this may be an effective implementation in field level to ensure sustainable pulse production.

5. Conclusions

The present study clearly demonstrated that plant growth regulators significantly influence vegetative growth, flowering, and yield performance of mungbean (*Vigna radiata* L.). Compared with other concentrations, the optimum ratio of combined application of 50 ppm IAA + 50 ppm GA₃ + 50 ppm NAA (T₇) showed the best results in Mungbean. In contrast, the lowest performances were found in untreated control plants, and lower performance in excess amounts of plant growth regulators. It was observed that the combined effect of higher concentrations (100 ppm) of IAA, GA₃, and NAA was comparatively less effective than the combined 50 ppm concentrations. This proves that optimum concentrations of plant growth regulators are more effective than excessive application to achieve better Mungbean growth and production. Therefore, the combined foliar application of 50 ppm IAA + 50 ppm GA₃ + 50 ppm NAA can be considered an effective agronomic practice in the field to obtain better vegetative growth and flowering characters and maximum yield under the agroecological environment in Bangladesh. However, further multi-location and multi-season studies are recommended to validate these findings in different climates, soil conditions, and mungbean genotypes; also, analysis of physiological, biochemical, and molecular mechanisms of plant growth regulator interactions on Mungbean would provide deeper observations to analyze their role in enhancing mungbean productivity.

Author Contributions

The study was conducted with the collaborative performance of the authors. Dr. Md. Ashabul Hoque, Jannatul Fardausy, and Md. Rafikul were involved in conceptualization and methodology preparation. Jannatul Fardausy and Md. Akram Hossain collected data. Md. Rafikul Islam analyzed the data and wrote the original draft. All authors were involved in the review and editing of the draft paper. Dr. Md. Ashabul Hoque supervised the study. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this research paper.

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