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RESEARCH PAPER

Drought management in chickpea through foliar nutrition

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Abstract: A field experiment was conducted to study the drought management in chickpea through foliar nutrition in the Northern Dry Zone of Karnataka during *rabi* 2023-24 at Regional Agricultural Research Station, Vijayapura, Karnataka. The experiment was laid out in a Randomized Complete Block Design with fourteen treatments and replicated three times. Treatments included foliar spray of water, urea @ 2%, KNO_3@ 0.5%, 19:19:19 @ 0.5%, $ZnSO_4$@ 0.5%, nano-urea @ 2 ml L^{-1}, nano-urea @ 4 ml L^{-1}, nano-zn @ 2 ml L^{-1}, nano-zn @ 4 ml L^{-1}, nano-urea @ 2 ml L^{-1}+ nano-zn @ 2 ml L^{-1}, nano-urea @ 2 ml L^{-1}+ nano-zn @ 4 ml L^{-1}, nano-urea @ 4 ml L^{-1}+ nano-zn @ 2 ml L^{-1} and nano-urea @ 4 ml L^{-1}+ nano-zn @ 4 ml L^{-1} at flower initiation and pod formation stages and these were compared with control (no spray) and recommended dose of fertilizers (RDF) is common for all treatments. The results revealed that, foliar spray of nano-urea @ 4 ml L^{-1} + nano-zn @ 4 ml L^{-1}at flower initiation and pod formation stage produced significantly higher number of pods per plant (38), seed weight per plant (7.58 g), seed yield (1633 kg ha^{-1}) and haulm yield (2205 kg ha^{-1}) as compared to other treatments except nano-urea @ 4 ml L^{-1} + nano-zn @ 2 ml L^{-1}. Significantly higher plant height (37.44 cm), leaf area index (0.85), relative chlorophyll content (53.47), NDVI value (0.92) and relative water content (73.71%) were recorded in nano-urea @ 4 ml L^{-1} + nano-zn @ 4 ml L^{-1} treatment.These findings suggest that foliar application of nano-urea @ 4 ml L^{-1} combined with nano-zn @ 2-4 ml L^{-1} at the flower initiation and pod formation stages along side the RDF can effectively enhance chickpea yield and profitability, even under drought conditions.

Key words: Chlorophyll content, Drought management, Nano-fertilizer, Nano-urea, Nano-zn

Introduction

Chickpea (*Cicer arietinum* L.) is a vital legume cultivated in nearly 50 countries, with its origins in the eastern Mediterranean and southwestern Asia. In northern Karnataka, it is mainly cultivated as a *rabi* crop under residual soil moisture since the normal rainfall in the *rabi* season is 134.00 mm in the zone-3 of Karnataka. Globally, chickpea covers 10.74 million hectares, producing 13.54 million tonnes with a productivity of 1261 kg ha^{-1} (Anon, 2022). India leads in chickpea production, contributing 70% of the global output, with 11.99 million tonnes grown over 9.85 million hectares. Chickpea, rich in protein (21.1%), carbohydrates (61.5%) and fats (4.5%), is a popular meat substitute and provides essential nutrients like calcium, iron and niacin. It also improves soil health through biological nitrogen fixation, benefiting both human diets and agriculture sustainability.

Chickpea encounters various stresses throughout its life cycle, which can be broadly classified into biotic and abiotic factors. Abiotic stresses, such as drought and salinity, cause greater yield losses in chickpea, exceeding 6.4 million tonnes, compared to 4.8 million tonnes lost due to biotic stresses (Ryan, 1997). Water stress is a significant abiotic factor that limits plant growth and yield, especially in chickpea. Drought reduces soil moisture, hindering essential processes such as nutrient uptake, stomatal conductance and photosynthesis, ultimately leading to stunted growth and lower yields. Additionally, it triggers oxidative stress and the accumulation of osmotic regulators like proline, emphasizing the need for adaptive strategies to mitigate its impacts (Maqbool *et al.*, 2017).

To address water scarcity, strategies such as using drought-tolerant chickpea varieties, seed hardening, mulching, rainwater harvesting, nutritional management, hydrogel application and land configuration can enhance resilience and optimize water use. Integrating these approaches helps to manage water stress and sustain chickpea production amid increasing drought frequency. Evidence indicates that mineral nutrients are vital for enhancing stress resistance, with foliar nutrient application proving effective in boosting crop yield and drought tolerance (Romheld and Kirkby, 2010; Marschner, 2012). This technique delivers essential nutrients directly to plant leaves, by passing soil-related limitations and improving stress resilience by supporting physiological functions and metabolic processes. As a result, foliar feeding helps plants better manage water stress and maintain productivity.

To optimize foliar feeding for water stress or drought management, it is essential to focus on specific nutrients that significantly enhance drought resilience. Among these, potassium, zinc and nitrogen stand out for their significant impact. Potassium regulates stomatal function, improves water-use efficiency and supports root growth and nutrient uptake, which are vital plant resilience under limited water availability (Milford and Johnston, 2007). Zinc plays a critical role in maintaining ionic balance, supporting critical metabolic processes, and enhancing osmolyte synthesis and antioxidant defences, which collectively strengthen the plant's stress response (Baybordi, 2006). Nitrogen, delivered through urea boosts chlorophyll and carotenoid content, improving photosynthesis and overall plant health. Together, these nutrients enable plants to better manage water stress and sustain productivity under adverse conditions.

In recent developments, nano fertilizers have emerged as a significant advancement in agriculture, leveraging the unique characteristics of nanoparticles to enhance reactivity and efficiency. With particle sizes ranging from 30 to 40 nm, these fertilizers, offer a high surface area that allows them to hold and release nutrient ions slowly and steadily, aligning with crop nutrient demand (Subramanian *et al.*, 2015). This innovation addresses critical challenges in nutrient management, offering a sustainable and efficient alternative to conventional fertilizers. Specifically, nano fertilizers like nano-urea and nano-zinc (Zn), recently developed by IFFCO, are designed to replace conventional fertilizer. The application of these nano nutrients through foliar sprays bypasses soil-related limitations and delivers nutrients directly to plant tissues, enhancing uptake efficiency and ensuring plants receive essential elements during key growth stages. Moreover, these nano fertilizers improve nutrient use efficiency (Kumar *et al.*, 2021), minimize the negative effects associated with overdosage, reduce soil toxicity and decrease application frequency while maximizing economic returns (Sekhon, 2014). By improving nutrient use efficiency, they not only reduce input costs but also help in achieving sustainable agriculture practices.Given the increasing challenges posed by water scarcity, the integration of nano fertilizers into drought management strategies holds immense potential. The present study is thus designed to explore the positive impact of foliar nutrition using nano-urea and nano zinc on chickpea yield under drought conditions.

Material and methods

A field experiment was conducted during the *rabi* season of 2023-24 at the Regional Agricultural Research Station, Vijayapura, Karnataka on vertisols with an alkaline reaction (pH 8.18), low salinity (0.30 dSm^{-1}), medium organic carbon (0.41%), low in available nitrogen (183.30 kg N ha^{-1}), medium in available phosphorus (30.60 kg P_2O_5 ha^{-1}), and high in available potassium (416.45 kg K_2O ha^{-1}). The experimental site was located at a latitude of 16^0 46' 17'. North, longitude of $75^0$44' 15''East and an altitude of 593.8 meters above mean sea level in the Northern Dry Zone of Karnataka (Zone 3). During the cropping period (October 2023 to January 2024), there was a deviation in mean monthly maximum and minimum temperatures, as well as relative humidity compared to the normal values. The total annual rainfall in 2023 was 325.2 mm, 1.8 mm higher than the 42-year normal, with July and September being the wettest months. A total of 12.6 mm of rainfall was recorded on single rainy day during the cropping period.

The experiment was conducted using a Randomized Complete Block Design (RCBD) with fourteen treatments replicated three times. The treatments included foliar spray of water, Urea @ 2%, KNO_3@0.5%, 19:19:19 @ 0.5%, $ZnSO_4$@ 0.5% Nanourea @ 2 ml L^{-1}, Nanourea @ 4 ml L^{-1}, Nano-zn @ 2 ml L^{-1}, Nano-zn @ 4 ml L^{-1}, Nanourea @ 2 ml L^{-1}+ Nano-zn @ 2 ml L^{-1}, Nano-urea @ 2 ml L^{-1}+ Nano-zn @ 4 ml L^{-1}, Nano-urea @ 4 ml L^{-1}+ Nano-zn @ 2 ml L^{-1} and Nanourea @ 4 ml L^{-1}+ Nano-zn @ 4 ml L^{-1}. These foliar sprays were applied at the flower initiation and pod formation stages and their effects were compared with control (no spray).The land was ploughed once after the previous crop was harvested followed by harrowing to achieve a fine tilth. At the time of sowing, the land was prepared to a fine seed bed and the experimental plots were laid out. The JG-11chickpea variety was used in the study. The fertilizer application followed the recommended package of practice of

UAS, Dharwad, which included. 10:25:0 kg NPK ha^{-1} +10 kg $FeSO_4$ ha^{-1}+10 kg $ZnSO_4$ ha^{-1} common to all treatments. The crop was sown with a spacing of 45 × 10 cm. Due to the incidence of pod borer [*Helicoverpa armigera* (Hubner)], sprays of Emamectin benzoate 5% SG @ 0.5 g L^{-1} of water was taken during flower initiation and pod formation stages. Harvesting was done at the physiological maturity of the crop. The net plot area (11.34 m^2), was harvested according to the treatments by cutting the plants at ground level. After complete drying, the harvested produce was weighed just before threshing to record pod weight per plot. Threshing was done manually, followed by winnowing and cleaning to separate seed and haulm. The crop was harvested on 2nd January 2024.

Five plants were randomly selected from each treatment within the net plot area and labelled with tags to record various growth and yield parameters.The mean value for each treatment was then determined. Periodical observations were recorded at 30 DAS, 60 DAS and at harvest. The plant height was measured from the ground level to the tip of the main shoot. LAI, SPAD and NDVI value were recorded using a LAI 2200C Plant Canopy Analyzer, SPAD-502, chlorophyll meter (Markwell *et al.*,1995) and Green Seeker™ Handheld Optical Sensor Unit (NTech Industries, Inc., USA), respectively. Relative leaf water content (RWC) was measured in 8 to 10 fully expanded leaflets before and one week after each nutrient spray. Fresh weight (FW) was recorded immediately, while turgid weight (TW) was measured after floating the leaflets in distilled water for 4 hours. Dry weight (DW) was obtained after oven drying at 65 ± 5°C for 48 hours. RWC (%) was calculated using Kramer's (1983) formula.

$$\text{RWC (\%)} = \frac{\text{Fresh weight - Dry weight (g)}}{\text{Turgid weight - Dry weight (g)}} \times 100$$

The yield attributes and yield were recorded from the net plots, and the seed yield was converted to hectare basis in kilograms. The harvest index (HI) was calculated by using the following formula suggested by Donald (1962).

$$\text{HI} = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})} \times 100$$

Results and discussion

Nutrient management is very important for maximizing productivity and optimizing the growth of plants. Of the different ways of application of nutrients, the use of nano-fertilizers through foliar application is very much in the limelight

Table 1. Effect of foliar nutrients on growth attributes of chickpea

Treatments		Plant height (cm)			Leaf area index (LAI)		
		30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T_1	Control (without spray)	18.12	20.90	24.63	0.64	0.65	0.48
T_2	Water spray	17.52	21.52	26.40	0.65	0.68	0.50
T_3	2% Urea spray	17.40	25.34	30.89	0.68	0.84	0.62
T_4	0.5% KNO_3	17.50	26.44	32.00	0.63	0.93	0.72
T_5	0.5% 19:19:19	17.28	26.10	31.86	0.67	0.91	0.70
T_6	0.5% $ZnSO_4$	17.36	25.30	30.75	0.62	0.81	0.60
T_7	Nano-urea @ 2 ml L^{-1}	17.74	25.44	31.36	0.64	0.87	0.66
T_8	Nano-urea @ 4 ml L^{-1}	17.82	26.06	31.76	0.67	0.90	0.69
T_9	Nano-zn @ 2 ml L^{-1}	18.26	25.36	31.11	0.61	0.86	0.64
T_{10}	Nano-zn @ 4 ml L^{-1}	17.64	25.63	31.42	0.64	0.88	0.67
T_{11}	Nano-urea @ 2 ml L^{-1} + Nano-zn @ 2 ml L^{-1}	18.40	26.59	32.08	0.62	0.95	0.73
T_{12}	Nano-urea @ 2 ml L^{-1} + Nano-zn @ 4 ml L^{-1}	17.42	26.62	32.12	0.65	0.96	0.75
T_{13}	Nano-urea @ 4 ml L^{-1} + Nano-zn @ 2 ml L^{-1}	17.88	29.82	36.33	0.64	1.08	0.83
T_{14}	Nano-urea @ 4 ml L^{-1} + Nano-zn @ 4 ml L^{-1}	18.32	30.26	37.44	0.65	1.10	0.85
S.Em±		0.93	1.21	1.45	0.03	0.04	0.03
C.D. (p = 0.05)		NS	3.51	4.22	NS	0.12	0.09

DAS – Days after sowing N S – Non significant

for its ability to increase nutrient uptake as well as utilization. Nano-fertilizers provide increased permeability, quick uptake, and translocation in the tissues of the plants with increased physiological response and growth. The results of the present work are given below under respective subheadings for clarity as well as for discussion.

Effect of foliar nutrients on growth parameters

Foliar application with nutrients had a significant effect on plant height and Leaf Area Index. The maximum plant height (37.44 cm) and LAI (0.85) were recorded with the foliar application of Nano-urea @ 4 ml L^{-1} + Nano-zn @ 4 mlL^{-1}. This was statistically on par with foliar application of nano-urea @ 4ml L^{-1} + nano-zn @ 2 ml L^{-1} (36.33 cm and 0.83, respectively) (Table 1). The water spray and control treatment recorded significantly lower values compared to all other treatments. Plant height plays a significant role in overall crop performance, as taller plants generally have increased photosynthetic capacity due to a larger leaf area, which supports greater energy production. Similarly, LAI a provides a measure of canopy density and light interception efficiency as it is the critical indicators of plant growth and productivity. The increase in plant height and LAI can be attributed to the enhanced nutrient availability provided by nano-fertilizers. Nano-urea and nano-zinc improve nutrient permeability and uptake, boosting enzyme activity, auxin metabolism, and cell expansion, ultimately leading to improved plant growth (Abd Alqader *et al.*, 2020; Midde *et al.*, 2022). The sufficient supply of nitrogen from nano-urea supports chlorophyll synthesis, while nano-zinc enhances enzymatic functions and auxin production, promoting vigorous leaf growth and a higher LAI. These results are consistent with the findings of Beeresha (2018) and Uma *et al.* (2019), who reported similar improvements in LAI with regulated nutrient availability. A significant and positive correlation was found between seed yield and plant height (r=0.971) and LAI (r=0.994) (Fig. 1).

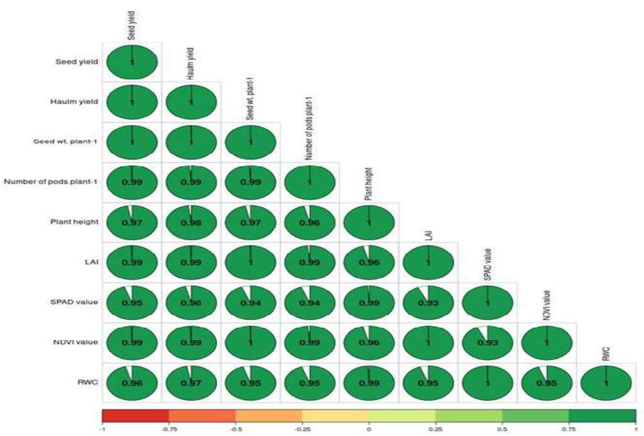

Fig 1. Correlation matrix analysis for yield, yield attributes and morphophysiological parameters of chickpea as influenced by foliar nutrition

Effect of foliar nutrients on physiological parameters

The relative chlorophyll content, measured by the SPAD meter, quantifies leaf greenness, while NDVI values indicate canopy coverage and overall plant health by reflecting the extent of photosynthetic active area. The application of various foliar nutrients significantly influenced both relative chlorophyll content and NDVI values. The foliar application of Nano-urea @ 4 ml L^{-1} + Nano-zn @ 4 ml L^{-1} resulted in higher SPAD and NDVI values (53.47 and 0.92, respectively),which were statistically on par with Nano-urea @ 4ml L^{-1} + Nano-zn @ 2 ml L^{-1} (52.78 and 0.90, respectively) (Table 2). This improvement can be attributed to the increased nutrient availability provided by the foliar application of Nano-urea and Nano zinc, enhancing chlorophyl synthesis and canopy development.The nitrogen supplied by Nano-urea improved leaf nitrogen content, directly boosting chlorophyll levels and photosynthetic efficiency, while Nano Zinc played a crucial role in chlorophyll production by minimizing oxidative damage and activating enzymes essential for pigment biosynthesis (Kanavi *et al.*, 2023; Sahana *et al.*, 2023). This enhanced chlorophyll concentration likely increased light interception and solar radiation utilization, improving overall photosynthesis. As a result, both SPAD and NDVI values increased, indicating healthier, more vigorous canopy

Table 2. Effect of foliar nutrients on physiological parameters of chickpea

Treatments		Relative chlorophyll (SPAD value)		NDVI value		RWC (%)		
		30 DAS	60 DAS	30 DAS	60 DAS	Before 1st spray	1 week after 1st spray	1week after 2nd spray
T_1	Control (without spray)	38.60	39.43	0.53	0.55	51.09	51.44	51.48
T_2	Water spray	38.19	39.70	0.52	0.56	50.98	52.06	52.12
T_3	2% Urea spray	40.88	46.42	0.54	0.68	57.02	60.77	63.17
T_4	0.5% KNO_3	41.86	46.68	0.59	0.78	56.99	61.09	64.09
T_5	0.5% 19:19:19	40.00	46.65	0.60	0.76	57.18	61.05	63.95
T_6	0.5% $ZnSO_4$	39.80	46.40	0.56	0.67	57.18	60.74	63.04
T_7	Nano-urea @ 2 ml L^{-1}	38.00	46.50	0.54	0.73	57.20	60.92	63.52
T_8	Nano-urea @ 4 ml L^{-1}	45.02	46.62	0.61	0.75	57.15	60.99	63.79
T_9	Nano-zn @ 2 ml L^{-1}	41.80	46.45	0.56	0.70	57.26	60.84	63.34
T_{10}	Nano-zn @ 4 ml L^{-1}	39.10	46.53	0.63	0.74	57.25	60.94	63.64
T_{11}	Nano-urea @ 2 ml L^{-1} + Nano-zn @ 2 ml L^{-1}	43.88	46.70	0.61	0.80	57.09	61.14	64.34
T_{12}	Nano-urea @ 2 ml L^{-1} + Nano-zn @ 4 ml L^{-1}	40.20	46.72	0.63	0.82	57.09	61.20	64.60
T_{13}	Nano-urea @ 4 ml L^{-1} + Nano-zn @ 2 ml L^{-1}	41.07	52.78	0.57	0.90	64.12	69.37	73.29
T_{14}	Nano-urea @ 4 ml L^{-1} + Nano-zn @ 4 ml L^{-1}	39.70	53.47	0.58	0.92	63.25	69.49	73.71
S.Em±		2.48	2.18	0.03	0.03	3.03	2.81	2.81
C.D. (p = 0.05)		NS	6.34	NS	0.09	NS	8.17	8.18

DAS – Days after sowing NS - Non significant, RWC -Relative Water Content;

development. The higher leaf area and improved canopy coverage contributed to greater dry matter production, better nutrient uptake and efficient source-to-sink translocation, findings that align with Lenka and Das (2019).

Relative water content (RWC) serves as a critical indicator of plant hydration and its ability to with stand drought stress. Higher RWC values reflect better water retention, leading to improved growth and productivity. In this study, the foliar application of Nano-urea @ 4 ml L^{-1} + Nano-zn @ 4 ml L^{-1} recorded the highest RWC (73.71%), comparable to Nano-urea @4 ml L-1 + Nano-zn @ 2 ml L-1 (73.29%) (Table 2). The efficient nitrogen delivery through Nano-urea promotes root development and enhances the plant's water management capacity (Gayathri *et al.*, 2023). Meanwhile, Nano Zinc supports vital processes like chlorophyll synthesis and osmotic adjustment by accumulating proline and soluble sugars under water-limited conditions (Arough *et al.*, 2016). Additionally, zinc strengthens vascular tissue, improving the plant's ability to maintain hydration (Gadallah, 2000). Together, these nano-nutrients optimize water use efficiency and enhance drought resilience. The correlation studies further support these findings (Fig.1), showing a positive and significant correlation between seed yield and RWC (r= 0.958).

Effect of foliar nutrients on yield and yield attributes of chickpea

A significant difference was observed among the various foliar nutrient treatments. Among all the treatments, the foliar application of Nano-urea @ 4 ml L^{-1} + Nano-zn @ 4 ml L^{-1} led to a significantly higher number of pods per plant (38), seed weight per plant (7.58 g), seed yield (1633 kg ha^{-1}) and haulm yield

Table 3. Effect of foliar nutrients on yield and yield attributes of chickpea

Treatments		Number of pods $plant^{-1}$	Seed weight $plant^{-1}$ (g)	Seed yield (kg ha^{-1})	Haulmyield (kg ha^{-1})	Harvest index (%)
T_1	Control (without spray)	24.00	5.52	1195	1680	41.56
T_2	Water spray	24.30	5.60	1210	1696	41.63
T_3	Foliar application of 2% Urea	28.24	6.26	1352	1889	41.71
T_4	Foliar application of 0.5% KNO_3	31.28	6.76	1450	1994	42.10
T_5	Foliar application of 0.5% 19:19:19	31.00	6.69	1438	1986	42.00
T_6	Foliar application of 0.5% $ZnSO_4$	28.02	6.18	1337	1872	41.66
T_7	Foliar application of Nano-urea @ 2 ml L^{-1}	29.35	6.38	1378	1913	41.87
T_8	Foliar application of Nano-urea @ 4 ml L^{-1}	30.00	6.62	1427	1969	42.02
T_9	Foliar application of Nano-zn @ 2 ml L^{-1}	29.00	6.32	1358	1894	41.76
T_{10}	Foliar application of Nano-zn @ 4 ml L^{-1}	29.50	6.52	1406	1948	41.92
T_{11}	Foliar application of Nano-urea @ 2 ml L^{-1} + Nano-zn @ 2 ml L^{-1}	31.61	6.85	1460	2004	42.15
T_{12}	Foliar application of Nano-urea @ 2 ml L^{-1} + Nano-zn @ 4 ml L^{-1}	33.00	6.90	1480	2009	42.42
T_{13}	Foliar application of Nano-urea @ 4 ml L^{-1} + Nano-zn @ 2 ml L^{-1}	37.00	7.48	1612	2178	42.53
T_{14}	Foliar application of Nano-urea @ 4 ml L^{-1} + Nano-zn @ 4 ml L^{-1}	38.00	7.58	1633	2205	42.55
S.Em±		1.06	0.19	42	58	2.04
C.D. (p = 0.05)		3.08	0.56	123	168	NS

NS – Non significant

(2205 kg ha^{-1}). However, these values were statistically similar to treatment involving the foliar application of Nano-urea @ 4ml L^{-1} + Nano-zn @ 2 ml L^{-1} (37, 7.48 g, 1612 kg ha^{-1} and 2178 kg ha^{-1}, respectively) (Table 3).The increase in yield and yield attributes can be attributed to the higher number of branches, which provide more sites for flower and pod formation, resulting in a greater number of pods per plant. Enhanced nutrient availability from nano fertilizers supports better seed development and increased seed weight per plant, as seen in the work of Sunil *et al.* (2024). Nano fertilizers facilitate controlled nutrient release throughout crop growth, boosting shoot and root biomass, photosynthesis and the translocation of assimilates to seeds, leading to improved pod number and seed weight (Sharma *et al*., 2023). Nitrogen promotes leaf growth and biomass accumulation, while nano nitrogen fertilizers enhance nutrient absorption and reduce leaching, improving nitrogen use efficiency. Zinc, crucial for photosynthesis and grain yield, enhances photosynthetic activity by activating carbonic anhydrase and improves pollen and seed production, corroborating findings from Bhat *et al*. (2017), Cakmak *et al*. (1998), Elshayb *et al*. (2021), Du *et al*. (2019) and Drostkar *et al*. (2016).

Conclusion

The study concludes that the foliar application of Nano-urea @ 4 ml L^{-1} + Nano-zinc @ 2-4 ml L^{-1} along with recommended dose of fertilizers, is highly effective in enhancing drought resilience in chickpea. This combination improves nutrient availability, which enhanced morphophysiological parameters such as plant height, LAI, SPAD value, NDVI value and RWC. These improvement contribute to better plant vigour, enhanced photosynthetic efficiency and ultimately, increased seed weight and overall yield. The findings contribute to the development of sustainable agricultural practices aimed at improving chickpea growth and yield under water-limited environments.

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