International Journal of Research in Agronomy 2025; 8(9): 567-570

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; 8(9): 567-570
Received: 02-07-2025
Accepted: 05-08-2025

SS Biradar
Department of Soil Science, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahilyanagar, Maharashtra, India

BM Kamble
Head, Department of Soil Science, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

SR Shelke
Analytical Chemist, Department of Soil Science, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

NJ Danawale
Chief Scientist (Seed Cell), Professor of Agronomy, Department of Agronomy, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

C Vairavan
Department of Soil Science, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahilyanagar, Maharashtra, India

Corresponding Author:
SS Biradar
Department of Soil Science, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahilyanagar, Maharashtra, India

Response to foliar sprays of different sources of zinc on growth, yield and economics of soybean in Inceptisol

SS Biradar, BM Kamble, SR Shelke, NJ Danawale and CVairavan

DOI: https://www.doi.org/10.33545/2618060X.2025.v8.i9h.3820

Abstract
The present investigation was undertaken to study the "response to foliar sprays of different sources of zinc on growth, yield, quality and nutrient uptake by soybean in Inceptisol". The experiment was conducted at research field of Post Graduate Institute Research Farm, Department of Soil Science, Mahatma Phule Krishi Vidyapeeth, Rahuri, during *kharif* 2024. The experimental soil was with dominat smectite type of mineral belonging to the order Inceptisol. The experiment was conducted in randomized block design with three replications and nine treatments comprising of application of GRDF and different zinc sources viz., T_1: Absolute control, T_2: GRDF (50:75:45 N: P_2O_5: K_2O kg ha^{-1} + 10 t ha^{-1} FYM), T_3: GRDF + two water sprays, T_4: GRDF + two foliar spray of 0.1% $ZnSO_4$, T_5: GRDF + two foliar sprays of chelated Zn @ 0.2%, T_6: GRDF + two foliar sprays of nano Zn @ 500 ppm, T_7: GRDF + two foliar sprays of nano Zn @ 1000 ppm, T_8: GRDF + two foliar sprays of nano Zn @ 1500 ppm and T_9: GRDF + two foliar sprays of chelated zinc 0.1%. Two foliar sprays of zinc fertilizer sources were applied at 30 and 45 days after sowing (DAS). The results revealed that among different treatment combinations, the significantly highest total chlorophyll (0.54 mg g^{-1}), grain yield (21.59 q ha^{-1}) and stover yield (19.89 q ha^{-1}) of soybean was recorded in GRDF + two foliar sprays of chelated Zn @ 0.2% (T_5) at 30 and 45 days after sowing. The numerically highest number of nodules and pods $plant^{-1}$ were recorded in treatment GRDF + two foliar sprays of chelated Zn @ 0.2% (T_5) at 30 and 45 days after sowing. Foliar sprays of different zinc sources on economics of soybean found beneficial aftter application different zinc treatments at 30 and 45 days after sowing.

Keywords: Nano zinc, chelated zinc, FYM, foliar sprays, total chlorophyll, soybean

1. Introduction

Soybean (*Glycine max* L.), rightly called as Golden Bean in the twenty first century, occupying major position among oilseed crops of the country since 2006. It is also the most important oil-bearing leguminous crop. The productivity potential of soybean is higher than that of other legumes. It is the richest source of quality protein which can be used for alleviating protein calorie malnutrition. Soybean contains around 40% protein with all the essential amino acids beside 18-20% oil. World soybean production in 2019-20 is estimated as 333.67 million tonnes from a total area of 120.50 million hectares. India ranks fourth in area 12.07 million ha accounting for 9.41% of the world area and fifth in production with 13.98 million tonnes in 2022-23 (Anonymous, 2023) [2]. The major soybean growing states are Madhya Pradesh, Maharashtra, Rajasthan, Karnataka and Telangana. In Maharashtra, soybean is cultivated on 3.8 M ha area with the production of 3.07 m ton and t is second position in India (Chirag *et al.*, 2023) [5]. Application of Zn gave the highest seed, oil yield fed^{-1} in soybean (Darwish *et al.*, 2002) [7]. Zinc is an essential micronutrient involved in several key metabolic and physiological processes such as enzyme activation, protein synthesis, growth regulation and hormone (auxin) production (Alloway, 2008) [1]. Plant availabile soil Zn is affected by soil pH, soil type, organic matter, soil moisture, mineralogy, Zn diffusion and plant uptake (Yin *et al.*, 2011) [27]. The mean concentration of 1.40±1.60 mg kg^{-1} for available Zn and its deficiency is 51.2% in Indian soils (Shukla *et al.*, 2021) [24].

Nanoparticle engineering is an emerging technological breakthrough that offers targeted enhancements in strength. The concept of 'nanotechnology' was first introduced in 1974 by Norio Taniguichi, a professor at Tokyo University of Science (Khan and Rizvi, 2014) [15]. Nanotechnology is the art and science of operating matter at the nanoscale and design, characterization, production and application of structure, device and system by regulatory shape and size at the nanoscale (1-100 nm).

Foliar application of zinc sources has proven highly effective in enhancing crop growth, yield and grain biofortification compared to soil-only application. Among the commonly used sources, $ZnSO_4$ is the most widely adopted and improves yield, chlorophyll content and grain Zn concentration in cereals and legumes; however, its efficiency often declines under calcareous and alkaline soils due to rapid fixation (Cakmak, 2008) [4]. In contrast, chelated Zn (Zn-EDTA) exhibits greater solubility and stability, leading to superior Zn uptake and grain enrichment at even lower doses than $ZnSO_4$; in wheat, foliar Zn-EDTA sprays resulted in higher grain Zn concentration and improved yield attributes compared with $ZnSO_4$ (Karak *et al.*, 2005) [13] and more recently, nano-Zn (ZnO nanoparticles) has emerged as a promising alternative due to its high surface area and enhanced penetration, allowing effective uptake at very low concentrations. Foliar-applied nano-Zn has been shown to increase yield, chlorophyll, antioxidant activity and grain Zn content in rice, wheat, soybean and brassica crops.

2. Materials and Methods

The experiment was laid out during *kharif* 2024 at Post Graduate Institute Research Farm of Department of Soil Science, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahilyanagar, Maharashtra (India). The location of the experimental farm lies between $19^{0}34'$ N latitude and $74^{0}64'$ E longitude. The elevation above mean sea level ranged from 465 m. The tract lies on the eastern side of western ghat and falls under scarcity zone.

The needed amount ofdifferenr sources of zinc are purchased from near by market. The experiment was conducted in randomized block design with three replications and nine treatments comprising of application of GRDF and different zinc sources viz., T_1: Absolute control, T_2: GRDF (50:75:45 N: P_2O_5: K_2O kg ha^{-1} + 10 t ha^{-1} FYM), T_3: GRDF + two water sprays, T_4: GRDF + two foliar spray of 0.1% $ZnSO_4$, T_5: GRDF + two foliar sprays of chelated Zn @ 0.2%, T_6: GRDF + two foliar sprays of nano Zn @ 500 ppm, T_7: GRDF + two foliar sprays of nano Zn @ 1000 ppm, T_8: GRDF + two foliar sprays of nano Zn @ 1500 ppm and T_9: GRDF + two foliar sprays of chelated zinc 0.1%. Two foliar sprays of zinc fertilizer sources were applied at 30 and 45 days after sowing (DAS).

The soil of experimental plot is with dominat smectite type of mineral belonging to order Inceptisol. In order to determine soil properties of experimental soil before sowing, the surface (0-15 cm depth) soil samples were collected randomly from selected spots covering experimental area. A composite soil sample was prepared and analysed for its various soil properties. The soil pH was moderately alkaline (8.41), with low salt content (0.18 dS m^{-1}), medium in organic carbon (3.3 g kg^{-1}). The soil was low in available nitrogen (242 kg ha^{-1}), moderate in available phosphorus (22.02 kg ha^{-1}) and very high in available potassium (318 kg ha^{-1}). The DTPA extractable Fe, Mn and Cu status in soil was sufficient (4.91, 5.12 and 1.491 mg kg^{-1}, respectively), however, the DTPA Zn (0.51 mg kg^{-1}) was deficient in soil.

The yield of grains and stover produced from each net plot were recorded separately in kg as per treatments. The yield per net plot was converted into quintal per hectare (q ha^{-1}). The data obtained was statistically analysed as per the methods described by Panse and Sukhatme (1995) [19].

3. Result and Discussion

3.1 Total chlorophyll at 45 and 55 DAS

The total chlorophyll content in soybean leaves at 45 and 55 DAS was significantly influenced by foliar application of different zinc sources and concentrations and data is depicted in Table 1. The highest total chlorophyll content was recorded in T_5 - GRDF + two foliar sprays of chelated Zinc (Zn-EDTA) @ 0.2% at 30 and 45 DAS, with values of 0.54 mg g^{-1} at 45 DAS and 0.58 mg g^{-1} at 55 DAS. Among the nano zinc treatments, T_7 (nano Zn @ 1000 ppm) was the next best performer, with total chlorophyll values of 0.52 mg g^{-1} at 45 DAS and 0.57 mg g^{-1} at 55 DAS, followed by T_8 (0.49 and 0.50 mg g^{-1}) and T_6 (0.46 and 0.46 mg g^{-1}). The superior performance of T_5 is attributed to the use of chelated zinc in the form of Zn-EDTA (zinc ethylene diamine tetraacetic acid). Zn-EDTA is a highly efficient source that remains stable and available to plants even under alkaline soil conditions. Zinc plays a central role in chlorophyll biosynthesis, enzyme activation and stabilizing chloroplast membranes, which directly supports higher pigment accumulation. Foliar application of Zn-EDTA ensures rapid uptake and translocation within the plant, leading to improved photosynthetic efficiency. These findings align with those of Fageria (2009) [9], who reported enhanced chlorophyll content in rice with Zn-EDTA.

3.2 Number of nodules and pods

The number of nodules plant^{-1} and pods plant^{-1} in soybean was found numerically higher though the results were statistically non significant with foliar application of different zinc sources and concentrations and data is mentioned in Table 1.

The highest nodule count (37) was observed in T_5 (GRDF + two foliar sprays of chelated Zn @ 0.2% as Zn-EDTA at 30 and 45 DAS), the lowest number of nodules was recorded in the control (T_1 - 23 nodules). The number of root nodule values were higher in Zn treated plots as compare to other treatments. similar results were obtained by Pal *et. al.* (2023) [18]. In case of pods, the maximum number of pods plant^{-1} (50) was recorded in T_5. The control (T_1) recorded the lowest number of pods plant^{-1} (29). The treatments receiving chelated zinc and higher nano Zn levels showed consistently higher pod formation, suggesting enhanced reproductive growth due to better zinc availability. These observations are close in confirmity with Dass *et. al.* (2023) [8].

3.3 Grain and stover yield

The results related to the topic effect of foliar sprays of different sources of zinc on growth, yield, quality and nutrient uptake by soybean in Inceptisol. The treatment GRDF along with two foliar sprays of 0.2% chelated Zn at 30 and 45 DAS recorded significantly highest grain yield (21.59 q ha^{-1}) and lowest yield (15.21q ha^{-1}) and in case of stover yield highest (19.89) and lowest (13.05), It is due The superior grain and stover yield performance in T5 can be attributed to the application of Zn-EDTA, a chelated and highly bioavailable form of zinc that ensures rapid foliar absorption, efficient translocation, and continuous supply during critical growth stages (Shivay *et al.*, 2016; Krishnasamy, 1996) [16]. Enhanced zinc availability through Zn-EDTA improved chlorophyll synthesis, protein formation, and cell division, thereby promoting vigorous vegetative growth, sustained photosynthesis, and higher biomass accumulation. Although nano Zn showed positive effects, Zn-EDTA proved superior to $ZnSO_4$ and nano Zn in enhancing both grain and dry matter yield and data is given in Table 1.

3.4 Economics

Economics of soybean influenced by application of different zinc sources with recommended dose of fertilizers is found beneficial and data is given in Table 2.

The highest cost of cultivation (Rs. 61,791 ha^{-1}) was recorded in T_8 - GRDF + two foliar sprays of nano Zn @ 1500 ppm and the lowest cost of cultivation (Rs. 36,807 ha^{-1}) was observed in T_1-absolute control. The higher values of gross monetary return (Rs. 1,05,648 ha^{-1}) was recorded in T_5, the lowest gross monetary return (Rs. 53,827 ha^{-1}) was observed under T_1 - absolute control, indicating the positive economic response of soybean to foliar-applied zinc sources, especially chelated zinc in the form of Zn-EDTA. Similar results were shown by Raj and Chandrashekhara (2019) and Bhumarkar *et al.*. The highest net monetary return (Rs. 46,247 ha^{-1}) was observed in T_5. In contrast, the lowest net monetary return (Rs. 17,019 ha^{-1}) was recorded in T_1-absolute control. The highest B:C ratio (1.78) was noticed in T_5, the lowest B:C ratio (1.46) was observed in T_1-absolute control.

Table 1: Effect of different zinc sources on growth, yield and yield attributing characters of soybean

Tr No.	Treatment details	Total chlorophyll (mg g^{-1})		Yield attributing characters		Yield (q ha^{-1})	
		At 45 DAS	At 55 DAS	Nodule $plant^{-1}$	Pods $plant^{-1}$	Grain	Stover
T_1	Absolute control	0.32	0.40	23	29	15.21	13.05
T_2	GRDF (50:75:45 N: P_2O_5: K_2O kg ha^{-1} + 10 t ha^{-1} FYM)	0.35	0.41	27	33	17.74	15.14
T_3	GRDF + Two water sprays	0.39	0.43	29	36	18.10	17.10
T_4	GRDF + Two foliar sprays of 0.1% $ZnSO_4$	0.43	0.44	32	38	19.48	17.92
T_5	GRDF + Two foliar sprays of Chelated Zn @ 0.2%	0.54	0.58	37	50	21.59	19.89
T_6	GRDF + Two foliar sprays of Nano Zn @ 500 ppm	0.46	0.46	33	41	19.51	18.09
T_7	GRDF + Two foliar sprays of Nano Zn @ 1000 ppm	0.52	0.57	36	45	20.77	19.15
T_8	GRDF + Two foliar sprays of Nano Zn @ 1500 ppm	0.49	0.50	35	44	20.55	19.00
T_9	GRDF + Two foliar sprays of Chelated Zn @ 0.1%	0.47	0.49	34	44	19.60	18.44
	S Em (±)	0.041	0.005	4.72	7.23	0.72	0.67
	CD at 5%	0.122	0.015	NS	NS	2.17	2.01

Table 2: Effect of different zinc sources on economics of soybean.

Tr No.	Treatment details	Gross monetary returns (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net monetary returns (Rs. ha^{-1})	B:C ratio
T_1	Absolute control	53827	36807	17019	1.46
T_2	GRDF (50:75:45 N: P_2O_5: K_2O kg ha^{-1} +10 t ha^{-1} FYM)	86807	58194	28613	1.49
T_3	GRDF + Two water sprays	88571	59035	29536	1.50
T_4	GRDF + Two foliar sprays of 0.1% $ZnSO_4$	91898	59293	32606	1.55
T_5	GRDF + Two foliar sprays of Chelated Zn at 0.2%	105648	59401	46247	1.78
T_6	GRDF + Two foliar sprays of Nano Zn at 500 ppm	95470	59576	35894	1.60
T_7	GRDF + Two foliar sprays of Nano Zn at 1000 ppm	101636	60498	41137	1.68
T_8	GRDF + Two foliar sprays of Nano Zn at 1500 ppm	100559	61791	38768	1.63
T_9	GRDF + Two foliar sprays of Chelated Zn at 0.1%	95911	59183	36728	1.62

4. Conclusions

The application of GRDF + two foliar sprays of chelated Zn @ 0.2% (Zn-EDTA) at 30 and 45 DAS to soybean was found beneficial for increase in growth, yield and yield attributing characters and economics of soybean in Inceptisol.

References

1. Alloway BJ. Zinc in soils and crop nutrition. 2nd ed. Brussels: International Zinc Association and International Fertilizer Industry Association; 2008. 135 p.
2. Anonymous. Indian Institute of Soybean Research [Internet]. Indore: ICAR-IISR; 2023 [cited 2025 Aug 15]. Available from: https://iisrindore.icar.gov.in
3. Bhayal L, Jain MP, Bhayal D, Meena K. Impact of foliar spray of NPK and Zn on soybean for growth, yield, quality, energetics and carbon footprint under dryland condition at Indore. Legume Research-An International Journal. 2022;45:174-181. doi:10.18805/LR-4732.
4. Cakmak I. Enrichment of cereal grains with zinc: agronomic or genetic biofortification? Plant and Soil. 2008;302:1-17. doi:10.1007/s11104-007-9466-3.
5. Chirag B, Channe Mukesh K, Maurya. Constraints of soybean production by farmers in Wardha District, Maharashtra. International Journal of Environment and Climate Change. 2023;13:1705-1712. doi:10.9734/ijecc/2023/v13i930890.
6. Choudhary P, Jhajharia A, Kumar R. Influence of sulphur and zinc fertilization on yield, yield components and quality traits of soybean (*Glycine max* L.). The Bioscan. 2014;9:137-142.
7. Darwish DS, El-Gharreib G, El-Hawary MA, Rafft OA. Effect of some macro and micronutrients application on peanut production in a saline soil. Egyptian Journal of Applied Sciences. 2002;17:17-32.
8. Dass A, Rajanna GA, Babu S, Lal SK, Choudhary AK, Singh R, *et al*. Foliar application of macro and micronutrients improves the productivity, economic returns and resource-use efficiency of soybean in a semiarid climate. Sustainability. 2022;14:5825. doi:10.3390/su14105825.
9. Fageria NK, Filho MB, Moreira A, Guimarães CM. Foliar fertilization of crop plants. Journal of Plant Nutrition.

2009;32:1044-1064. doi:10.1080/01904160902872826.
10. Hossain MS, Paul AK, Khan MA, Hasan MM. Effect of foliar application of zinc and boron on the growth and yield of wheat. International Journal of Bio-Resource and Stress Management. 2025;16:23-35. doi:10.23910/1.2025.3549.
11. Imsong W, Tzudir L, Longkumer LT, Gohain T, Kawikhonliu Z. Effect of sulphur and zinc fertilization on the quality and economics of soybean (*Glycine max* L. Merrill) under Nagaland condition. Biological Forum - An International Journal. 2023;15:307-312.
12. Jyothi C, Prasad PRK, Reddy DS, Rao KV. Effect of foliar nutrition at different growth stages on yield and quality of soybean (*Glycine max* L.). Journal of Research ANGRAU. 2013;41:61-63.
13. Karak T, Singh UK, Das S, Das DK, Kuzyakov Y. Comparative efficacy of $ZnSO_4$ and Zn-EDTA application for fertilization of rice. Archives of Agronomy and Soil Science. 2005;51:253-264. doi:10.1080/03650340500072116.
14. Kaur A, Singh G, Singh K, Dhaliwal SS, Sharma V. Enhancing the productivity and nutritional quality of lentil (*Lens culinaris* L.) with combined foliar application of zinc and urea. Journal of Plant Nutrition. 2025;48:737-750. doi:10.1080/01904167.2024.2398192.
15. Khan MR, Rizvi TF. Nanotechnology: scope and application in plant disease management. Plant Pathology Journal. 2014;13:214-231. doi:10.3923/ppj.2014.214.231.
16. Krishnasamy R. Effect of zinc chelates on dry matter production and uptake of micronutrients by sorghum. Madras Agriculture Journal. 1996;83:87-388.
17. Kumar RSA, Augustine R, Dhivyalakshmi T. Evaluating the efficacy levels of zinc fertilizers on growth, yield and quality of maize (*Zea mays* L.). Agricultural Science Digest-A Research Journal. 2024;6:1-6. doi:10.18805/ag.D-6001.
18. Pal V, Singh G, Dhaliwal SS. Effects of sequential and tank mix applications of zinc, iron and nitrogen on symbiotic parameters, productivity and economics of chickpea (*Cicer arietinum* L.) under field conditions. Journal of Soil Science and Plant Nutrition. 2023;23:2673-2686. doi:10.1007/s42729-023-01396-6.
19. Panse VG, Sukhatame PV. Statistical methods for agriculture workers. 4th ed. New Delhi: Indian Council of Agricultural Research; 1995.
20. Rahman A, Akram YM, Awan ZI. Response of rice to zinc application and different nitrogen sources in calcareous soil. Science Vision. 2002;8:100-103.
21. Sahu SK, Mishra GN, Pani SC. Effect of zinc sources on uptake of zinc and other micronutrients by rice on Vertisol. Journal of the Indian Society of Soil Science. 1994;42:487-489.
22. Sathyanarayana E, Padmaja G, Sharma SHK, Vidya GC, Sagar S, Bharghavi J, *et al*. Effect of different sources and levels of nitrogen, phosphorus and zinc on soil fertility, nutrient content, uptake and yield of soybean. The Pharma Innovation Journal. 2021;10:1152-1156.
23. Sharma BS, Rajeev, Devi S. Impact of zinc foliar spray on maize (*Zea mays* L.) growth, yield and nutrient uptake. International Journal of Research in Agronomy. 2024;7:477-482. doi:10.22271/agr.2024.v7.i2g.718.
24. Shukla AK, Behera SK, Prakash C, Tripathi A, Patra AK, Dwivedi BS, *et al*. Deficiency of phyto-available sulphur, zinc, boron, iron, copper and manganese in soils of India. Scientific Reports. 2021;11:19760. doi:10.1038/s41598-021-98947-7.
25. Thiyageshwari S, Ramanathan G. Uptake of nutrients as influenced by application of micronutrients and cytozyme to soybean in inceptisol. Journal of Soils and Crops. 2001;11:1-6.
26. Wasmatkar RP, Ingole GL, Raul PD. Effect of different levels of sulphur and zinc on quality and uptake of nutrient of soybean. Journal of Maharashtra Agriculture Universities. 2002;27:244-246.
27. Yin X, Gwathmey O, Main C, Johnson A. Effects of sulfur application rates and foliar zinc fertilization on cotton lint yields and quality. Agronomy Journal. 2011;103:1794-1803. doi:10.2134/agronj2011.0168.