**Effect of Foliar Application of Gibberellic Acid on Growth and Yield of Mungbean**

**(*Vigna radiata* L.)**

**ABSTRACT**

|  |
| --- |
| Gibberellic acid (GA3) can significantly improve growth, yield and yield components of mungbean when applied as a foliar spray or seed treatment. This study aimed to determine the optimal rate and time of foliar GA₃ application on the improvement of growth and yield of mungbean (Yezin 14) variety in the post-monsoon seasons of 2023-24 and 2024-25. The experiment was conducted at Yezin Agricultural University farm, Myanmar by using Randomized Complete Block Design with three replications. In both experiments, there were ten treatments: control (no GA3 with water spray) (T1), 50 ppm GA3 at 20 days after sowing (DAS) (T2), 100 ppm GA3 at 20 DAS (T3), 150 ppm GA3 at 20 DAS (T4), 50 ppm GA3 at 40 DAS (T5), 100 ppm GA3 at 40 DAS (T6), 150 ppm GA3 at 40 DAS (T7), 50 ppm GA3 at 20 and 40 DAS (T8), 100 ppm GA3 at 20 and 40 DAS (T9) and 150 ppm GA3 at 20 and 40 DAS (T10). Key growth parameters yield and yield components, and some physiological traits were measured throughout the growing season. Results showed that foliar application of 100 ppm GA₃ at both 20 and 40 DAS (T9) significantly enhanced plant height, SPAD value, leaf area index (LAI), crop growth rate (CGR), and total dry matter compared to other treatments. This treatment also resulted the highest number of branches and pods per plant, pod length, seed yield (1927.9 kg ha⁻1 in 2023-24 and 1554.7 kg ha⁻1 in 2024-25), shelling percentage, and harvest index. These findings highlight that application of 100 ppm GA3 twice during the early growth stages markedly enhances mungbean productivity under the agro-climatic conditions of Yezin, Nay Pyi Taw.  |

***Keywords****:* ***Mungbean; GA3; growth; yield; foliar application***

**1. Introduction**

Pulses are Myanmar's largest export and the second most important crop for domestic consumption. They provide dietary protein and fiber and are a significant source of vitamins and minerals. Among pulses, mungbean (*Vigna radiata* L.) is one of the most important short-season grain legumes in the conventional farming systems of tropical and temperate regions. It can be grown on a variety of soils and under diverse climatic conditions, as it is tolerant to drought (Malik et al., 2006). The seed of mungbean contains approximately 26% protein, 62.5% carbohydrates, 1.4% fat, 4.2% fiber, and essential minerals and vitamins (Ali & Gupta, 2012).

Plant growth regulators (PGRs) are natural or synthetic compounds that influence physiological processes such as germination, growth, flowering, fruiting, and senescence (Small & Degenhardt, 2018). Foliar application is often preferred when quick nutrient supply is required or when soil conditions hinder nutrient uptake (Salisbury & Ross, 1985). Additionally, GA3, a key plant growth regulator, plays a crucial role in stem elongation, seed germination, breaking dormancy, leaf expansion, flowering, and fruit development (Hedden & Phillips, 2000; Rezaie, 2007). Application of an appropriate concentration of GA3 has been shown to significantly affect the growth and yield components of various crops, including mungbean (Naserpur, 2007). As demand for pulses continues to rise in the world and due to more crop diversification, abrupt weather, limited land availability, resource poor cultivator, etc might lead to focus on other avenues to increase production and productivity of pulse crop. In this juncture, optimizing the use of plant growth regulators like GA3 offers a valuable pathway toward sustainable legume production. The present study highlights that to achieve maximum seed yield, it is important to apply GA3 at optimum concentration at appropriate growth stages i.e 20 and 40 DAS can significantly enhance the productivity of the mungbean cultivar. A favourable condition for crop growth and development may be induced by applying a growth regulator exogenously in a proper concentration at a proper time in the mungbean crop by GA3**.** However, despite its potential benefits, research on the effects of different GA3 application rates and times on mungbean growth and yield in Myanmar remains limited.

This study was conducted to address this knowledge gap by investigating the effects of foliar GA₃ application on the growth and yield of mungbean (Yezin 14) variety during the post-monsoon seasons of 2023-24 and 2024-25. Specifically, the objectives were as follows:

1. To investigate the effect of GA3 on growth and yield of mungbean, and
2. To determine the appropriate rate and time of GA3 for mungbean production

**2. Material and Methods**

**2.1 Experimental Site**

The field experiment was conducted during the post-monsoon seasons of 2023-24 and 2024-25 at the Agronomy farm, Yezin Agricultural University, Myanmar (latitude 19.72°N, longitude 96.13°E and 129 meters above sea level). The soil type of the experimental area was sandy loam. The total experimental area was (661.5) m2, with each plot measuring 5 m × 2 m with 1m distance between plots.

**2.2 Experimental Design and Treatments**

The study was employed a Randomized Complete Block Design (RCBD) with three replications. Ten foliar application treatments of gibberellic acid (GA3) were as follows:

* T1 : Control (no GA3 with water spray)
* T2 : 50 ppm GA3 applied at 20 DAS
* T3 : 100 ppm GA3 applied at 20 DAS
* T4 : 150 ppm GA3 applied at 20 DAS
* T5 : 50 ppm GA3 applied at 40 DAS
* T6 : 100 ppm GA3 applied at 40 DAS
* T7 : 150 ppm GA3 applied at 40 DAS
* T8 : 50 ppm GA3 applied at both 20 and 40 DAS
* T9 : 100 ppm GA3 applied at both 20 and 40 DAS
* T10 : 150 ppm GA3 applied at both 20 and 40 DAS

Each treatment was randomly assigned to individual plots, and GA3 foliar applications were made manually using a hand sprayer between 09:00 and 11:00 in the morning to ensure uniform coverage and optimal absorption.

**2.3 Preparation of GA₃ Solutions**

GA3 powder was dissolved in water to prepare stock solutions. For 50 ppm, 50 mg of GA3 was dissolved in water to make a final volume of 1 L. Similarly, 100 ppm and 150 ppm solutions were prepared by dissolving 100 mg and 150 mg of GA3, respectively, in 1 L of water.

**2.4 Crop Management**

The land was ploughed and harrowed to achieve fine tilth, followed by leveling and marking of plots. Yezin 14 mungbean variety, commonly grown in central Myanmar, was used as tested cultivar. Two to Three seeds were sown in each hole at a spacing of 30 cm × 10 cm. Sowing depth was 2-3 cm in soil. The plot was composed of seven lines. Thinning was carried out at 14 DAS to maintain two healthy plants per hill. Urea, Triple Super Phosphate, Muriate of Potash were applied as basal at final land preparation at 14, 30 and 20 kg ha-1 respectively. Insecticide sprays and manual weeding were done whenever it was needed in both seasons. Pods were harvested twice during the post-monsoon season in each year.

**Table 1. Physicochemical properties of experimental soil before experiment**

|  |  |
| --- | --- |
| **Characteristics** | **Rating** |
| Sand (%) | 82.36 |
| Silt (%) | 10.66 |
| Clay (%) | 6.98 |
| Soil textural class  | Loamy sand |
| Available N (mg kg-1) | 105 (High) |
| Available P2O5 (mg kg-1) | 12 (Medium) |
| Available K2O (mg kg-1) | 47 (Low) |
| Exchangeable Ca (cmolc kg-1) | 2.9 (Low) |
| Exchangeable Mg (cmolc kg-1) | 0.88 (Medium) |
| Exchangeable Na (cmolc kg-1) | 0.09 (Very low) |
| Organic matter (%) | 0.76 (Low) |
| Moisture (%) | 12.71 |
| pH | 6(Moderately acid) |



**Figure 1. Monthly rainfall, maximum and minimum temperature during experimental periods in Yezin**

**2.5 Data Collection and Calculation**

**Growth Parameters**

Plant height was measured weekly from 21 to 70 DAS on five tagged plants per plot using a meter scale from the base to the uppermost growing point of the plant. The number of branches per plant was recorded at harvest from five randomly selected plants per plot. Total dry matter (TDM) was measured at 10-day intervals from 30 to 70 DAS. Five plants per plot were oven-dried at 70 °C for 72 hours, and dry weights of leaves, stems, and reproductive parts were recorded.

**SPAD value** : Chlorophyll content was estimated using a SPAD meter at 58 DAS on five randomly selected plants per plot.

**Leaf area index (LAI)**: Leaf area index (LAI) was determined at 10-day intervals from 30 to 70 DAS using a Li-Cor 3100 leaf area meter. LAI was calculated as the ratio of total leaf area to ground area by the formula described by Watson, (1947).

**LAI** = $\frac{Leaf area}{Ground area}$

**Crop growth rate (CGR)**: CGR of mungbean was measured in g m-2 day-1 by the formula, Watson, (1947).

$$CGR =\frac{(W2 - W1)}{(T2 - T1) × Area}$$

Where,

W1 and W2 = total dry weight of plant

 T1 and T2 = sampling times

Number of pods per plant was counted from five randomly selected plants per plot at harvest. Pod length was measured from ten randomly collected pods per plot. The number of seeds per pod was determined using 10 pods per plot. Hundred seed weight was weighed from a random sample of 100 seeds per plot using an electrical balance. Shelling percentage (%) was calculated by dividing the weight of seeds by the weight of the pods and multiplying by 100.The harvest index was estimated by dividing the seed yield and biological yield from the same area and multiplying the result by 100 (Gardner et al., 1985). Total seed yield was calculated from the actual harvest area per plot and converted to kilograms per hectare (kg ha-1) and adjusted to 12% moisture content.

**2.6 Statistical Analysis**

All collected data were subjected to analysis of variance (ANOVA) using Statistix 8.0 software. Significant differences among treatment means were separated using the Least Significant Difference (LSD) test at the 0.05 % probability level.

**3. Results and Discussion**

**3.1 Plant Height**

The foliar application of GA3 significantly affected plant height in both experimental seasons (2023-24 and 2024-25). The tallest plants were recorded for treatment T9 (100 ppm GA3 applied at both 20 and 40 DAS), reaching 56.75 cm and 67.22 cm at 70 DAS in the respective seasons (Fig. 2A and 2B). In contrast, the control (T1) showed the shortest plant height (45.06 cm and 54.64 cm) in both seasons. The increase in plant height may be due to dual applications of 100 ppm GA3 that suggests a cumulative effect of hormone action on internode elongation and meristematic activity. Similar results of increases due to GA₃ treatments have been found in various plants by different researchers (Tasnim et al., 2019; Jahan et al.,2018). The dose-dependent effect of GA3 was also evident, as higher concentrations (e.g., 150 ppm) did not yield greater increases in plant height compared to 100ppm. These findings suggest that appropriate GA3 concentration is crucial for maximizing growth of mungbean without inducing physiological stress or diminishing returns.

 (A) (B)

**Figure 2. Mean values of plant height as affected by different foliar gibberellic acid application during post-monsoon season, (A) 2023–24 and (B) 2024–25**

**3.2 SPAD Value**

There was significantly different in SPAD value among different concentrations of foliar GA3 application (Table 2). The highest SPAD value (52.38 in 2023-24 and 38.62 in 2024-25) was recorded from treatment T9 (100 ppm GA₃ at both 20 and 40 DAS), whereas the lowest values were obtained in the control plots (T1). According to research on mungbean, foliar spraying of GA3 can improve nutrient absorption especially nitrogen and magnesium which are critical for chlorophyll synthesis and as a result, SPAD values. These results are supported by several studies reporting that GA3 enhanced the chlorophyll content in *Vigna radiata* (Karamany et al., 2019) as well as other crops like wheat (Pazuki et al., 2013).

|  |  |  |
| --- | --- | --- |
| **Treatments** | **SPAD values at 58 DAS** | **SPAD values at 58 DAS** |
| **(2023-24)** | **(2024-25)** |
| T1 | 41.55 j | 30.50 c |
| T2 | 42.61 i | 31.96 bc |
| T3 | 43.89 f | 34.39 bc |
| T4 | 48.29 b | 32.92 ab |
| T5 | 45.47 d | 34.10 bc |
| T6 | 45.85 c | 36.22 ab |
| T7 | 43.54 g | 32.65 bc |
| T8 | 43.07 h | 32.31 bc |
| T9 | 52.38 a | 38.62 a |
| T10 | 44.86 e | 33.65 bc |
| LSD 0.05 | 4.58 | 4.12 |
| Pr > F | \*\* | \* |
| CV % | 5.91 | 7.11 |

**Table 2. Mean values of SPAD value as affected by different foliar gibberellic acid application during the post-monsoon seasons, 2023-24 and 2024-25**

\* Means followed by different letter in the same column are significantly different by LSD test at 5% level

**3.3 Total Dry Matter (TDM)**

Total dry matter (TDM) accumulation was significantly affected by GA3 application (Fig. 3A and 3B). TDM was recorded at ten-day intervals started from 30 to 70 DAS. The maximum TDM (18.67 g m⁻² in 2023-24 and 13.83 g m⁻² in 2024-25) at 70 DAS was achieved with treatment T9, while the minimum was recorded in the control (T1). Exogenous GA3 application stimulated overall plant growth by enhancing cell division and elongation, resulting in increased biomass production (Akter et al., 2007). Among the treatments, T9 consistently outperformed others, likely due to the synergistic effect of two application timings that ensured sustained hormonal influence during critical growth phases. This result is consistent with previous studies showing that GA3 improves dry matter accumulation in crops such as mustard and soybean by enhancing leaf area and photosynthetic capacity (Islam et al., 2021).

 (A) (B)

**Figure 3. Mean values of total dry matter as affected by different foliar gibberellic acid application during post-monsoon season, (A) 2023–24 and (B) 2024–25**

**3.4 Leaf Area Index (LAI)**

The GA3 application had a significant effect on LAI, with treatment T₉ showing the highest LAI (4.68 in 2023-24 and 1.96 in 2024-25) at 50 DAS. The lowest LAI was observed in the control (T1) (Fig. 4A and 4B). The highest leaf area index observed with GA3 application may result from its role in upregulating genes that promote cell wall loosening and carbohydrate metabolism, which supports greater leaf development. This indicates that LAI and TDM are the most important parameters for increasing seed yield. Tesfaye et al. (2006) reported that attainment of high LAI reduces soil water evaporation, intercepts and converts radiation into dry matter efficiently and partitioning of the dry matter to the seed which is the major requirement for high seed yield.

 (A) (B)

**Figure 4. Mean values of leaf area index (LAI) as affected by different foliar gibberellic acid application during post-monsoon season, (A) 2023–24 and (B) 2024–25**

**3.5 Crop Growth Rate (CGR)**

Crop growth rate (CGR) was significantly higher in GA3-treated plots compared to the control, particularly during the growth stages (40-50 DAS) (Fig. 5A and 5B). The maximum CGR (27.09 g m⁻2 day⁻1 in 2023-24 and 17.48 g m⁻2 day⁻1 in 2024-25) was recorded in treatment T9. This enhancement in CGR values is mainly due to faster translocation of assimilates and utilization of carbohydrates by the sink in an efficient way. Improvement in growth parameters of mungbean crop due to foliar application of different concentrations of GA3 over untreated (control) may be because of beneficial effects of GA3 on cell multiplication that might reflect the rapid increase in CGR, increase in photosynthetic activity and supported efficient translocation of photosynthates from source to sink resulted in higher dry matter accumulation in mungbean crop. The results of the present experiment support by the findings of (Salingpa et al., 2018; Sarwar et al., 2017). Further findings suggested by (Singh & Jambukiya, 2020) in green gram and (Kunjammal & Sukumar, 2019) in green gram. Thus, foliar application of GA3 appears to be a promising strategy for boosting mungbean productivity by accelerating growth dynamics.

 (A) (B)

**Figure 5. Mean values of crop growth rate as affected by different foliar gibberellic acid application during post-monsoon season, (A) 2023-24 and (B) 2024-25**

**3.6 Yield and Yield Components**

Foliar application of GA3 significantly improved several yield components including number of branches per plant, number of pods per plant, pod length, number of seeds per pod, shelling percentage and harvest index. Treatment T9 (100 ppm GA3 applied at both 20 and 40 DAS) consistently outperformed other treatments in both seasons (Tables 3 and 4). The increase in pod number per plant could be linked to enhanced flowering and fruit set facilitated by GA3-induced hormonal regulation (Ilias et al., 2007). Similarly, pod length and seed count per pod were positively influenced by GA3, likely due to enhanced xylem and phloem development, facilitating better nutrient supply to developing seeds (Agawane & Parhe, 2015). Harvest index (HI) was also significantly improved by GA3 application treatments compared with control, with T9 achieving the highest HI (0.38 and 0.42 in the two seasons). Improved HI indicates better partitioning of assimilates toward reproductive structures, likely due to enhanced sink strength and source-sink coordination (Navya et al., 2021).

 The maximum seed yield was observed from treatment T9, with seed yields of 1927.9 kg ha-1 in 2023-24 and 1554.7 kg ha-1 in 2024-25, which represented significant improvements compared to other treatments (Fig. 6A and 6B). These results are consistent with earlier studies in soybean and mungbean where GA3 application enhanced yield through similar physiological mechanisms (Tiwari et al., 2018; Upadhyay & Ranjan, 2015).

Pr>F = \*\* LSD0.05 = 149.06 CV (%) = 6.01

Pr>F = \*\*

LSD0.05 = 222.48 CV (%) = 10.33

 (A) (B)

**Figure 6. Mean values of seed yield as affected by different foliar gibberellic acid**

 **application during the post- monsoon season, (A) 2023-24 and (B) 2024-25**

T**able 3. Yield and yield components of mungbean as affected by foliar gibberellic acid**

 **application during the post-monsoon season, 2023-24**

\* Means followed by different letter in the same column are significantly different by LSD test at 5% level

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **Branches plant-1 (no.)** | **Pods plant-1 (no.)** | **Pod length (cm)** | **Seeds pod-1 (no.)** | **Hundred seed weight (g)** | **Shelling %** | **Harvest index** |
| T1 | 3.40 e | 25.00 d | 8.24 c | 9.77 c | 5.64 | 69.66 d | 0.23 c |
| T2 | 4.52 cd | 41.00 c | 9.00 ab | 10.93 b | 6.05 | 72.75 abc | 0.35 ab |
| T3 | 4.27 d | 50.67 abc | 9.11 ab | 10.83 b | 5.95 | 72.32 bc | 0.36 ab |
| T4 | 5.15 abc | 50.00 abc | 9.10 ab | 10.83 b | 5.81 | 71.80 bc | 0.31 b |
| T5 | 4.80 bcd | 46.00 bc | 8.88 b | 11.00 b | 5.51 | 71.38 cd | 0.32 b |
| T6 | 4.94 abc | 53.33 abc | 9.24 ab | 11.03 b | 6.1 | 72.65 abc | 0.37 ab |
| T7 | 4.83 bcd | 50.33 abc | 9.07 ab | 10.83 b | 5.78 | 72.78 abc | 0.33 ab |
| T8 | 5.36 ab | 55.00 ab | 9.27 ab | 11.20 b | 5.79 | 73.41 ab | 0.36 ab |
| T9 | 5.57 a | 61.67 a | 9.36 a | 12.20 a | 6.24 | 74.38 a | 0.38 a |
| T10 | 5.25 ab | 58.67 ab | 9.35 a | 11.27 ab | 5.79 | 72.89 abc | 0.34 ab |
| LSD 0.05 | 0.64 | 13.02 | 0.42 | 0.99 | 0.55 | 2.03 | 0.06 |
| Pr > F | \*\* | \*\* | \*\* | \* | ns | \* | \*\* |
| **CV %** | **7.77** | **15.44** | **2.68** | **5.29** | **5.42** | **1.63** | **9.87** |

**Table 4. Yield and yield components of mungbean as affected by foliar gibberellic**

 **acid application during the post-monsoon season, 2024-25**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **Branches plant-1****(no.)** | **Pods plant-1 (no.)** | **Pod length****(cm)** | **Seeds pod-1 (no.)** | **Hundred seed weight (g)** | **Shelling %** | **Harvest index** |
| T1 | 3.23 e | 28.00 c | 8.59 c | 10.70 c | 6.69 | 69.47 c | 0.25 b |
| T2 | 4.30 cd | 42.00 b | 10.04 b | 11.47 b | 6.52 | 73.01 ab | 0.41 a |
| T3 | 4.07 d | 48.93 ab | 9.88 b | 11.63 ab | 6.65 | 72.63 ab | 0.38 a |
| T4 | 4.90 abc | 47.93 ab | 10.14ab | 11.63 ab | 6.63 | 73.23 ab | 0.39 a |
| T5 | 4.57 bcd | 44.00 ab | 10.30ab | 11.80 ab | 6.73 | 73.20 ab | 0.36 a |
| T6 | 4.70 abc | 49.67 ab | 10.26ab | 11.53 ab | 6.79 | 72.71 ab | 0.41 a |
| T7 | 4.60 bcd | 49.33 ab | 10.28ab | 11.57 ab | 6.46 | 72.42 b | 0.35 a |
| T8 | 5.10 ab | 52.00 ab | 10.35ab | 11.93 ab | 6.70 | 74.40 ab | 0.40 a |
| T9 | 5.30 a | 54.33 a | 10.68a | 12.17 a | 6.80 | 74.84 a | 0.42 a |
| T10 | 5.00 ab | 50.00 ab | 10.31ab | 11.80 ab | 6.72 | 74.48 ab | 0.41 a |
| LSD 0.05 | 0.61 | 11.32 | 0.62 | 0.66 | 0.27 | 2.28 | 0.09 |
| Pr > F | \*\* | \*\* | \*\* | \* | ns | \*\* | \* |
| **CV %** | **7.76** | **14.16** | **3.59** | **3.30** | **2.39** | **1.82** | **14.45** |

\* Means followed by different letter in the same column are significantly different by LSD

 test at 5% level

**4. Conclusion**

The results demonstrated that foliar application of GA3 significantly enhanced key growth parameters including plant height, SPAD values, total dry matter, leaf area index (LAI) and crop growth rate (CGR). Among all treatments, the application of 100 ppm GA3 at both 20 and 40 days after sowing (T9) produced the highest seed yield across both experimental seasons (2023-24 and 2024-25). This treatment also resulted in significant improvements in yield and yield components, including the number of branches per plant, pods per plant, pod length, seeds per pod, shelling percentage, harvest index, and ultimately, seed yield. Based on findings of the two seasons study, the application of 100 ppm GA3 at 20 and 40 DAS was identified as the optimum concentration and appropriate time of foliar treatment for enhancing the growth and yield of mungbean under the studied conditions. The present study highlights that to achieve maximum seed yield, it is important to apply GA3 at optimum concentration at appropriate growth stages, which can significantly enhance the productivity of the tested mungbean cultivar. As global demand for pulses continues to rise, optimizing the use of plant growth regulators like GA3 offers a valuable pathway toward sustainable intensification of legume production, especially in resource-limited settings.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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