Study of physiological growth indices of chickpea (*Cicer arietinum* L.) to soil and foliar application through integrated nutrient management practices

ABSTRACT

An investigation was conducted in Rabi season of 2023-24 at the instructional farm of Karunya Institute of Technology and Sciences, Coimbatore, to evaluate the performance of physiological indices on chickpeas under soil and foliar application. The experiment was established on a Factorial Randomized Block Design (FRBD)in the field trials and was replicated three times. The treatments were soil application of NPK 100 ~~per cent~~percent (A_1), NPK 100 ~~per cent~~percent + FYM 10 t ha^{-1} (A_2), NPK 100 ~~per cent~~percent + Vermicompost 5 t ha^{-1} (A_3), NPK 75 ~~per cent~~percent + FYM 10 t ha^{-1} (A_4) and NPK 75 ~~per cent~~percent + Vermicompost 5 t ha^{-1} (A_5) combined with foliar applications, viz., Nano-$_{DAP}$ (B_1) and Nano-$_{Urea}$ (B_2). The results of the study revealed that morpho-physiological attributes of chickpeas were statistically increased by the ~~combined~~ application of soil (NPK 75 percent + Vermicompost 5 t ha^{-1}) combined with foliar (Nano$_{\text{-urea}}$) nutrient management practices.The results of this study underscore the importance of integrated nutrient management practices involving soil and foliar applications in enhancing the physiological indices of chickpeas.

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Keywords: Chickpea, Nano-DAP, Nano-Urea, Crop Growth Rate, Relative Growth Rate, Chlorophyll index

1. INTRODUCTION

Chickpea (*Cicer arietinum* L.) is India's second major pulse crop after the common bean (Phaseolus vulgaris); chickpea is grown predominantly under rainfed conditions. It benefits farming systems with a lower carbon footprint due to biological nitrogen fixation to increase soil health[1].Chickpea is grown in an area of 15.1 million ha (hectares) worldwide, with a total production of 15.8 million tonnes [2]. India and Australia are the top producers~~ contributing together 73 per cent of ~~, contributing together 73 percent of the total area and production [3]. Pulses are cultivated in an area of 27.9 million hectares in India, with a total production of 23.1 million tonnes. Meanwhile, chickpea is grown in an area of 13.7 million ha with a total production of 10.2 million tonnes with productivity of 1447 kg ha^{-1} in India and 40.6 lakh hectares of area with 37.67 lakh production and 9.23 lakh productivity in Tamil Nadu[4].

~~Chickpea can fix N up to 140 kg ha^{-1} from the atmosphere and receives 80 per cent of its~~Chickpeas can fix N up to 140 kg ha^{-1} from the atmosphere and receive 80 percent of their nitrogen (N) needs through symbiotic nitrogen fixation[Ref]. It leaves a sizable quantity of residual nitrogen for succeeding crops and contributes as organic matter that helps maintain and improve soil health. ~~The plant nutrients are the major sources for increasing quality and quantity in chickpea~~Plant nutrients are the primary sources for increasing the quality and quantity of chickpeas. Nutrient availability is one of the significant constraints for food production and soil fertility, with unequal utilization of plant nutrients affecting crop growth, development, and yield [5]. The sole application of chemical fertilizers results in good crop production, but it affects soil health and status. Therefore, ~~an~~ effective nutrient management can be done by integrating chemical fertilizers with organic manures such as farmyard manure and vermicompost.

Integrated Nutrient Management (INM) plays a crucial role in agricultural sustainability, encompassing the integration of synthetic fertilizers, organic manure, compost, biofertilizers, and micronutrients. By combining these elements, INM aims to optimize crop yields while minimizing nutrient losses and ensuring agricultural profitability. Among the crop nutrients, nitrogen stands out for its pivotal role in plant growth and development. Consequently, adopting foliar application of nutrients emerges as a more efficient strategy than traditional fertilization methods. Foliar fertilization involves directly spraying or applying liquid or water-soluble fertilizers onto plant leaves, facilitating rapid nutrient absorption by bypassing the soil uptake pathway. This supplementary feeding approach proves particularly beneficial during periods of nutrient deficiencies, stress, or accelerated growth, ensuring timely nutrient delivery to support plant health and productivity. Foliar nutrition minimizes nutrient loss, boosts bioavailability, and economizes crop output by lowering cultivation costs and reducing the quantity of fertilizer applied to crops [6].

Nano-$_{\mathbf{Urea}}$, a new agricultural input based on nanotechnology, has a particle size of 20 to 50 nm, offering a substantially higher surface area than regular urea prills. Liquid Nano-$_{\mathbf{Urea}}$, when directly sprayed onto leaves, enables absorption through stomata, providing crops with a targeted nutrient. Nano-$_{\mathbf{DAP}}$, a white liquid fertilizer that provides phosphorous and nitrogen to plants in a 2.5 :1 ratio, improves crop growth and yields. Nano-$_{\mathbf{DAP}}$ has great absorption capacity and easily penetrates plant tissues through stomata when used as a foliar spray [8]. Additional nutrient delivery is a critical aspect in boosting grain production in legumes. The degree of bloom drops impacts chickpea production, contributing features, and yield. The plant's retention of blossoms results in a ~~bigger~~ more significantyield than projected[9]. The present study is aimed to determine the physiological attributes of ~~chickpea through~~ chickpeas through the combined application of soil and foliar applications of nano-fertilizers.

2. MATERIALS AND METHODS

A field experiment was carried out at Karunya Institute of Technology and Science, Coimbatore, Tamil Nadu ~~to study the response of chickpea (*Cicer arietinum* L.) to soil and foliar application through integrated nutrient management practices under Coimbatore region during~~ , to study the response of chickpea (*Cicer arietinum* L.) to soil and foliar application through integrated nutrient management practices under the Coimbatore region during the *Rabi* season of 2023-24. The climatic condition

~~under~~ in the Coimbatore district of Tamil Nadu is subtropical. The total rainfall received during the crop-growing period was 128 mm. The weekly maximum and minimum temperatures during the experimental period ranged from 21.0°C to 35.1°C and 5.2°C to 15.1°C, respectively. The soil of the experimental plot was sandy clay loam with low organic carbon (0.42 ~~per cent), low in available nitrogen (164 kg ha^{-1}), high in available phosphorus (28.5 kg ha^{-1})~~percent), low in available nitrogen (164 kg ha-1), high in available phosphorus (28.5 kg ha-1), and low in available potassium (235 kg ha^{-1}). The soil reaction of the experimental field was alkaline(pH 8.10) with an electrical conductivity of 0.28 dSm^{-1}.

Please provide some chemical characteristics information on the FYM and VC used (macronutrient content, C/N ratios) if you have any.

Please provide the %N, %P_2O_5 and % K_2O in the compound fertilizer used.

Comment [User2]: Available N or total N? Available N is ammonium and nitrate

List 1. Treatment details:

A Factor (Soil)	Application
(A_1)	NPK 100 per cent
(A_2)	NPK 100 per cent + FYM 10 t ha^{-1}
(A_3)	NPK 100 per cent + VC 5 t ha^{-1}
(A_4)	NPK 75 per cent + FYM 10 t ha^{-1}
(A_5)	NPK 75 per cent + VC 5 t ha^{-1}
B Factor (Foliar)	**Application**
(B_1)	Nano-$_{\mathbf{DAP}}$
(B_2)	Nano-$_{\mathbf{Urea}}$

What is the amount of NPK fertilizer required per hectare if the NPK percentage is 100%?The experiment was laid out in factorial randomized block design with soil application of NPK 100 ~~per cent~~percent (A_1),NPK 100 ~~per cent~~percent + FYM 10 t ha^{-1} (A_2), NPK 100 ~~per cent~~percent + Vermicompost 5 t ha^{-1} (A_3), NPK 75 ~~per cent~~percent + FYM 10 t ha^{-1} (A_4) and NPK 75 ~~per cent~~percent + Vermicompost 5 t ha^{-1} (A_5) combined with foliar applications, viz., Nano-$_{\mathbf{DAP}}$ (B_1) and Nano-$_{\mathbf{Urea}}$ (B_2). The chickpea seeds are sown in well-prepared land by dibbling method with seed rates of 90 kg ha^{-1}. A spacing of 30 × 10 cm was adopted. The crop was produced in an irrigated environment with one pre-planting irrigation applied 7 days before sowing and just one lifesaving irrigation. Hand weeding was done between ~~crop and rows at~~ crops and rows 30 to 45 days after sowing. The crops were harvested manually using ~~sickle, wrapped into bundles with tags from each plot, and sun dried~~a sickle, wrapped into bundles with tags from each plot, and sun-dried. Threshing procedures were also carried out ~~treatment-wise manually~~manually and treatment-wise. The combination effect of soil and foliar ~~application~~ applications was significant. This increase in production resulted from increased chickpea crop growth and development with the application of organic and inorganic ~~fertilizer it~~fertilizers. It might be due to the higher nutrient availability during crop growth, which eventually boosted growth. The data collected on various characters studied during the experiment were subjected to statistical analysis in a factorial randomized block design (FRBD). The significance of the difference was tested by the "f" test at a 5 percent level.

Comment [User3]: Please rewrite

Comment [User4]: Should be written in "Results"

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Crop growth rate

The crop growth rate ($g^{-1}m^{-2}day$) for each specified stage was calculated using the standard formula given by Radford (1967)[10]below:

$$CGR = \frac{W_2 - W_1}{p(T_2 - T_1)}$$

Where,

W_2= Dry weight of crop plant at the time interval T_2

W_1 = Dry weight of crop plant at the time interval T_1

p = ground area occupied by the plant in m^2

Relative growth rate

The relative growth rate ($g^{-1}g^{-1}day$) for each observational stage was worked out by substituting the corresponding dry matter accumulation values of that very stage in the formula ~~was~~ given by Radford (1967)[10]under:

$$RGR = \frac{Log_e W_2 - Log_e W_1}{T_2 - T_1}$$

Where,

W_2 and W_1 are the dry matter of plants at the time of T_2 and T_1

Chlorophyll Rate

The chlorophyll content of the crop was measured using an At LEAF Digital Chlorophyll Meter, which was very easy to handle~~, and the~~. The values were recorded quickly and perfect SPAD (Soil Plant Analysis Development) value were maintained properly.

3. RESULTS AND DISCUSSION

3.1. Physiological attributes of chickpea

3.1.1. Crop growth rate ($g^{-1}m^{-2}day$)

The result showed that the effect of combined application of soil and foliar application with NPK 75 percent + Vermicompost along with Nano-Urea (A5B2) resulted in a higher crop growth rate 60 DAS to at harvest 2.36 $g^{-1}m^{-2}day^{-1}$. ~~Whereas the lower crop growth rate was observed in the combination of 100 per cent~~The lower crop growth rate was observed in the combination of 100 percent NPK with Nano-$_{DAP}$0.81 $g^{-1}m^{-2}$ day^{-1} (A_1B_1) (Table 1). The growing trend of CGR might be attributed to increased photosynthetic activity~~ and a favourable response of CGR lead~~, and a favorable response of CGR leads to an increased plant population. Similar results were also reported by(Edwards*et al*., 2005)[11] in maize (Figure. 1). CGR decreases after harvest owing to leaf senescence and a drop in leaf area index.

3.1.2. Relative growth rate ($g^{-1}g^{-1}$day)

The result showed that the effect of combined treatment of soil and foliar application with NPK 75 percent + Vermicompost along with Nano-$_{Urea}$ (A_5B_2) resulted in ~~the~~ a higher relative growth rate at 65 DAS- At harvest (0.0230 g $^{-1}$g^{-1}day), whereas the lower relative growth rate was observed in the combination of (A_1B_1) 100 ~~per cent~~percent NPK with Nano-$_{DAP}$0.0200 g $^{-1}$g^{-1}day (Table 1). The combined application of NPK 75 percent + Vermicompost with Nano-Urea greatly influences relative growth parameters, constituting a multifaceted approach to augment plant growth and productivity. The treatment enhances nutrient availability, soil structure, and stress tolerance, thereby eliciting profound physiological responses, notably reflected in the RGR of plants. With more macronutrients, micronutrients, and organic matter, the treatment optimizes metabolic processes, energy utilization, and biomass accumulation. Uniformly released, the Nano-$_{Urea}$ sustains nutrient availability throughout the growth cycle. A higher supply of nitrogen boosts plant growth and enhances physiological activities, ~~there by~~thereby amplifying the production of growth and yield components (Figure. 2). These result findings were in close agreement with the findings of(Saithejaa *et al.,* 2022) [12] on the green gram, (Omran*et al*., 2018)[13] on mung bean.

3.1.3. Chlorophyll rate

The result showed that the effect of combined treatment of soil and foliar application with NPK 75 ~~per cent~~percent + Vermicompost along with Nano-$_{Urea}$ (A_5B_2) resulted in higher during peak flowering stage at 65 DAS - At harvest (0.0230), whereas the lower chlorophyll content at peak flowering stage was observed in the combination of 100 ~~per cent~~percent NPK with Nano-$_{DAP}$(A_1B_1 -0.0200) (Table 1). The foliar application of water-soluble fertilizers accelerated crop growth during the early stages~~,~~ and gradually slowed as the crop matured. This phenomenon may be attributed to the ~~rapid absorption of macro and micronutrients by the crop~~crop's rapid absorption of macro and micronutrients. Increased total chlorophyll and enzyme activities were observed, leading to enhanced photosynthesis. Due to the heightened leaf thickness, there is a likelihood of increased chlorophyll density within the leaves, thereby potentially sustaining more efficient photosynthesis (Figure. 2). These are similar findings collaborated withKashiwagi *et al*., 2010 [14] andKumar*et al*., 2018[15] on sesame.

4. CONCLUSION

The findings of this study indicate that the combined application of soil and foliar NPK 75 ~~per cent~~percent, Vermicompost, and Nano-$_{Urea}$ exhibited remarkable efficacy in enhancing chickpea growth and productivity. Treatment led to significantly higher crop growth rates, relative growth rates, and chlorophyll rates than other combinations. These improvements can be attributed to the multifaceted approach of nutrient supply, enhanced soil structure, and stress tolerance. The sustained release of nutrients from nano ~~played~~ plays a pivotal role in optimizing metabolic processes and biomass accumulation throughout the growth cycle.

Discuss whether the leaf absorption of nano-urea was better than that of nano-DAP. Between Diammonium Phosphate (DAP) and Urea as foliar fertilizers, Urea is generally more readily absorbed by plants when applied as a foliar spray. This is due to several factors:

1. Solubility: Urea is highly soluble in water, facilitating plant leaf uptake. When sprayed onto foliage, urea quickly dissolves and can be absorbed by the plant's stomata (small openings on leaves).

2. Nitrogen Content: Urea contains a high nitrogen concentration (46% nitrogen), a key nutrient for plant growth. Nitrogen is essential for forming proteins, enzymes, chlorophyll, and other essential plant compounds.

3. Ease of Uptake: Urea can move relatively quickly through leaf tissues compared to phosphorus-containing fertilizers like DAP. This enhances its efficiency in providing nitrogen to plants through foliar application.

Diammonium Phosphate (DAP) contains nitrogen and phosphorus, but phosphorus is less effectively absorbed through foliar application than nitrogen. Phosphorus tends to be less mobile in plant tissues and is more commonly applied through soil application, where it can interact with soil particles and roots.

Therefore, if you are considering foliar fertilization specifically for nitrogen supplementation, urea would generally be a more suitable choice due to its high solubility and rapid absorption characteristics by plant leaves. However, for phosphorus supplementation, DAP would be more effective when applied to the soil, where it can interact with the root system for uptake.

Please add some more references to the discussion about the different mechanisms.

How about the yield? Generally, chickpeas have a linear relationship between yield and crop growth rate.

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Treatments	Crop growth rate ($g^{-1}m^{-2}day^{-1}$)			Relative growth rate ($g^{-1}g^{-1}day^{-1}$)			Chlorophyll rate		
	30-45 DAS	45- 60 DAS	60 DAS-Harvest	30-45 DAS	45- 60 DAS	60 DAS-Harvest	At vegetative	At initial flowering	At peak flowering
SOIL APPLICATION									
NPK 100 percent	0.38	0.84	1.21	0.0385	0.0425	0.0213	13.15	31.75	35.40
NPK 100 percent + FYM 10 t ha^{-1}	0.43	0.94	1.35	0.0395	0.0430	0.0215	14.99	32.30	36.40
NPK 100 percent + VC 5 t ha^{-1}	0.49	1.09	1.56	0.0395	0.0435	0.0218	15.90	33.40	36.96
NPK 75 percent + FYM 10 t ha^{-1}	0.56	1.22	1.77	0.0400	0.0435	0.0218	16.00	35.45	37.85
NPK 75percent + VC 5 t ha^{-1}	0.59	1.29	1.87	0.0400	0.0435	0.0218	16.60	36.77	40.90
S.E (d) ±	0.01	0.03	0.05	0.0002	0.0001	0.0001	0.42	0.23	0.38
CD (p=0.05)	0.03	0.07	0.10	0.0004	0.0002	0.0001	0.89	0.49	0.81
FOLIAR APPLICATION									
Nano-$_{DAP}$	0.32	0.63	1.03	0.0364	0.0408	0.0204	10.28	28.29	481.29
Nano-$_{Urea}$	0.66	1.52	2.08	0.0426	0.0456	0.0228	20.38	39.58	643.74
S.E.(d) ±	0.02	0.05	0.07	0.0003	0.0002	0.0001	0.67	0.37	0.61
CD (p=0.05)	0.05	0.12	0.15	0.0006	0.0004	0.0002	1.41	0.77	1.28
INTERACTION (A×B)									
S.E. ±	0.03	0.08	0.10	0.0004	0.0003	0.0001	0.95	0.52	0.86
CD (p=0.05)	0.07	0.16	0.22	0.0009	0.0005	0.0003	1.99	1.08	1.81

Table.Table 1 Effect of Nano-fertilizer on crop physiological growth indices.

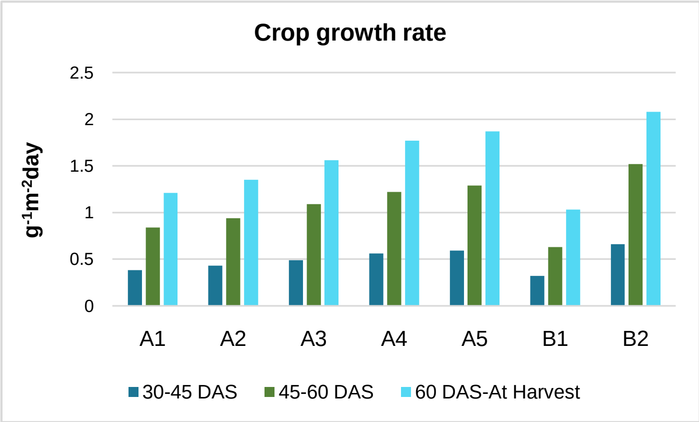

Figure. 1 Effect of Nano-fertilizers on crop growth rate

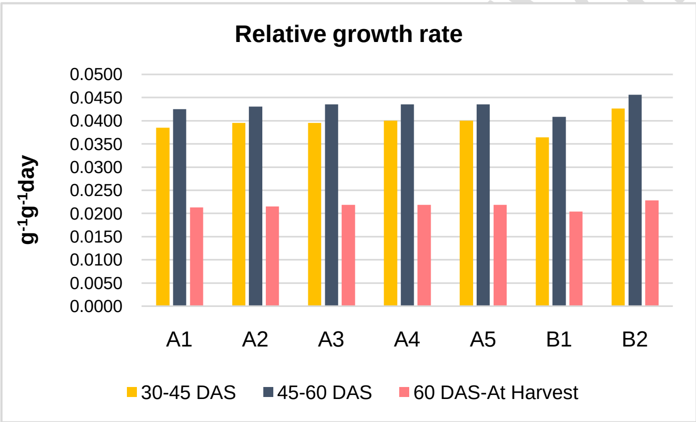

Figure. 2 Effect of Nano-fertilizers on Relative ~~growth rate~~Growth Rate

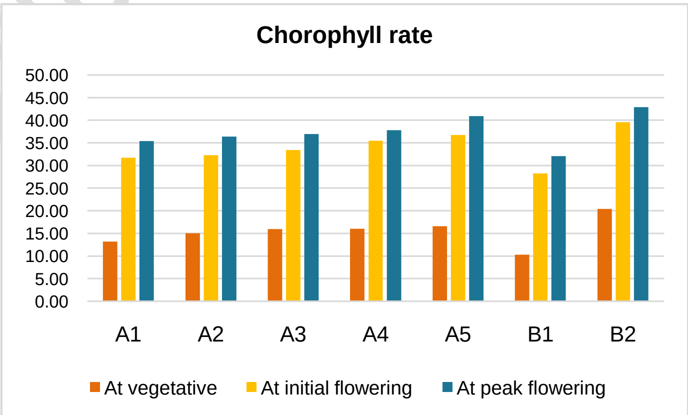

Figure. 3 Effect of Nano-fertilizers on Chlorophyll rate