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# EFFECT OF NANO DAP ON GROWTH AND YIELD ATTRIBUTES OF GREEN GRAM (*Vigna radiata* L.)

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**ABSTRACT**

A pot experiment was conducted during the *Kharif* season of 2023 at Department of Soil Science, SAS, Medziphema Campus, Nagaland University, evaluate the effect of Nano Diammonium Phosphate (Nano-DAP) on growth and yield attributes of green gram (*Vigna radiata* L.) in acidic soil. Thirteen treatments, including control ($T_0$), T1: 100% DF (20:40:40 kg N:P:K $ha^{-1}$), T2: 75% P + 100% N and K,T3: 50% P + 100% N and K, T4: 25% P + 100% N and K, T5: T2 + seed treatment (ST) with Nano DAP @ 5 ml $kg^{-1}$ seed + 2 foliar sprays (FS) @ 2 ml $L^{-1}$, T6: T2 + ST with Nano DAP @ 5 ml $kg^{-1}$ seed + 1 FS @ 4 ml $L^{-1}$ , T7: T3 + ST with Nano DAP @ 5 ml $kg^{-1}$ seed + 2 FS @ 2 ml $L^{-1}$ , T8: T3 + ST with Nano DAP @ 5 ml $kg^{-1}$ seed + 1 FS @ 4 ml $L^{-1}$, T9: T4 + ST with Nano DAP @ 5 ml $kg^{-1}$ seed + 2 FS @ 2 ml $L^{-1}$, T10: T4 + ST with Nano DAP @ 5 ml $kg^{-1}$ seed + 1 FS @ 4 ml $L^{-1}$, T11: ST with Nano DAP @ 5 ml $kg^{-1}$ seed + 2 FS @ 2 ml $L^{-1}$ and T12**:** ST with Nano DAP @ 5 ml $kg^{-1}$ seed + 1 FS @ 4 ml $L^{-1}$ were arranged in a completely randomized design with three replications. Growth parameters, including plant height, number of leaves, and branches, as well as yield attributes such as pod length, pods per plant, seeds per pod, seed and stover yield, and harvest index, were recorded. Results revealed that treatments integrating Nano-DAP with reduced phosphorus $T_6$: $T_2$ + seed treatment + one foliar spray @ 4 ml $L^{-1}$), and ($T_5$: $T_2$ + seed treatment + two foliar sprays @ 2 ml $L^{-1}$) produced the highest plant height (50.20 and 50.08 cm), number of leaves (31.38 and 31.22), branches (5.55 and 5.45), pod length (8.80 and 8.33 cm), pods per plant (18.38 and 17.70), seeds per pod (12.43 and 11.80), seed yield (11.6 and 11.5 g $pot^{-1}$), stover yield (14.8 and 14.7 g $pot^{-1}$), and harvest index (43.91 and 43.87 %), outperforming the control ($T_0$) and reduced phosphorus treatments without Nano-DAP ($T_2$–$T_4$). Enhanced performance was attributed to improved nitrogen and phosphorus availability, promoting vegetative growth, reproductive development, and assimilate partitioning. These findings suggest that integrating Nano-DAP with partial fertilizer doses ($T_5$ and $T_6$) is an effective strategy for improving growth, yield, and nutrient use efficiency in green gram, supporting sustainable pulse production.

***Keywords*** **:** Mung bean, Acidic soil, Nano-DAP, Nutrient management, Plant growth, Yield attributes, Phosphorus use efficiency, Sustainable agriculture.

## Introduction

Among the various pulse crops grown in India, green gram (*Vigna radiata* L.) holds a significant position as a traditional legume, primarily cultivated during the *Kharif* season (Mondal and Sengupta, 2020). It is an important dietary source of protein and contributes to sustainable agriculture through its ability to fix atmospheric nitrogen via a symbiotic relationship with *Rhizobium* species (Khandare *et al.*, 2024). The efficiency of nitrogen fixation and overall crop productivity largely depend on nutrient availability, particularly phosphorus, which promotes nodulation and enhances protein content, dry matter accumulation, and grain yield (Pandey *et al.*, 2016). Green gram is considered the third most important pulse crop in India after chickpea and pigeonpea. During 2023–24, it was cultivated on 3.787 million hectares, producing 2.916 million tonnes, with an average yield of 670 kg $ha^{-1}$ (Anonymous, 2024). However, the productivity of green gram is often limited due to poor nutrient management, especially phosphorus deficiency (Poudel *et al.*, 2023). In recent years, nanotechnology-based fertilizers have emerged as a promising strategy to improve nutrient use efficiency and crop performance (Nehra *et al.*, 2024). One such innovation, Nano Diammonium Phosphate (Nano DAP), has attracted attention as a potential alternative to conventional fertilizers due to its higher surface area, controlled nutrient release, and enhanced bioavailability (Girigoud *et al.*, 2023). Nano DAP supplies essential nitrogen and phosphorus while also stimulating microbial activity in the rhizosphere, thereby improving nodulation and nitrogen fixation in leguminous crops (Saitheja *et al.*, 2022). Therefore, studying the effect of Nano DAP on the yield attributes of green gram is essential to understand its potential for enhancing productivity, improving nutrient efficiency, and promoting sustainable agriculture. Such research can help optimize fertilizer management practices, reduce reliance on conventional chemical fertilizers, and ultimately contribute to improved pulse production and food security (Patel *et al.*, 2020).

## Materials and Methods

### Experiment site and treatment details

A pot experiment titled "Effect of Nano DAP on Growth and Yield Attributes of Green Gram (*Vigna radiata* L.) in Acidic Soil of Nagaland" was conducted at the Experimental Research Farm of the Department of Soil Science, SAS, Medziphema Campus, Nagaland University, during the *Kharif* season of 2023. The site is located at an altitude of 305–310 m above mean sea level, at 25°45′43″ N latitude and 93°53′04″ E longitude. Medziphema is a sub-humid tropical region with 70–80% relative humidity, 2000–3000 mm of rainfall, and temperatures ranging from 21–30°C in summer to a minimum of 8°C in winter.

Prior to the experiment, the soil was analyzed for its physico-chemical, biological, and physical properties. The soil was very strongly acidic (pH 4.54) with high organic carbon content (1.19%). Available nitrogen (129.23 kg $ha^{-1}$) and potassium (106.66 kg $ha^{-1}$) were low, while phosphorus (11.12 kg $ha^{-1}$) was medium. The cation exchange capacity was low (9.70 cmol ($p^+$) $kg^{-1}$), and electrical conductivity was normal (0.06 dS $m^{-1}$). Soil microbial respiration (0.688 mg $CO_2$ $g^{-1}$ soil 24 $h^{-1}$) and microbial biomass carbon (258.44 µg $g^{-1}$) indicated moderate biological activity. Physical properties such as bulk density (1.33 g $cm^{-3}$), particle density (2.22 g $cm^{-3}$), and porosity (24.26%) were also measured.

The experiment was conducted using a Completely Randomized Design (CRD) with three replications and thirteen treatments, including a control. The treatments included the following:

### Treatments Details

| | |
|---|---|
| $T_0$ | Control (no fertilizer) |
| $T_1$ | 100% Recommended Dose of Fertilizer (20:40:40 kg N:P:K $ha^{-1}$) |
| $T_2$ | 75% phosphorus + 100% nitrogen and potash |
| $T_3$ | 50% phosphorus + 100% nitrogen and potash |
| $T_4$ | 25% phosphorus + 100% nitrogen and potash |
| $T_5$ | $T_2$ + seed treatment with Nano DAP @ 5 ml/kg seed + two foliar sprays @ 2 ml/L |
| $T_6$ | $T_2$ + seed treatment with Nano DAP @ 5 ml/kg seed + one foliar spray @ 4 ml/L |
| $T_7$ | $T_3$ + seed treatment with Nano DAP @ 5 ml/kg seed + two foliar sprays @ 2 ml/L |
| $T_8$ | $T_3$ + seed treatment with Nano DAP @ 5 ml/kg seed + one foliar spray @ 4 ml/L |
| $T_9$ | $T_4$ + seed treatment with Nano DAP @ 5 ml/kg seed + two foliar sprays @ 2 ml/L |
| $T_{10}$ | $T_4$ + seed treatment with Nano DAP @ 5 ml/kg seed + one foliar spray @ 4 ml/L |
| $T_{11}$ | Seed treatment with Nano DAP @ 5 ml/kg seed + two foliar sprays @ 2 ml/L |
| $T_{12}$ | Seed treatment with Nano DAP @ 5 ml/kg seed + one foliar spray @ 4 ml/L |

### Experimental setup and crop management

The study was conducted in earthen pots, which were cleaned, sun-dried for two days, and filled with 15 kg of soil per pot on 26 June 2022 to ensure uniform growing conditions. Each pot received fertilizers supplying the recommended doses of nitrogen, phosphorus, and potassium: 194 mg urea, 1116 mg single super phosphate, and 148.7 mg muriate of potash. Nano DAP was applied as a seed treatment (5 ml $kg^{-1}$) and as a foliar spray (2 or 4 ml $L^{-1}$) according to the treatment specifications. Seeds of green gram (Pant Moong-2 variety) were sown at five seeds per pot, 1.5 cm deep, on 17 July 2023, and thinned to two healthy plants per pot 15 days after sowing. Hand weeding was performed at 20, 30, and 45 DAS, and insect and pest infestations were managed by hand picking and insecticide sprays at 30 and 45 DAS. Pod harvesting was carried out in two to three pickings. After the final picking, the remaining crop was harvested from ground level to record stover yield. Harvested pods were sun-dried for 5–10 days before threshing, and seeds were separated and cleaned manually for further analysis.

### Observations Recorded

Observations on growth attributes, including plant height (cm), number of leaves per plant, and number of branches per plant, were recorded from tagged plants at 20 DAS, 40 DAS, and at harvest for each treatment.

Yield attributes, including pod length (cm), number of seeds per pod, and number of pods per plant, were also recorded from tagged plants. Pod length and seed number per pod were measured from five randomly selected pods per plant, and averages were calculated for each treatment. Seed and stover yields (g $pot^{-1}$) were determined after drying, threshing, and cleaning. The harvest index (%) was calculated from seed and stover yield data. Economic yield was considered as seed yield, while biological yield was defined as the sum of seed and stover yields. The harvest index for each treatment was calculated using the following formula:

$$Harvest\ index = \frac{Economic\ yield}{Biological\ yield} \times 100$$

**Statistical analysis**

The data were statistically analyzed following the procedures described by Gomez and Gomez (1984). Statistical significance was determined using an F-test, and differences between treatment means were compared at a 5% probability level using the critical difference (CD).

## Results and Discussion

**Growth Attribute – Plant height**

Table 1 shows that the plant height of mung bean was significantly influenced by different fertilizer levels and Nano-DAP applications at all growth stages (20 DAS, 40 DAS, and at harvest). The results clearly indicated that integrated nutrient management practices enhanced vegetative growth compared to the control. At 20 DAS, the highest plant height was recorded in T1 (19.33 cm), followed closely by T6 (19.07 cm) and T5 (18.70 cm), while the lowest was observed in the control (T0: 14.20 cm). A similar trend was observed at 40 DAS, where T6 (38.07 cm) and T5 (38.02 cm) recorded maximum plant height, surpassing even the 100% recommended dose of fertilizer (T1: 37.04 cm). At harvest, T6 (50.20 cm) recorded the highest plant height, closely followed by T5 (50.08 cm) and T1 (49.77 cm), whereas the control (36.53 cm) remained significantly lower. The enhanced plant height in T5 and T6 may be attributed to improved nutrient availability and uptake, particularly phosphorus and nitrogen, through Nano-DAP application. The nanoscale formulation likely increased nutrient use efficiency, leading to better cell division, elongation, and overall vegetative growth. In contrast, reduced phosphorus treatments without Nano-DAP (T2–T4) resulted in comparatively lower plant height, highlighting the essential role of phosphorus in crop growth. These findings are supported by Khan *et al.* (2017) and Ghimirey *et al.* (2024). The present study suggests that integrating Nano-DAP with reduced fertilizer doses can effectively enhance plant growth and may serve as a sustainable nutrient management strategy. Similar results have been reported in previous studies, where combining 50% RDF with 50% nano N: P: K and $ZnSO_4$ improved rice plant height, indicating enhanced nutrient availability and uptake (Elavarasan *et al.*, 2021). Kanjilal *et al.* (2023) reported that foliar application of nano-phosphorus significantly increased plant height. Nano-fertilizers have been shown to enhance growth by improving nutrient absorption and utilization (Nehra *et al.*, 2024; Thakur *et al.*, 2024). According to Khandare *et al.* (2024), foliar application of nano-urea and Nano-DAP significantly increased chickpea growth by enhancing nutrient use efficiency.

**Number of leaves per plant**

Table 1 revealed that the number of leaves per plant was significantly influenced by different nutrient management practices at all growth stages (20 DAS, 40 DAS, and at harvest). At 20 DAS, the maximum number of leaves was recorded in T1 (12.5), followed closely by T6 (12.3) and T5 (12.2), while the minimum was observed in the control (T0: 8.2). At 40 DAS, T6 (24.58) and T5 (24.32) again recorded the highest leaf counts, comparable to T1 (24.20), whereas the control remained the lowest (18.80). At harvest, the trend persisted, with T6 (31.38) and T5 (31.22) producing the maximum number of leaves, closely followed by T1 (31.11), while T0 (23.90) recorded the minimum. The higher leaf number in T5 and T6 indicates that Nano-DAP improved nutrient availability, particularly phosphorus and nitrogen, promoting cell division and leaf expansion. Treatments with reduced phosphorus without Nano-DAP (T2–T4) produced fewer leaves, highlighting the essential role of phosphorus in vegetative growth. These results suggest that integrating Nano-DAP with partial fertilizer doses enhances leaf development, canopy formation, and photosynthetic capacity, supporting higher yields. Consistent with previous reports, Jadhav *et al.* (2022) showed that SPAD-based nano-urea enhanced maize leaf number by improving nitrogen uptake and nutrient-use efficiency.

**Number of branches per plant**

The number of branches per plant was significantly influenced by different nutrient management practices at all growth stages (Table 1). At harvest, the highest number of branches was recorded in $T_6$ (5.55), followed closely by $T_5$ (5.45) and $T_1$ (5.36), while the control ($T_0$: 2.32) produced the lowest. Early-stage observations (20 and 40 DAS) showed similar trends, with Nano-DAP-treated plants producing more branches than reduced phosphorus treatments without Nano-DAP ($T_2$–$T_4$). The increased branching observed in $T_5$ and $T_6$ can be attributed to enhanced nutrient availability, particularly phosphorus and nitrogen supplied through Nano-DAP, which stimulated meristem activity and promoted vegetative growth. Treatments without Nano-DAP exhibited fewer branches, indicating that reduced phosphorus limits branch formation. These findings suggest that integrating Nano-DAP with partial fertilizer doses improves branching, thereby contributing to better canopy development and potential yield. Similarly, Girigoud *et al.* (2023) reported that foliar application of nano-fertilizers increased the number of branches per plant by enhancing nutrient uptake and improving nutrient-use efficiency.

**Yield Attribute- Pod length, Pods per plant, and Seeds per pod**

Different nutrient management practices significantly influenced pod length, number of pods per plant, and seeds per pod (Table 2). At harvest, the highest values were recorded in T6, with pod length (8.80 cm), pods per plant (18.38), and seeds per pod (12.43), followed closely by T5 (8.33 cm, 17.70 pods, 11.80 seeds) and T1 (7.77 cm, 17.12 pods, 10.70 seeds). The lowest values were observed in the control (T0: 4.80 cm, 12.33 pods, 6.53 seeds), indicating the positive effect of balanced fertilization and Nano-DAP application. The superior performance of T5 and T6 can be attributed to enhanced phosphorus and nitrogen availability through Nano-DAP, which likely improved flower formation, pollination efficiency, and seed set. Reduced phosphorus treatments without Nano-DAP (T2–T4) produced smaller pods and fewer seeds, highlighting the critical role of phosphorus in reproductive development. These outcomes are consistent with Sahu *et al.* (2024), who reported that increasing P levels led to a higher number of seeds per pod. The present results suggest that integrating Nano-DAP with partial fertilizer doses effectively enhances yield-contributing traits, supporting better reproductive growth and potential yield. Previous studies support these findings. Mondal and Sengupta (2020) reported that the application of 50% RDF with Bio-nano P at 25 and 50 DAS resulted in the highest number of pods. Elavarasan *et al.* (2021) observed that 50% RDF combined with 50% nano N:P:K and $ZnSO_4$ increased productive tillers by enhancing nutrient uptake. Saitheja *et al.* (2022) found that 100% RDN with foliar nano-urea increased pods per plant, seeds per pod, and grain yield. Girigoud *et al.* (2023) demonstrated that foliar application of nano-fertilizers maximized seed number and pods per plant by improving nutrient uptake and nutrient-use efficiency. Kanjilal *et al.* (2023) showed that foliar application of nano-phosphorus significantly increased the number of pods per plant in greengram. Similarly, Poudel *et al.* (2023) reported that 100% N and K, 75% P, and two foliar nano-P sprays at tillering and panicle initiation increased panicle number and length in wheat.

**Seed Yield, Stover Yield, and Harvest Index:**

Seed yield, stover yield, and harvest index (HI) of mung bean were significantly influenced by different nutrient management practices (Table 2). At harvest, the highest seed yield was recorded in $T_6$ (11.6 g pot$^{-1}$), closely followed by $T_5$ (11.5 g pot$^{-1}$) and $T_1$ (11.3 g pot$^{-1}$), whereas the control ($T_0$) produced the lowest yield (6.2 g pot$^{-1}$). Similarly, stover yield was highest in $T_6$ (14.8 g pot$^{-1}$) and $T_5$ (14.7 g pot$^{-1}$). The harvest index was slightly superior in $T_5$ (43.91%) and $T_6$ (43.87%) compared to $T_1$ (43.52%). Reduced phosphorus treatments without Nano-DAP ($T_2$–$T_4$) resulted in lower seed yield, underscoring the importance of balanced fertilization for reproductive efficiency. The superior yield and harvest index in Nano-DAP-integrated treatments ($T_5$ and $T_6$) can be attributed to enhanced nutrient availability and uptake, particularly phosphorus and nitrogen, which likely improved pod development, seed set, and assimilate partitioning. Nano-DAP application through seed treatment and foliar spray compensated for reduced fertilizer doses, promoting efficient nutrient utilization for seed production. These results are consistent with previous studies. Baghla *et al.* (2023) reported that the combined application of RDF with foliar bio-nano P and K increased wheat yield through improved nutrient-use efficiency. Kanjilal *et al.* (2023) found that foliar application of nano-phosphorus significantly enhanced greengram yield. Singh *et al.* (2023) observed that foliar application of nano N and P at 30 DAS improved yield by enhancing nutrient availability and uptake. Poudel *et al.* (2023) reported that foliar sprays of nano-P with 100% N:K and 75% P improved wheat yield and quality, increasing grain, straw, and biological yield, as well as harvest index. Similarly, Zangani *et al.* (2024) concluded that elevated phosphorus levels enhanced seed yield.

## Conclusion

Integrating Nano-DAP with reduced fertilizer doses significantly improved the growth, yield attributes, and productivity of mung bean. Nano-DAP enhanced plant height, leaf number, and branching, as well as pod length, pods per plant, seeds per pod, and seed yield, by improving nutrient availability and nutrient-use efficiency, particularly of phosphorus and nitrogen. Treatments without Nano-DAP exhibited lower growth and yield, emphasizing the critical role of phosphorus in crop performance. These findings indicate that Nano-DAP integration represents an effective and sustainable nutrient management strategy for enhancing mung bean productivity under reduced fertilizer input.

## Future scope

Future studies should focus on optimizing Nano-DAP doses, evaluating its long-term effects on soil health, and exploring its integration with other nutrients. Mechanistic investigations on nutrient uptake and yield enhancement, along with assessments of economic and environmental benefits, will facilitate wider adoption of Nano-DAP in mung bean and other crops.

**Table 1 :** Effect of different nutrient sources on plant height, number of leaves, and number of branches of green gram (*Vigna radiata* L.)

| Treatment | Plant height (cm) | | | Number of leaves plant$^{-1}$ | | | Number of branches plant$^{-1}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | 20 DAS | 40 DAS | At Harvest | 20 DAS | 40 DAS | At Harvest | 20 DAS | 40 DAS | At Harvest |
| **$T_0$: Control** | 14.20 | 32.13 | 36.53 | 8.2 | 18.80 | 23.90 | 2.27 | 2.13 | 2.32 |
| **$T_1$:** 100% Recommended dose of fertilizer (20, 40 and 40 kg N:P:K ha$^{-1}$ ) | 19.33 | 37.04 | 49.77 | 12.5 | 24.20 | 31.11 | 3.76 | 4.08 | 5.36 |
| **$T_2$:** 75% Phosphorus + 100 % Nitrogen and Potash | 16.10 | 34.05 | 38.77 | 9.9 | 19.80 | 26.57 | 2.17 | 2.25 | 2.77 |
| **$T_3$:** 50% Phosphorus | 15.47 | 33.93 | 38.33 | 9.5 | 19.60 | 25.33 | 2.13 | 2.18 | 2.45 |
| **$T_4$:** 25% Phosphorus | 14.33 | 33.60 | 37.63 | 8.7 | 19.23 | 25.13 | 2.80 | 2.16 | 2.37 |
| **$T_5$:** $T_2$ +ST with Nano DAP @ 5 ml kg$^{-1}$ seed + 2 FS with Nano DAP @ 2 ml L$^{-1}$ | 18.70 | 38.02 | 50.08 | 12.2 | 24.32 | 31.22 | 3.55 | 4.13 | 5.45 |
| **$T_6$:** $T_2$ + ST with Nano DAP @ 5 ml kg$^{-1}$seed + 1 FS with Nano DAP @ 4 ml L$^{-1}$ | 19.07 | 38.07 | 50.20 | 12.3 | 24.58 | 31.38 | 3.56 | 4.21 | 5.55 |
| **$T_7$:** $T_3$ + 100 % Nitrogen and Potash + ST with Nano DAP @ 5 ml kg$^{-1}$ seed + 2 FS with Nano DAP @ 2 ml L $^{-1}$ | 17.80 | 36.80 | 48.80 | 11.5 | 22.53 | 30.23 | 3.16 | 3.77 | 4.48 |
| **$T_8$:** $T_3$ + 100 % Nitrogen and Potash + ST with Nano DAP @ 5 ml kg$^{-1}$ seed + 1 FS with Nano DAP @ 4 ml L $^{-1}$ | 18.27 | 36.87 | 49.17 | 11.8 | 23.23 | 30.80 | 3.22 | 4.02 | 5.33 |
| **$T_9$:** $T_4$ + 100 % Nitrogen and Potash + ST with Nano DAP @ 5 ml kg$^{-1}$ seed + 2 FS with Nano DAP @ 2 ml L $^{-1}$ | 17.13 | 35.17 | 45.33 | 11.1 | 21.77 | 29.37 | 2.48 | 3.30 | 4.09 |
| **$T_{10}$:** $T_4$ + 100 % Nitrogen and Potash + ST with Nano DAP @ 5 ml kg$^{-1}$seed + 1 FS with Nano DAP @ 4 ml L$^{-1}$ | 17.40 | 35.63 | 48.20 | 11.2 | 22.17 | 29.63 | 2.59 | 3.43 | 4.16 |
| **$T_{11}$:** ST with Nano DAP @ 5 ml kg$^{-1}$ seed + 2 FS with Nano DAP @ 2ml L$^{-1}$ | 16.43 | 34.50 | 39.47 | 10.3 | 20.20 | 27.17 | 2.22 | 2.37 | 3.68 |
| **$T_{12}$:** ST with Nano DAP @ 5 ml kg$^{-1}$ seed + 1 FS with Nano DAP @ 4ml L$^{-1}$ | 16.60 | 34.93 | 39.67 | 10.6 | 20.63 | 27.40 | 2.31 | 2.80 | 3.74 |
| **SEm ±** | **0.13** | **0.13** | **0.77** | **0.09** | **0.07** | **0.09** | **0.06** | **0.10** | **0.03** |
| **CD (P= 0.05)** | **0.40** | **0.38** | **2.25** | **0.26** | **0.22** | **0.27** | **0.18** | **0.29** | **0.10** |

DAS; Days after sowing

**Table 2 :** Effect of different nutrient sources on yield attributes of green gram (*Vigna radiata* L.).

| Treatment | Pod length cm$^{-1}$ | No. of pod plant$^{-1}$ | No. of seed pod$^{-1}$ | Seed yield (g pot$^{-1}$) | Stover yield (g pot$^{-1}$) | Harvest index (%) |
|---|---|---|---|---|---|---|
| **$T_0$: Control** | 4.80 | 12.33 | 6.53 | 6.2 | 11.1 | 35.83 |
| **$T_1$:** 100% Recommended dose of fertilizer (20, 40 and 40 kg N:P:K ha$^{-1}$ ) | 7.77 | 17.12 | 10.70 | 11.3 | 14.7 | 43.52 |
| **$T_2$:** 75% Phosphorus + 100 % Nitrogen and Potash | 5.80 | 14.12 | 7.77 | 7.0 | 13.2 | 34.65 |
| **$T_3$:** 50% Phosphorus | 5.23 | 13.27 | 7.30 | 6.9 | 11.5 | 37.68 |
| **$T_4$:** 25% Phosphorus | 4.90 | 12.72 | 6.93 | 6.3 | 11.3 | 35.73 |
| **$T_5$:** $T_2$ +ST with Nano DAP @ 5 ml kg$^{-1}$ seed + 2 FS with Nano DAP @ 2 ml L$^{-1}$ | 8.33 | 17.70 | 11.80 | 11.5 | 14.7 | 43.91 |
| **$T_6$:** $T_2$ + ST with Nano DAP @ 5 ml kg$^{-1}$seed + 1 FS with Nano DAP @ 4 ml L$^{-1}$ | 8.80 | 18.38 | 12.43 | 11.6 | 14.8 | 43.87 |
| **$T_7$:** $T_3$ + 100 % Nitrogen and Potash + ST with Nano DAP @ 5 ml kg$^{-1}$ seed + 2 FS with Nano DAP @ 2 ml L $^{-1}$ | 7.13 | 16.46 | 10.13 | 11.1 | 14.5 | 43.30 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **$T_8$:** $T_3$ + 100 % Nitrogen and Potash + ST with Nano DAP @ 5 ml $kg^{-1}$ seed + 1 FS with Nano DAP @ 4 ml $L^{-1}$ | 7.33 | 16.78 | 10.37 | 11.2 | 14.6 | 43.47 |
| **$T_9$:** $T_4$ + 100 % Nitrogen and Potash + ST with Nano DAP @ 5 ml $kg^{-1}$ seed + 2 FS with Nano DAP @ 2 ml $L^{-1}$ | 6.40 | 15.48 | 9.30 | 10.0 | 14.4 | 40.98 |
| **$T_{10}$:** $T_4$ + 100 % Nitrogen and Potash + ST with Nano DAP @ 5 ml $kg^{-1}$seed + 1 FS with Nano DAP @ 4 ml $L^{-1}$ | 6.80 | 15.77 | 9.73 | 10.4 | 14.5 | 41.82 |
| **$T_{11}$:** ST with Nano DAP @ 5 ml $kg^{-1}$ seed + 2 FS with Nano DAP @ 2ml $L^{-1}$ | 6.13 | 14.33 | 8.33 | 7.3 | 14.3 | 33.95 |
| **$T_{12}$:** ST with Nano DAP @ 5 ml $kg^{-1}$ seed + 1 FS with Nano DAP @ 4ml $L^{-1}$ | 6.37 | 14.53 | 8.87 | 7.4 | 14.3 | 34.15 |
| **SEm ±** | **0.07** | **0.10** | **0.08** | **0.10** | **0.05** | **0.29** |
| **CD (P= 0.05)** | **0.21** | **0.30** | **0.24** | **0.29** | **0.17** | **0.87** |

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