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Morphological and Productivity Response of Chickpea (*Cicer arietinum* L.) to Nano Biofertilization

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ABSTRACT

Background: Chickpea productivity in the last decade has been declined due to improper management of inorganic and organic nutrient sources and it has been contended that the usual native soil rhizobial populations are insufficient/ineffective in N_2 – fixation. Rhizobium based biofertilizers may substitute nitrogenous chemical fertilizers and provide a suitable way of achieving sustainable production. The effective use of exogeneous application of nano emulsion biofertilizer can enhance yield by reducing flower drop, regulating pod formation besides improving soil quality. In view of above consideration, the present investigation entitled “Morphological and productivity response of chickpea (*Cicer arietinum* L.) to nano biofertilization” was carried out.

Methods: The field experiment was conducted on sandy clayey loam soil during two consecutive *Rabi* seasons of 2022-2023 and 2023-2024. The experiment was laid out in randomized complete block design (Factor) with three replications, assigning 45 treatments consisting of five soil applications (100% RDF; 100% RDF + FYM; 100% RDF + Vermicompost; 75% RDF + FYM; and 75% RDF + Vermicompost) as first factor and three foliar applications (Nano DAP; Nano Urea and Nano emulsion biofertilizer) as second factor treatments.

Result: Application of Nano emulsion biofertilizer to chickpea variety (NBeG-49) at harvest had shown significant higher plant height (35.03 cm), dry matter production (3251.43 kg ha^{-1}), leaf area index (0.90), crop growth rate (1.59 gm^{-2} day^{-1}), relative growth rate (26.3 mg g^{-1} day^{-1}), chlorophyll (SPAD value) (58.22), number of pods/plant (24.93), seed yield (1111.60 kg ha^{-1}), straw yield (2501.10 kg ha^{-1}) and nitrogen uptake (70.56 kg ha^{-1}), phosphorus uptake (203.21 kg ha^{-1}) and potassium uptake (54.30 kg ha^{-1}).

Key words: Biofertilizer, Chickpea, Nano emulsion, Rhizobium.

INTRODUCTION

The world’s human population is expected to grow to about 8.5 billion during the year 2030 and 9.7 billion in 2050. It is projected to reach a peak population of around 10.4 billion people during the 2080s and to remain at that level until 2100 (United Nations, 2022). While population growth is an important driver for increased food demand, its impact is amplified by changes in the type and quantities of food demanded per person. Moreover, certain food and food production systems have higher environmental burdens in terms of greenhouse gas emissions, water, land, energy and primary nutrient use. Encouraging consumption of healthier diets that include sustainability considerations would requires wide range of actions that combines nutrition education campaigns with economic measures and changes to food production environments.

A valuable representative of this group of food supply (crops) is chickpea (*Cicer arietinum* L.), the seeds of which contain approximately 21.1% protein, 61.5% carbohydrates and 4.5% fat. One of the major pulse crop, chickpea accounts for 49% of the total pulses produced in India. It is grown in an area of about 9.99 million ha, producing 11.91 million tonnes with an average productivity of 1192 kg/ha (ICAR-IIPR, 2021-22). The global chickpeas market grew from $13.93 billion in 2022 to $14.9 billion in 2023 at a compound annual growth rate (CAGR) of 7.0%.

Chickpea cultivation contributes a significant amount of residual nitrogen to the soil and adds organic matter, thereby improving soil health and fertility (Siddique *et al.*, 2005). But majority of farmers usually grow pulses in marginal land without proper use of inorganic and organic nutrients including biofertilizers. This faulty nutrient management practices results in reduction of soil organic matter content and multi-nutrient deficiency. It is evident that, increasing and extending the role of biofertilizers such as *Rhizobium* can reduce the need for chemical fertilizers and decreases the adverse environmental effects in long run. The use of biofertilizers with the ability to fix atmospheric nitrogen and solubilize phosphorus and potassium can be an appropriate method of crop nutrient management. Biofertilizers modulates the effect of water stress and improve crop yield by increasing the proline and soluble carbohydrate content and the absorption of mineral elements such as potassium and phosphorus.

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The application of biofertilizers such as beneficial soil microorganisms has emerged as a potential solution to promote plant adaptability, yield and tolerance to environmental constraints (Batool *et al*., 2020).

Fertilization done through foliar application has received considerable attention to increase their seed production, nutrient uptake particularly when the soil moisture is poor. It is thus characterized by its affordability, high penetration rate and most plants can absorb it rapidly and hydrolyse in the cytosol. Main advantage of foliar application of nutrients is that it often produces instantaneous progress in plant growth and development. Nutrient management *via* foliar application at critical stages of growth is absolutely essential for their timely utilization of deficient nutrient and improved crop performance (Alshaal and El-Ramady, 2017). Furthermore, liquid nano emulsion biofertilizer also fulfils the crop nutrient requirements with higher nutrient availability during peak growing periods and their application eliminates their deficiencies particularly under the organic production systems. Thus, the present study was therefore taken to investigate the morphological and productivity response of chickpea (*Cicer arietinum* L.) to nano biofertilization under irrigated conditions of Coimbatore region of South Tamil Nadu.

MATERIALS AND METHODS

Field experiment was conducted during *rabi* season of 2022-2023 and 2023-2024 at the North farm, School of Agriculture Sciences, Karunya University, Coimbatore. The crop was sown during 10th and17th October in 2022 and 2023 and harvested on 13th and 20th February in 2023 and 2024 respectively. The experimental site is situated at 10.934°N latitude and 76.75°E longitude with an altitude of 467 m above mean sea level. The soil of the experimental area was clayey loam in texture with a pH of 7.9, EC 0.37 dS/m, OC 0.35% and available nitrogen, phosphorus and potash were 180, 13.7, 298 kg ha^{-1} respectively. The experiment comprised five levels of soil applications (100% RDF; 100% RDF + FYM 10 t ha^{-1}; 100% RDF + Vermicompost 5 t ha^{-1}; 75% RDF + FYM; and 75% RDF + Vermicompost) and three levels of foliar applications (Nano- DAP 2 ml/lt; Nano-Urea 2ml/lt and Nano emulsion biofertilizer (*Rhizobium* and *PSB*) 5ml/lt @ 30 and 45 DAS) were laid out in FRBD design and replicated thrice. Chickpea variety NBeG 49 was used for this study. The seeds were treated with PSB @ 25 g kg^{-1} of seed and sown at a spacing of 30 × 10 cm crop geometry with a seed rate of 75 kg ha^{-1} with gross plot size of 4 × 3 m and net plot size 3.5 × 2.1 m. The recommended dose of fertilizer nitrogen (25 kg ha^{-1}), phosphorus (50 kg ha^{-1}) and potash (20 kg ha^{-1}) were applied as basal application at the time of sowing. The data collected for different parameters were subjected to appropriate statistical analysis under factorial randomized block design (FRBD) by following the procedure of analysis of variance as described by Gomez and Gomez (1984). The treatment effects were tested at 5% probability level for their significance.

RESULTS AND DISCUSSION

Growth parameters

The data revealed that maximum plant height at harvest was found with the application of 50% RDF + VC at 5 t ha^{-1}

Table 1: Growth and physiological attributes of chickpea to nano and mineral fertilization (Pooled data of 2022-23 and 2023-24).

Treatment	Harvest stage		60 DAS to Harvest stage			Peak flowering stage
	Plant height (cm)	Dry matter production (kg ha^{-1})	Leaf area index	Crop growth (g m^{-2} day^{-1})	Relative growth (mg g^{-1} day^{-1})	Chlorophyll (SPAD value)
Soil application						
S_1-100% RDF	25.19	2178.98	0.60	1.05	24.1	41.76
S_2-75% RDF + FYM at 10 t ha^{-1}	25.51	2241.30	0.60	1.12	25.2	42.76
S_3- 75% RDF + VC at 5 t ha^{-1}	27.20	2357.18	0.67	1.14	25.2	43.13
S_4 - 50% RDF + FYM at 10 t ha^{-1}	27.78	2522.78	0.67	1.21	25.3	45.00
S_5 -50% RDF + VC at 5 t ha^{-1}	29.38	2665.35	0.77	1.28	25.5	49.36
SE(d)±	0.76	71.65	0.02	0.02	0.2	1.31
CD at 5%	1.56	146.78	0.04	0.05	NS	2.70
Foliar application						
F_1 - Nano DAP	20.77	1607.81	0.44	0.78	23.9	32.08
F_2 - Nano Urea	25.23	2320.11	0.65	1.11	25.0	42.91
F_3 - Nano emulsion biofertilizer	35.03	3251.43	0.90	1.59	26.3	58.22
SE(d)±	0.98	92.50	0.02	0.03	0.2	1.70
CD at 5%	2.02	189.49	0.05	0.07	0.5	3.49
S×F	S	S	S	S	S	NS

RDF: Recommended dose of fertilizer; FYM: Farm yard manure; VC: Vermicompost; DAP: Di-ammonium phosphate; SPAD: Soil plant analysis development; S: significant at P≤0.05; NS: Non-significant at P> 0.05.

which was statistically at par with 50% RDF + FYM at 10 t ha^{-1} but was significantly higher than control treatment (Table 1). Higher plant height under 50% RDF + VC at 5 t ha^{-1} might be ascribed due to involvement of zinc in auxin metabolism in combined applications of nutrients that leads to hormonal activity. Among the foliar application treatments, higher plant height at harvest was found with F_3 which was statistically similar with F_2 but significantly higher than F_1. This might be due to the growth promoting substances secreted by the microbial inoculants, which in turn might have led to better crop growth attributes during foliar applications (Singh *et al*., 2015).

However, at harvest maximum dry matter production was recorded with the application of 50% RDF + VC at 5 t ha^{-1} which was statistically at par with 50% RDF + FYM at 10 t ha^{-1} but was significantly higher than other treatments. The combined addition of these helped in better photosynthetic efficiency of crop plants which in turn increased translocation of photosynthate to sink. This remains a main tool for getting higher total dry matter accumulation. The outcomes are in similar with the results of Nandanyiya *et al*. (2016).

At harvest stage higher dry matter production was observed with the application of F_3 which was statistically higher than F_2 and F_1. The reason for better growth and development in the above treatments might be due to the greater availability of nutrients in soil due to fertiliser application with biofertilizer and biofertilizer might have enhanced meristematic activity leading increased availability of major nutrients to plant from deeper layers of soil ultimately resulting in increased plant growth in terms of plant height and dry matter accumulation. The results are in close association with the findings of Ahmed *et al.* (2017) in chickpea.

Maximum leaf area index at harvest was recorded with the application of 50% RDF + VC at 5 t ha^{-1} which was statistically at par with 50% RDF + FYM at 10 t ha^{-1} and 75% RDF + VC at 5 t ha^{-1} but was significantly higher than other treatments. Higher leaf area index under 50% RDF + VC at 5 t ha^{-1} might be ascribed to balanced use of fertilizers that resulted in better formation of photosynthates which promotes the metabolic activities, number of functional leaves per plant increased ultimately led to enhanced leaf area index.

Among the nano fertilizer treatments, higher leaf area index at harvest was found with F_3 which was significantly higher than F_2 and F_1. This may be due to better nutrient uptake and availability which increased plant height and higher number of functional leaves per plant that enhanced leaf area index (Jaipaul *et al*., 2011 and Abiyot Abeje *et al*., 2022).

However, at 60 DAS to harvest, maximum crop growth rate was found with the application of 50% RDF + VC at 5 t ha^{-1} which was statistically at par with 50% RDF + FYM at 10 t ha^{-1} and significantly higher than 75% RDF + VC at 5 t ha^{-1}, 75% RDF + FYM at 5 t ha^{-1} and control. Increase in crop growth rate might be due to balanced nutrients attributed to better nutritional environment for plant growth at active vegetative stages because of enhancements in cell multiplications, cell elongation and cell expression in plant body which ultimately increased the CGR (Verma *et al*., 2019 and Jitendra *et al*., 2023). At 60 DAS to harvest stage higher crop growth rate was observed with the application of F_3 which was significantly superior over all other treatments.

Table 2: Yield attributes, yield and nutrient uptake of chickpea to nano and mineral fertilization (Pooled data of 2022-23 and 2023-24).

Treatment	Yield attributes			Yield			Nutrient uptake (kg ha^{-1})		
	No. of pods/plant (g)	No. of seeds/pod	100 seed weight (g)	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest Index	N	P	K
Soil application									
S_1-100% RDF	17.33	1.11	21.83	740.33	1680.75	30.07	47.28	136.19	36.39
S_2- 75% RDF + FYM at 10 t ha^{-1}	17.89	1.11	22.13	759.33	1731.00	30.13	48.64	140.08	37.43
S_3- 75% RDF + VC at 5 t ha^{-1}	18.55	1.22	22.53	794.33	1824.75	30.37	51.15	147.32	39.36
S_4- 50% RDF + FYM at 10 t ha^{-1}	19.33	1.22	22.67	849.67	1953.42	30.45	54.74	157.67	42.13
S_5- 50% RDF + VC at 5 t ha^{-1}	20.56	1.22	22.90	905.33	2056.17	30.50	57.84	166.58	44.51
SE(d) ±	0.38	0.15	1.51	24.51	55.06	1.51	1.55	4.15	1.13
CD (P=0.05)	0.77	NS	NS	50.21	112.79	NS	3.17	8.50	2.32
Foliar application									
F_1- Nano DAP	12.60	1.00	20.70	524.60	1261.85	29.37	34.89	100.49	26.85
F_2- Nano Urea	18.67	1.20	22.22	793.20	1784.70	30.75	50.35	145.01	38.75
F_3- Nano emulsion biofertilizer	24.93	1.33	24.32	1111.60	2501.10	30.77	70.56	203.21	54.30
SE(d) ±	0.49	0.19	1.95	31.65	71.08	1.95	3.46	5.36	1.46
CD (P=0.05)	1.00	NS	NS	64.82	145.61	NS	7.08	10.97	2.99
S×F	S	NS	NS	S	S	NS	S	S	S

RDF: Recommended dose of fertilizer; FYM- Farm yard manure; VC: Vermicompost; DAP: Di-ammonium phosphate; N: Nitrogen; P: Phosphorus; K: Potassium; S: significant at P≤0.05; NS: Non-significant at P>0.05.

Application of nano emulsion biofertilizer increases the crop growth rate and facilitates the solubilization and mobilization of phosphorus and nitrogen and increases nutrient uptake that attributed more biomass accumulation at active vegetative stages which increased the crop growth rate (Egamberdieva *et al*., 2015).

Maximum chlorophyll (SPAD value) at peak flowering stage was found with the application of 50% RDF + VC at 5 t ha^{-1} which was statistically higher than other treatments. Higher chlorophyll (SPAD value) under 50% RDF + VC at 5 t ha^{-1} might be due to the observed behaviour linked to the fact that fertilizers as well as mix of organic and chemical fertilizers offer a larger amount of residual nitrogen to plants. This excess nitrogen content most likely caused a rise in chlorophyll levels which are important components of photo synthetically active pigments that give leaves their green hue. At peak flowering stage higher chlorophyll (SPAD value) was found with the application of F_3 which was significantly superior over all other treatments. It might be due to the increased nutrient availability and uptake by chickpea through colonization in the rhizosphere and thus increases the chlorophyll (SPAD value), because nutrients availability is crucially important in increasing chlorophyll biosynthesis. These results are in good agreement with Abhirami *et al*. (2023).

Yield and yield attributes

Yield attributes is a resultant effect of the vegetative development of crop that determines the yield. Yield attributes, *viz*., number of pods/plant is significantly affected by soil application of nutrients except number of seeds/ pod and 100-seed weight (Table 2). However, at harvest stage maximum number of pods/plant were recorded with 50% RDF + VC at 5 t ha^{-1} which was statistically at par with 50% RDF + FYM at 10 t ha^{-1} but significantly higher than 75% RDF + VC at 5 t ha^{-1}, 75% RDF + FYM at 5 t ha^{-1} and 100% RDF. The increase in number of pods/plant is due to the application of balanced fertilizers that lead to increased flowers and pollen grain viability and thereby increased number of pods/plant (Munazza *et al*., 2021).

Table 3: Interaction effect of soil and foliar applications of nutrients on seed yield of chickpea (Pooled data of 2022-23 and 2023-24).

Seed yield (kg/ha)	S_1	S_2	S_3	S_4	S_5	Mean
Treatment						
F_1	508	511	520	526	558	2177
F_2	705	747	820	840	854	3283
F_3	1008	1020	1043	1183	1304	4515
Mean	1549	1598	1688	1760	1847	6965
		SE(d) ±			CD (P=0.05)	
S × F		54.81			112.28	

S_1-100% RDF, S_2 - 75% RDF + FYM at 10 t ha-1, S3 - 75% RDF + VC at 5 t ha^{-1}, S_4 - 50% RDF + FYM at 10 t ha^{-1}, S_5 - 50% RDF + VC at 5 t ha^{-1}, F_1 - Nano DAP, F_2 - Nano Urea and F_3 - Nano emulsion biofertilizer, respectively.

Nano emulsion biofertilizer have significantly influenced the yield attributes, viz., number of pods/plant. Maximum number of pods/plant at harvest stage was found with F_3 which was significantly higher than other treatments, respectively. It might be due to the fact that foliar applications with nano emulsion biofertilizer enhanced the floral buds, prevented the floral shedding and activate the biochemical functions in plants, enzyme activation, photosynthesis, cell division and translocation of photosynthates from source to sink that resulted in higher number of pods $plant^{-1}$. Similar results were also reported by Gurrala Suresh *et al*. (2024).

Seed and stover yield were influenced significantly by different soil and foliar applications of nutrients, except harvest index. Higher seed and stover yield were found with the application of 50% RDF + VC at 5 t ha^{-1} which was statistically at par with 50% RDF + FYM at 10 t ha^{-1} and significantly higher than other treatments. The increase in seed and stover yield is due to adequate nutrients supply which helps in better translocation of photosynthates from source to sink that results in increased plant growth and yield attributes which ultimately resulted in higher crop yield as documented by Singh *et al*. (2016) and Singh *et al*. (2023).

However nano emulsion biofertilizer treatment has significantly influenced the seed and stover yield. Among the different nano fertilizer treatments, higher seed and stover yield were observed with F_3 which was statistically similar with F_2 but significantly higher than F_1. This might be due to the well-recognized availability of plant growth promoting bacteria that might have enhanced the plant growth activities viz., nutrient solubilization, production of secondary metabolites, enhanced nitrogen fixation and production of plant growth hormones (Ali *et al*., 2017).

The interaction effect of different soil and foliar fertilizer applications on seed yield was significant (Table 3). However, 50% RDF + VC at 5 t ha^{-1} along with Nano emulsion biofertilizer resulted in the highest seed yield (1847 kg ha^{-1}) which was statistically at par with 50% RDF + FYM at 10 t ha^{-1} along with Nano emulsion biofertilizer but significantly higher than 75% RDF + VC at 5 t ha^{-1} (S_3) along with Nano emulsion biofertilizer. The release of growth-promoting chemicals generated by microbial inoculants may have contributed to the combined application's likely better results by improving root establishment, water and nutrient uptake and transpiration (Verma *et al*., 2019).

Nutrient uptake

Nitrogen (N), phosphorus(P) and potassium (K) uptake was influenced significantly by soil and foliar application of nutrients. The interaction effect of different soil application levels and foliar applications on nutrient uptake was found significant (Table 4). However, Nano emulsion biofertilizer

Table 4: Interaction effect of soil and foliar applications of nutrients on NPK uptake of chickpea (Pooled data of 2022-23 and 2023-24).

Seed yield (kg/ha)	S_1			S_2			S_3			S_4			S_5			Mean		
Treatment	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
F_1	33.12	95.40	25.49	33.75	97.21	25.98	35.20	101.39	27.09	35.83	103.19	27.57	36.54	216.27	28.12	34.90	122.70	26.85
F_2	44.75	128.88	34.44	47.41	136.56	36.49	52.05	149.91	40.05	53.32	153.56	41.03	54.21	105.24	41.82	50.35	134.83	38.77
F_3	63.98	184.28	49.24	64.74	186.47	49.82	66.20	190.67	50.95	75.09	216.27	57.79	82.77	156.12	63.70	70.55	186.76	54.30
Mean	47.28	136.19	36.39	48.63	140.08	37.43	51.15	147.32	39.36	54.75	157.67	42.13	57.84	159.21	44.55	51.93	148.10	39.97

		SE(d) ±	CD (P=0.05)
S × F	N	3.46	7.08
	P	9.28	19.00
	K	2.53	5.18

S_1-100% RDF, S_2- 75% RDF + FYM at 10 t ha-1, S3 - 75% RDF + VC at 5 t ha^{-1}, S_4 -50% RDF + FYM at 10 t ha^{-1}, S_5 - 50% RDF + VC at 5 t ha^{-1}, F_1 - Nano DAP, F_2 - Nano Urea and F_3 - Nano emulsion biofertilizer respectively.

N- Nitrogen; P- Phosphorus; K- Potassium

along with 50% RDF + VC at 5 t ha^{-1} recorded with the highest N, P and K uptake which was statistically at par with Nano emulsion biofertilizer along with 50% RDF + FYM at 5 t ha^{-1} but significantly higher than Nano urea and Nano DAP combined treatments. The higher nutrient uptake might be ascribed due to balanced amount of fertilizers that offers a natural solution enriched with crucial nutrients, humic acids, plant growth-regulating hormones and enzymes, which positively influence plant nutrition, photosynthesis and the nutrient uptake.

Higher N, P and K uptake were observed with the application of F_3, which was significantly higher than other treatments. This may be due to the fact that microorganisms favoured nitrogen fixation, solubilization, mobilization of plant nutrients and reduced the need for chemical fertilizers and enhanced the nutrient availability and uptake to plants, which is similar to the findings reported by Gulen and Nizamettin (2021) and Singh *et al.* (2024).

CONCLUSION

The field experimental study investigated the effects of different levels of fertilizer and organic manures addition with and without nano emulsion biofertilizer on growth, yield and yield attributes, chlorophyll (SPAD value) and nutrient uptake of chickpea. All the treatments with nano emulsion biofertilizer showed better response in improving the tested growth and yield attributes of chickpea. While the addition of nano emulsion biofertilizer with fertilizers and manures further enhanced the promotive effect of Nano emulsion biofertilizer on chickpea growth. Combined use of 50% RDF + VC at 5 t ha^{-1} with nano emulsion biofertilizer was the most effective treatment in enhancing growth, yield and yield attributes and nutrient uptake of chickpea. Furthermore, the combination of nano urea and nano DAP was also found to be at par with fertilizers and manures in improving growth and yield of chickpea. Our findings suggest that the combined use of 50% RDF + VC at 5 t ha^{-1} with Nano emulsion biofertilizer could be effective in improving growth and yield of chickpea and serve as an alternate eco-friendly option to the conventional usage of single source fertilizer inputs for sustainable agriculture and environmental stewardship.

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Conflict of interest

The authors declare that they have no conflict of interest.

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