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# Effect of nano phosphorus conjugate levels and different mulches on growth indices of green gram (*Vigna radiata.* L)

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**Abstract**
The research entitled "Effect of Nano Phosphorus Conjugate Levels and different Mulches on Growth indices of Green Gram (*Vigna radiata.* L)" was conducted during the *summer* season of 2025 at the Instructional Farm, College of Agriculture, Dapoli. The experiment was laid out in a split-plot design comprising three levels of nano phosphorus conjugate levels ($P_1$ - Nano phosphorus @ 100 ppm, $P_2$ -Nano conjugate phosphorus @ 100 ppm, and $P_3$ - Nano conjugate phosphorus @ 200 ppm) as main plot treatments, and six mulches treatments including 100% wool mulch (200GSM) ($M_1$), 100% wool mulch with micronutrients (200GSM) ($M_2$), polythene mulch (Silver black 30 micron) ($M_3$), paddy straw mulch ($M_4$), wool-coir-jute blend (200GSM) ($M_5$), and without mulch ($M_6$) in sub-plots. Results revealed that nano phosphorus conjugate @ 200 ppm ($P_3$) significantly enhanced plant growth attributes such as plant height, number of branches, trifoliate leaves, leaf area, and leaf area index, at all growth stages of green gram. Similarly, mulch treatment 100% wool mulch with micronutrients ($M_2$) highest value recorded. The interaction of nano phosphorus conjugate @ 200 ppm and 100% wool mulch with micronutrients ($P_3M_2$) was found to be most effective in enhancing growth parameters, including maximum plant height (51.10 cm), number of branches (5.58), Leaf area (1529.13cm$^2$), Leaf area index (2.45) plant dry matter accumulation (17.95 g) and number of nodules at peak flowering (37.52). conversely, the highest number of nodules at flowering initiation (45.17) was recorded under the treatment combination of nano phosphorus conjugate @ 200 ppm combined paddy straw mulch ($P_3M_4$). From the study, it is concluded that the application of nano phosphorus conjugate @ 200 ppm in combination with 100% wool mulch enriched with micronutrients ($P_3M_2$) offers a sustainable and effective agronomic strategy for maximizing green gram productivity and profitability during *summer* season under Konkan conditions.

**Keywords:** Green gram, nano phosphorus, nano phosphorus conjugate, biodegradable mulches, growth, and growth indices

## Introduction
Among the pulses green gram is one of the most important, grown in almost everywhere of our country. India is the largest producer and consumer of green gram. Green gram is locally known as mung or moong [*Vigna radiata* (L.)], belongs to the family Leguminaceae and it is self-pollinated crop. Green gram is a source of high-quality protein (25%) having high digestibility. Mung bean has high food value with 1.0-1.5% oil, 3.5-4.5% fiber, 4.5-5.5% ash and 62-65% carbohydrates and it's easy digestible protein (20-28%) serves as a major source of dietary protein for part of a nutritionally balanced diet in the vast majority of people from Asian countries (Somta and Srinives 2007) [14]. During 2023-24, the total pulse crop area in India was estimated at 275.05 lakh hectares, with a total production of 242.46 lakh metric tons and an average productivity of 881 kg ha$^{-1}$. In India, during the same period, green gram was cultivated across 3.787 million hectares, producing 2.916 million tons with an average yield of 670 kg ha$^{-1}$. Kharif green gram production was estimated at about 11.44 lakh tons, which is 34% less than the previous year's production. Furthermore, the primary states for Rabi green gram cultivation were Odisha (82.4%), Andhra Pradesh (8.1%), and Tamil Nadu (4%). The production of Rabi and *summer* green gram was estimated at about 17.72 lakh tons, which is 9% less than the

previous year's production (3rd Advance Estimates from the DA&FW).

The role of nano phosphorus is to solve the problem of phosphorus fixation and supply adequate phosphorus to the crop for its proper growth and development. So, in that case use of Nano-P in different combinations with bulk P-fertilizer for enhancing its use efficiency may be explored for profitable farming. Nano-fertilizers are having dimensions of 1 - 100 nm, one of the main advantages of using nano fertilizers is that the nutrients having extensive surface area, it capable to hold nutrients and have a controlled and sustained release provided the nutrients uptake which complement with the crop requirement (Preetha and Balakrishnan, 2017) [12]. Subramanian *et al.*, (2008) [15]

Instead of using synthetic mulch materials, alternative, natural, biodegradable mulch materials, which are often waste fibers from the textile industry (e.g., jute, wool mulch, various waste products from the cotton industry), are new potential tools that may be used in crop production. Wool is rich in nutrients, especially nitrogen, and it has a good ability to retain moisture; this has proven to be an excellent mulch material in several experiments. (Katalin Juhos, 2023) [7], Plastic mulch is a product used in a similar fashion to mulch, to suppress weeds and conserve water in crop production. Certain plastic mulches also act as a barrier to keep methyl bromide, both a powerful fumigant and ozone deplete, in the soil (Emmert 1957) [4]

## Materials and Methods

Field investigation was conducted at the Research Farm, Department of Agronomy, College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra (17°45' N and 73°11' E, 244.0 m AMSL) during *summer* season of 2025. A 90 cm wide space was left per raised bed. Gross plot size for each treatment was 5.20 m x 3.0 m and inter and intra-row spacing was 25 cm X 25 cm. The experiment was laid out in Split Plot Design with thrice replications. The main plot featured three nano phosphorus levels ($P_1$ - Nano phosphorus @ 100 ppm, $P_2$ -Nano conjugate phosphorus @ 100 ppm, and $P_3$ - Nano conjugate phosphorus @ 200 ppm) and six mulches treatments including 100% wool mulch (200GSM) ($M_1$), 100% wool mulch with micronutrients (200GSM) ($M_2$), polythene mulch (Silver black 30 micron) ($M_3$), paddy straw mulch ($M_4$), wool-coir-jute blend (200GSM) ($M_5$), and without mulch ($M_6$) in sub-plots.

## Results and Discussion

### Effect of nano phosphorus conjugate levels

The data given in the Table 1 indicates that the plant height (cm), number of trifoliate leaves plant$^{-1}$, number of branches plant$^{-1}$, leaf area (cm$^2$), leaf area index, plant dry matter accumulation (g) and number of nodule plant$^{-1}$ were significantly influenced due to nano phosphorus conjugate levels during all growth stage However, the data in the table is presented at harvest. The treatment nano phosphorus conjugate @ 200 ppm ($P_3$) recorded significantly higher the plant height (43.83 cm), number of trifoliate leaves plant$^{-1}$ (10.21), number of branches plant$^{-1}$ (4.79), leaf area (1223.13 cm$^2$), leaf area index (1.96), plant dry matter accumulation (14.09 g) and number of root nodule plant$^{-1}$ over rest of the treatments. These results were corroborated with the findings of Kanjilal *et al.* (2023) [9] found that treatment $T_6$ 100% through nano-phosphorus (2ml L$^{-1}$) at 15 DAS recorded significantly tallest plant, larger root volume, greater leaf area, maximum dry matter. Pisal *et.al.* (2024) [11] found that the Nano phosphorus conjugate at 100 ppm ($C_5$) recorded significantly higher plant height, higher number branches plant$^{-1}$ and higher dry matter production.

### Effect of mulches

Different mulches treatments significantly influenced the plant height, number of trifoliate leaves plant$^{-1}$, number of branches plant$^{-1}$, and plant data dry matter accumulation (g), of green gram crop in at harvest stage. There itself leaf area (cm$^2$), leaf area index, was present at 60 DAS and number of nodules present at flowering initiation and peak flowering stage. Notably treatment 100% wool mulch with micronutrients (200GSM) ($M_2$), consistently outperformed other treatments, exhibiting significantly higher value of plant height (7.96 cm), number of trifoliate leaves plant$^{-1}$ (10.36), number of branches plant$^{-1}$ (4.91), leaf area (1217.19 cm$^2$), leaf area index (1.95) and plant dry matter accumulation (15.59 g), over other treatment. Also, number of root nodules plant$^{-1}$ at flowering initiation (31.06) and peak flowering (43.84) stage highest root number of nodules recorded under paddy straw mulch ($M_4$) (Result shown in Table 1). These results are similar of Kadam *et al.* (2014) [8] reported that the plant growth of barley crop in terms of plant height, tillers/plant, leaf area and number of leaves plant$^{-1}$ was better for the felt wool at soil depth of 30 cm than 15cm.

### Interaction effect

The data presented in Tables 3 and 4 indicates a significant interaction effect between nano phosphorus conjugate levels and different mulches. This interaction significantly influenced plant height (cm), the number of branches plant$^{-1}$, and plant dry matter accumulation (g) of the green gram crop at the harvest stage.

Leaf area (cm$^2$) and leaf area index were significantly influenced at 60 DAS. The number of nodules was also significantly affected at both flowering initiation and peak flowering stages.

**Table 1:** Various growth indices of green gram as influenced periodically by different treatments

| Treatments | | Plant height (cm) | Number of branches plant$^{-1}$ | Number of trifoliate leaves | Leaf area (cm$^2$) | Leaf area index (LAI) | Dry matter accumulation (g) | Number of nodules | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | FI | PF |
| **Main plot: Nano phosphorus conjugate levels (P)** | | | | | | | | | |
| $P_1$ | Nano phosphorus @100ppm | 33.28 | 3.43 | 7.47 | 797.37 | 1.28 | 10.64 | 19.06 | 31.08 |
| $P_2$ | Nano phosphorus conjugate@100 ppm | 39.94 | 4.04 | 8.32 | 936.05 | 1.50 | 12.86 | 18.84 | 34.08 |
| $P_3$ | Nano phosphorus conjugate @200 ppm | 43.83 | 4.79 | 10.21 | 1223.13 | 1.96 | 14.09 | 27.24 | 37.34 |
| S.Em. ± | | 0.06 | 0.04 | 0.10 | 15.32 | 0.02 | 0.04 | 0.22 | 0.20 |
| CD at 5% | | 0.27 | 0.15 | 0.40 | 60.16 | 0.10 | 0.18 | 0.86 | 0.79 |
| **Sub plot: Mulches (M)** | | | | | | | | | |
| $M_1$ | 100% Wool mulch | 41.32 | 4.25 | 9.77 | 1148.67 | 1.84 | 14.21 | 25.06 | 35.51 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | (200GSM) | | | | | | | | |
| $M_2$ | 100% Wool mulch with micronutrients (200GSM) | 44.44 | 4.91 | 10.36 | 1217.19 | 1.95 | 15.59 | 28.74 | 42.00 |
| $M_3$ | Polythene mulch (30 micron) | 39.30 | 4.02 | 8.95 | 1018.07 | 1.63 | 12.69 | 18.19 | 33.00 |
| $M_4$ | Paddy straw mulch | 39.07 | 3.74 | 7.91 | 898.39 | 1.44 | 10.09 | 31.06 | 43.84 |
| $M_5$ | Wool-coir-jute blended mulch (200GSM) | 40.29 | 4.50 | 9.26 | 1183.43 | 1.89 | 14.00 | 15.17 | 28.67 |
| $M_6$ | Without mulch | 29.69 | 3.08 | 5.77 | 447.33 | 0.72 | 8.61 | 12.06 | 21.99 |
| S.Em. ± | | 0.26 | 0.04 | 0.12 | 11.03 | 0.02 | 0.12 | 0.32 | 0.56 |
| CD at 5% | | 0.74 | 0.12 | 0.35 | 31.87 | 0.05 | 0.33 | 0.93 | 1.62 |
| **Interaction Effect (P×M)** | | | | | | | | | |
| S.Em. ± | | 0.77 | 0.13 | 0.37 | 33.10 | 0.05 | 0.35 | 0.97 | 1.69 |
| CD at 5% | | 2.22 | 0.37 | NS | 95.60 | 0.15 | 1.00 | 2.79 | 4.87 |

**Table 2:** Interaction effects of nano phosphorus conjugate levels and different mulches on plant height (cm) and number of branches

| Treatment | Plant height (cm) | | | | | | Treatment | Number of branches plant$^{-1}$ | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **$M_1$** | **$M_2$** | **$M_3$** | **$M_4$** | **$M_5$** | **$M_6$** | | **$M_1$** | **$M_2$** | **$M_3$** | **$M_4$** | **$M_5$** | **$M_6$** |
| $P_1$ | 33.85 | 36.40 | 32.85 | 36.69 | 33.00 | 26.90 | $P_1$ | 3.30 | 4.36 | 3.34 | 3.06 | 3.58 | 3.08 |
| $P_2$ | 43.03 | 45.81 | 41.91 | 38.71 | 42.59 | 27.58 | $P_2$ | 4.51 | 4.81 | 4.14 | 3.61 | 4.58 | 2.57 |
| $P_3$ | 47.09 | 51.10 | 43.15 | 41.80 | 45.27 | 34.60 | $P_3$ | 4.94 | 5.58 | 4.59 | 4.71 | 5.35 | 3.60 |
| S.Em. ± | 0.77 | | | | | | S.Em. ± | 0.13 | | | | | |
| CD at 5% | 2.22 | | | | | | CD at 5% | 0.37 | | | | | |

**Table 3:** Interaction effects of nano phosphorus conjugate levels and different mulches on dry matter accumulation and leaf area (cm$^2$)

| Treatment | Dry matter accumulation (g) | | | | | | Treatment | Leaf area (cm$^2$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **$M_1$** | **$M_2$** | **$M_3$** | **$M_4$** | **$M_5$** | **$M_6$** | | **$M_1$** | **$M_2$** | **$M_3$** | **$M_4$** | **$M_5$** | **$M_6$** |
| $P_1$ | 11.99 | 13.37 | 10.79 | 9.05 | 11.35 | 7.30 | $P_1$ | 854.20 | 864.20 | 814.39 | 868.17 | 1011.11 | 372.12 |
| $P_2$ | 14.75 | 15.46 | 12.51 | 11.29 | 14.24 | 8.94 | $P_2$ | 1111.17 | 1258.25 | 813.10 | 753.49 | 1275.93 | 404.38 |
| $P_3$ | 15.89 | 17.95 | 14.77 | 9.93 | 16.40 | 8.92 | $P_3$ | 1480.65 | 1529.13 | 1426.73 | 1073.51 | 1263.24 | 565.50 |
| S.Em. ± | 0.37 | | | | | | S.Em. ± | 0.38 | | | | | |
| CD at 5% | 1.01 | | | | | | CD at 5% | 1.09 | | | | | |

**Table 4:** Interaction effects of nano phosphorus conjugate levels and different mulches on leaf area index (LAI) and number of nodules at peak flowering

| Treatment | Leaf area index (LAI) | | | | | | Treatment | Number of nodules at peak flowering | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **$M_1$** | **$M_2$** | **$M_3$** | **$M_4$** | **$M_5$** | **$M_6$** | | **$M_1$** | **$M_2$** | **$M_3$** | **$M_4$** | **$M_5$** | **$M_6$** |
| $P_1$ | 1.37 | 1.38 | 1.30 | 1.39 | 1.62 | 0.60 | $P_1$ | 20.83 | 21.50 | 20.00 | 25.50 | 13.00 | 13.50 |
| $P_2$ | 1.78 | 2.01 | 1.30 | 1.21 | 2.04 | 0.65 | $P_2$ | 25.33 | 27.20 | 12.00 | 22.50 | 15.50 | 10.50 |
| $P_3$ | 2.37 | 2.45 | 2.28 | 1.72 | 2.02 | 0.90 | $P_3$ | 29.00 | 37.52 | 22.57 | 45.17 | 17.00 | 12.17 |
| S.Em. ± | 0.05 | | | | | | | 0.43 | | | | | |
| CD at 5% | 0.15 | | | | | | | 1.33 | | | | | |

**Table 5:** Interaction effects of nano phosphorus conjugate levels and different mulches on number of nodules at flowering initiation

| Treatment | Number of nodules at flowering initiation | | | | | |
|---|---|---|---|---|---|---|
| | **$M_1$** | **$M_2$** | **$M_3$** | **$M_4$** | **$M_5$** | **$M_6$** |
| $P_1$ | 30.50 | 32.00 | 33.50 | 39.00 | 27.50 | 17.47 |
| $P_2$ | 36.00 | 41.50 | 32.00 | 45.00 | 28.00 | 23.00 |
| $P_3$ | 40.03 | 49.17 | 33.50 | 47.53 | 30.50 | 23.50 |
| S.Em. ± | 1.21 | | | | | |
| CD at 5% | 3.50 | | | | | |

The treatment combination nano phosphorus conjugate @ 200 ppm combined 100% wool mulch with micronutrients (200GSM) ($P_3M_2$) recorded in significantly higher values for different growth indices compared to all other treatment combinations. plant height (51.10 cm), number of branches plant$^{-1}$(5.58), leaf area (1529.13 cm), leaf area index (2.45), plant dry matter accumulation (17.95 g), and number of nodules at peak flowering (49.17).

Conversely, the highest number of nodules at flowering initiation (45.17) was recorded under the treatment combination of nano phosphorus conjugate @ 200 ppm combined paddy straw mulch ($P_3M_4$). These results are like those of Kader *et al.* (2023) [1] who found that the application of $Ch_3$ and WPM: white plastic mulch caused considerable increases in the plant height, shoot dry weight, root dry weight. Reddy *et al.* (2023) [13] was found that treatment ($T_7$) (Phosphorous (60kg ha$^{-1}$) + Sawdust mulches (22.5kg ha$^{-1}$) recorded higher plant height (43.24 cm), higher plant dry weight (5.32 g).

## Conclusion

The experiment revealed that the treatment combined nano phosphorus conjugate @ 200 ppm combined 100% wool mulch with micronutrients (200GSM) ($P_3M_2$), resulted in significantly higher growth attributes, such as plant height, number of trifoliate leaves plant$^{-1}$, number of branches plant$^{-1}$, and plant dry matter accumulation and number of root nodule at peak flowering stage. conversely the treatment combined nano phosphorus conjugate @ 200 ppm with paddy straw mulch ($P_3M_4$), resulted in significantly higher root nodules at flowering initiation and peak flowering stage, in the green gram crop.

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