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Effect of Nano-DAP on growth and yield of Pigeonpea under rainfed condition

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Abstract
A field experiment was conducted during kharif 2022 at ICAR-KVK, Kalaburagi to study the Nutrient management with Nano-DAP in pigeonpea. There were eight treatments consisting of different doses of RDF (two treatments with 50% RDF, two with 75% RDF, three with 100% RDF and one absolute control) with different doses of Nano-DAP sprayed (2 and 4 ml L^{-1}) at 45 & 60 DAS. Results revealed that application of 100% RDF as basal and Nano-DAP foliar spray @ 4 ml L^{-1} at 45 and 60 DAS has produced significantly higher plant (213.6 cm) at harvest and higher number of branches per plant (34.7) at harvest also higher dry matter production (151.1g $plant^{-1}$) at harvest. It has resulted in enhanced number of pods per plant (194), test weight (11.85 g) and seed yield (1477 Kg/ha) and stalk yield (4619 Kg/ha) of pigeonpea also enhanced by application of Nano-DAP.

Keywords: Pigeonpea, Foliar nutrition, Nano-DAP, IFFCO

1. Introduction

Pulses are gaining more important position in Indian agriculture. After the green revolution, India has become self-sufficient in case of food grain production. However, India is still lagging in pulses production and is dependent on imports for domestic consumption particularly in recent years. Therefore, there is an immediate need for another revolution in the case of pulse production. Pigeonpea (*Cajanus cajan* L. Mill sp.) is an important legume crop, plays a vital role in the daily diet, and belongs to the family *Leguminosae*. It is also known as red gram, tur, and arhar. It is often cross-pollinated crop (20 to 70%). The food values of pigeonpea includes 22.3% protein, 1.7% fat, 3.5% mineral, 1.5% fiber, and 57.5% carbohydrates in 100 g edible portions. Globally, pigeonpea is grown in an area of 63.57 lakh hectares with a production of 54.75 lakh tonnes and productivity of 861.25 kg/ha (FAO STAT, 2021). India ranks first in pigeonpea production globally with 43.4 lakh tonnes cultivated under 49.8 lakh hectares with a productivity of 871 kg/hectare in 2021-22 (agricoop.nic.in). In *Kharif* 2022, pigeonpea production was 38.9 lakh tonnes in an area of 46.2 lakh hectares (Agricoop.nic).

The productivity of pulses in India (764 kg ha^{-1}) is far below the average productivity of the world (848 kg ha^{-1}). During the last four decades, the total area under pulses remained virtually stagnant (22 to 24 million ha) with almost stable production (12 to 14 million tons), even though the population has increased by many folds. As a result, the present per capita availability of pulses has declined from 51.1 g day^{-1} in 1970-71 to less than 41.9 g day^{1} (2017) as against FAO/WHO's recommendation of 80 g day^{-1}. It has led to a severe shortage of pulses in India, which has aggravated the problem of malnutrition in a large section of the vegetarian population. Thus, there is an urgent need to increase the production of pulses to meet the increasing demand by adopting the appropriate production technologies.

Pigeonpea is mainly cultivated in marginal lands which are low in fertility. The mineral nutrient deficiency limits nitrogen fixation and ultimately reduces the yield. Both major and micronutrients are important for nodulation. In pigeonpea, fertilizers are applied as basal doses. It is a long-duration crop and over the period the nutrients are lost and during its critical growth stages, nutrient deficiency is observed. In addition to causing losses, excessive use of fertilizer results in a decline in pulse nodulation. To avoid this, foliar spraying of Nano DAP at critical stages could be a sustainable alternative practice. Nano fertilizers materials have a nanometer scale (1-100 nm), containing macro and micronutrients that are delivered to crops in a controlled mode. The main features of nano fertilizers are their small size. Their larger contact area and responsiveness facilitate nutrients to enter plants and improve nutrient use efficiency by minimizing losses.

Nano-DAP (8% N & 16% P) fertilizer have been developed indigenously, for the first time in the world at IFFCO Nano Biotechnology Research Centre (NBRC), Kalol, Gujarat through a proprietary patented technology. Farmers are using DAP fertilizers for soil as well as foliar application to crops. However, the efficacy is lower. Thus, the goal of the current study is to determine the effect of Nano-DAP on growth, yield, of Pigeonpea in black soil under rainfed condition.

2. Materials and Methods

A field experiment was conducted during *kharif*, 2022 at Krishi Vigyan Kendra, Kalaburagi, on *Vertisol* having pH 8.23 and EC 0.21 dSm^{-1}. The experimental site was located at a 17º 34' N latitude and 76º 79' E longitude with 478 meters above mean sea level altitude and coming under North Eastern Dry Zone of Karnataka (Zone 2). The soil was low in organic carbon content (4.32 g kg^{-1}) and available P_2O_5 (26.2 kg ha^{-1}), and low in available N (203 kg ha^{-1}) with high available K_2O content (362 kg ha^{-1}).

The research was carried in out in Randomized complete block design, with eight treatments consisting of different doses of RDF (two treatments with 100% RDF, two treatments 75% RDF, two treatments 50% RDF and one absolute control) with different doses of Nano-DAP 2 ml and 4 ml sprayed at 45 and 60 days after sowing (DAS). After the previous crop was harvested, the ground was ploughed once again, followed by two harrowing. The field was prepped to a good seedbed and the field was set out in preparation for sowing. The variety, GRG-811 was used. The basal application of fertilizers in the form of urea, DAP and $ZnSo_4$ were applied as per treatments with recommended dose of (25:50:00:20 N: P_2O_5: K_2O: $ZnSO_4$ kg ha^{-1}).

2.1 Statistical analysis

The data collected from the experiment at different growth stages and at harvest were subjected to statistical analysis as described by Gomez and Gomez (1984) [2]. The level of significance used in the "F" test was given at 5 per cent. Critical difference (CD) values are given in the table at a 5 per cent level of significance, wherever the "F- test was significant.

3. Results and Discussion

3.1 Growth attributes

3.1.1 Plant height

There was no significant difference among treatment at 30 DAS. Significantly higher plant height were noticed in the treatment receiving 100% RDF + Nano-DAP spray @ 4 ml l^{-1} each at 45 and 60 DAS (72.6, 117.1, 177.8, 196.3 and 213.6 at 60, 90, 120, 150 DAS and at harvest, respectively) it was on par with 100% RDF + Nano-DAP spray @ 2 ml l^{-1} at 45 and 60 DAS (68.6, 111.2, 168.7, 188.8 and 209.5 at 60, 90, 120, 150 DAS at harvest respectively). Similar results were reported by Akshay. [3], Luma and ahmed[4] Yasser *et al.* (2020) [5] and Gupta *et al.* (2022) [6]. Combined application of chemical and nano fertilizers increased the availability of nitrogen and phosphorous which accelerated the enzymatic activity of photosynthesis, carbohydrate metabolism, synthesis of protein and cell division and cell elongation which in turn enhanced the plant height.

Table 1: Plant height of Pigeonpea at different growth stage as influenced by foliar application of Nano-DAP

Treatment	Plant height (cm)					
	30 DAS	**60 DAS**	**90 DAS**	**120 DAS**	**150 DAS**	**At harvest**
T_1: 100% RDF + 2 ml Nano-DAP foliar application @ 45 and 60 DAS	23.8	68.6	111.2	168.7	188.8	209.5
T_2: 100% RDF + 4 ml Nano-DAP foliar application @ 45 and 60 DAS	24.6	72.6	117.1	177.8	196.3	213.6
T_3: 75% RDF + 2 ml Nano-DAP foliar application @ 45 and 60 DAS	21.0	63.9	102.0	159.9	174.6	191.3
T_4: 75% RDF + 4 ml Nano-DAP foliar application @ 45 and 60 DAS	24.4	65.4	105.9	161.9	178.2	194.4
T_5: 50% RDF + 2 ml Nano-DAP foliar application @ 45 and 60 DAS	23.9	57.3	91.5	145.6	155.8	173.0
T_6: 50% RDF + 4 ml Nano-DAP foliar application @ 45 and 60 DAS	24.8	58.1	95.2	146.7	159.1	175.8
T_7: RDF (25:50:0 N: P_2O_5: K_2O Kg/ha)	25.2	63.3	101.8	157.9	175.7	187.0
T_8: Absolute control	22.8	51.0	85.0	127.7	140.7	156.8
S.Em±	2.0	2.3	3.4	4.9	5.7	5.9
CD@ 5%	NS	7.08	10.33	15.04	17.42	17.90

Note: FYM @ 5 tonnes ha^{-1} & Zinc Sulphate @15kg ha^{-1} for all the treatments except T_8
RDF (recommended dose of fertilizer)

3.1.2 Number of branches: There was no significant difference at 30 DAS. Significantly more number of branches per plant were noticed in the treatment receiving 100% RDF+ Nano-DAP spray @ 4 ml l^{-1} each at 45 and 60 DAS (22.7, 19.6, 24.2, 34.4 and 34.7 at 30, 60, 90, 120, 150 DAS and at harvest, respectively). It was on par with 100% RDF+ Nano-DAP spray @ 2 ml l^{-1} each at 45 and 60 DAS (Table 2). Similar result were reported by Lin and zing (2007) [7] and Ramesh and Tarafdar (2013) [8]. Increase in branch number due to nano fertilizer having reduced particle size, which improved fertilizer interaction, nutrient uptake, and ultimately, more number of branch development.

Table 2: Number of branches per plant at different growth stages of Pigeonpea as influenced by foliar application of Nano-DAP

Treatment	Number of branches $plants^{-1}$					
	30 DAS	**60 DAS**	**90 DAS**	**120 DAS**	**150 DAS**	**At harvest**
T_1: 100% RDF + 2 ml Nano-DAP foliar application @ 45 and 60 DAS	4.40	20.7	17.4	22.5	32.5	32.9
T_2: 100% RDF + 4 ml Nano-DAP foliar application @ 45 and 60 DAS	5.1	22.7	19.6	24.2	34.4	34.7
T_3: 75% RDF + 2 ml Nano-DAP foliar application @ 45 and 60 DAS	4.2	21.8	16.5	17.7	30.3	31.2
T_4: 75% RDF + 4 ml Nano-DAP foliar application @ 45 and 60 DAS	4.7	25.0	17.0	18.5	32.2	32.4
T_5: 50% RDF + 2 ml Nano-DAP foliar application @ 45 and 60 DAS	4.4	20.4	14.3	15.0	26.0	26.4
T_6: 50% RDF + 4 ml Nano-DAP foliar application @ 45 and 60 DAS	4.2	24.6	14.9	16.0	26.3	27.1

T7: RDF (25:50:0 N: P_2O_5: K_2O)	4.7	24.0	15.1	17.5	27.8	29.7
T8: Absolute control	4.4	23.6	11.6	12.3	20.9	23.1
S.Em±	0.47	2.03	0.66	0.76	0.9	1.0
CD@ 5%	NS	NS	2.00	2.32	2.93	3.2

Note: FYM @ 5 tonnes ha^{-1} & Zinc Sulphate @15kg ha^{-1} for all the treatments except T8
RDF (recommended dose of fertilizer)

3.1.3 Total dry matter production
There no significant difference at 30DAS. Significantly maximum dry matter production were noticed in the treatment receiving 100% RDF + Nano-DAP spray @ 4 ml l^{-1} each at 45 and 60 DAS (37.52, 54.10, 112.15, 146.42 and 151.31 at 30, 60, 90, 120, 150 DAS and at harvest, respectively). it was on par with 100% RDF + Nano-DAP spray @ 2 ml l^{-1} each at 45 and 60 DAS (Table 3). Similar result were reported by Saakshi *et al.* [9]. Sharma *et al.* (2022) [10] and Maheta *et al.* (2023) [11]. Combined application of fertilizer and nano urea spray enhanced nutrient use efficiency for improved growth and increased dry matter production in plants.

Table 3: Total dry matter production at different growth stages of Pigeonpea as influenced by foliar spray of Nano-DAP

Treatment	Total dry matter production (g $plant^{-1}$)					
	30 DAS	**60 DAS**	**90 DAS**	**120 DAS**	**150 DAS**	**At harvest**
T1: 100% RDF + 2 ml Nano-DAP foliar application @ 45 and 60 DAS	10.43	33.96	52.36	108.90	144.33	146.73
T2: 100% RDF + 4 ml Nano-DAP foliar application @ 45 and 60 DAS	11.04	37.52	54.10	112.15	146.42	151.31
T3: 75% RDF + 2 ml Nano-DAP foliar application @ 45 and 60 DAS	8.56	31.75	47.92	100.66	131.72	132.36
T4: 75% RDF + 4 ml Nano-DAP foliar application @ 45 and 60 DAS	9.06	33.11	49.37	102.12	133.04	134.98
T5: 50% RDF + 2 ml Nano-DAP foliar application @ 45 and 60 DAS	7.31	26.80	44.68	91.39	118.50	120.40
T6: 50% RDF + 4 ml Nano-DAP foliar application @ 45 and 60 DAS	7.84	27.70	45.06	92.16	120.69	122.66
T7: RDF (25:50:0 N: P_2O_5: K_2O Kg/ha)	8.16	29.41	47.74	98.85	131.29	131.83
T8: Absolute control	6.71	19.79	39.65	82.03	108.41	110.38
S.Em±	0.35	1.23	1.38	3.17	3.81	3.95
CD@ 5%	NS	3.74	4.21	9.61	11.57	11.98

Note: FYM @ 5 tonnes ha^{-1} & Zinc Sulphate @15kg ha^{-1} for all the treatments except T8
RDF (recommended dose of fertilizer)

3.2. Yield parameter
3.2.1. Grain and stalk yield
Significantly higher grain (1477) and stalk (4619) yield was recorded by application of 100% RDF as basal + Nano-DAP spray @ 4 ml l^{-1} each at 45 and 60 DAS over rest of the treatments and was found on par with 100% RDF as basal + Nano-DAP spray @ 2 ml l^{-1} each at 45 and 60 DAS, seed (1345) and stalk (4477) yield was recoeded kg ha^{-1} and recommended dose of fertilizers (RDF) seed (1139) and stalk (3807) yield was recorded kg ha^{-1}. Significantly lower grain yield was recorded in absolute control (747 and 2497 kg ha^{-1} at seed and stalk respectively) as compared to all other treatments. Similar result were reported (Table 4)

The substantial grain yield increase with Nano-DAP application, especially when combined with conventional fertilizer, stores essential nutrients in plant cells, releasing them gradually to counter biotic and abiotic stress and boost grain production. Nano fertilizers promote rapid plant growth and metabolic processes, such as photosynthesis, leading to increased photosynthate accumulation and translocation to vital plant parts.

Similar outcomes were reported by El-Azizy *et al.* (2021) [12], demonstrating the efficacy of nano phosphorus fertilizer in increasing seed yield. Combined application of regular urea and nano urea maintained nutrient availability throughout the crop cycle, reducing flower drop and enhancing yield-contributing factors. This improved assimilate translocation to seeds and overall pigeonpea yield, aligning with similar findings in chickpea and black gram by Kumar *et al.* (2020) [13], Bhargavi and Sundari (2023) [14] and Rajesh (2023) [15].

The application of Nano-DAP significantly increased stalk yield, likely due to the optimal combination of conventional and nano fertilizers, which enhances stalk production by delivering nutrients in a controlled and demand-driven manner. This precise nutrient delivery regulates plant development and improves target activity, resulting in enhanced crop biomass. Similar findings were reported by Nair *et al.* (2010) [16] indicating that the efficient transport of nano-urea fertilizer by plants may contribute to increased photosynthesis rates and greater dry matter accumulation, consequently boosting stover output when applied as a foliar spray. Khalil *et al.* (2019) [17], Mallikarjuna (2021) [18] and Rajput *et al.* (2022) [19]. also reported similar outcomes

3.2.2 Harvest index
The information about the Pigeonpea harvest index revealed that foliar sprays of Nano-DAP at different concentration were not statistically significant, as indicated in Table 4. Pigeonpea harvest index were between 23.0% and 24.2%.

Table 4: Seed yield, stalk yield and harvest index of Pigeonpea as influenced by foliar spray of Nano-DAP

Treatment	Grain yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Harvest Index (%)
T1: 100% RDF + 2 ml Nano-DAP foliar application @ 45 and 60 DAS	1345	4477	23.1
T2: 100% RDF + 4 ml Nano-DAP foliar application @ 45 and 60 DAS	1477	4619	24.2
T3: 75% RDF + 2 ml Nano-DAP foliar application @ 45 and 60 DAS	1194	3981	23.1
T4: 75% RDF + 4 ml Nano-DAP foliar application @ 45 and 60 DAS	1250	4184	23.0
T5: 50% RDF + 2 ml Nano-DAP foliar application @ 45 and 60 DAS	959	3211	23.0

T_6: 50% RDF + 4 ml Nano-DAP foliar application @ 45 and 60 DAS	1022	3376	23.2
T_7: RDF (25:50:0 N: P_2O_5: K_2O Kg/ha)	1139	3807	23.0
T_8: Absolute control	747	2497	23.0
S.Em ±	45	139	0.006
CD@ 5%	137	423	NS

Note: FYM @ 5 tonnes ha^{-1} & Zinc Sulphate @15kg ha^{-1} for all the treatments except T_8
RDF (recommended dose of fertilizer)

4. Conclusion

Combined application of conventional and nano fertilizers i.e., 100% RDF as basal + Nano-DAP spray @ 4 ml l^{-1} each at 45 and 60 DAS helped to increase growth attributes, yield parameters by the pigeonpea plants. The results of this study suggest that the application of Nano-DAP in the form of foliar sprays, in combination with conventional fertilizers, can be a promising strategy to improve crop performance and agricultural sustainability in similar environmental conditions.

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6. Competing interests

Authors have declared that no competing interests exist

7. Authors' Contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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