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Nakhate PR
Ph.D. Scholar, Department of Soil Science and Agricultural Chemistry, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

Durgude AG
Analytical Chemist, Senior Scientist (Soil), AICRP IWM, Dept. of Agronomy, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

Acharya SM
Ph.D. Scholar, Department of Soil Science and Agricultural Chemistry, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

Bhakare BD
Ex-Head, Department of Soil Science and Agricultural Chemistry, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

Kamble BM
Head, Department of Soil Science and Agricultural Chemistry, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

Gaikwad RA
Ph.D. Scholar, Department of Agricultural Botany and Plant Physiology, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

Corresponding Author:
Nakhate PR
Ph.D. Scholar, Department of Soil Science and Agricultural Chemistry, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

Effect of foliar application of nano zinc on available nutrient status of wheat under zinc deficient and sufficient soils of inceptisol

Nakhate PR, Durgude AG, Acharya SM, Bhakare BD, Kamble BM and Gaikwad RA

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Abstract

Zinc deficiency in cereal crops can be solved by the application of Zn through foliar application. Nanotechnology is one of the options to enhance the nutritional value of crops as some engineered nanoparticles (NPs) could be used as a fertilizer. Zinc can be used in the form of zinc oxide (ZnO) NPs. The present study used the soil and foliar application and then evaluated the effect of foliar application of Nano Zinc on nutrient concentration and available nutrient status of wheat (*Triticum aestivum* L.) under zinc deficient and sufficient soils of Inceptisol. The field experiment consisted of soil application and as well as foliar application of bulk Zn sources and Nano Zn source. Results revealed that the application of General Recommended Dose of Fertilizers (120:60:40 kg ha^{-1} $N:P_2O_5:K_2O$ + 10 t ha^{-1} FYM) along with soil application of $ZnSO_4.7H_2O$ @ 20 kg ha^{-1} found beneficial for increase in macro as well as micronutrients in soil, under Zn deficient soil for of wheat under zinc deficient soil of Inceptisol. However, under zinc sufficient soil, the application of General Recommended Dose of Fertilizers (120:60:40 kg ha^{-1} $N:P_2O_5:K_2O$ + 10 t ha^{-1} FYM) along with Two foliar sprays of nano zinc @ 0.15% found beneficial for increase in macro as well as micronutrients in soil.

Keywords: Nanoparticles (NPs), available Nutrients

Introduction

Zinc is a micronutrient that plays a crucial role in various processes within plants. It's essential for the biosynthesis of proteins and enzymes, maintaining the integrity of cell membranes, promoting seed development, and facilitating numerous metabolic activities. In fact, zinc is a key component of many enzyme classes. A large portion of these zinc-based enzymes are involved in tasks such as DNA transcription, RNA translation, and RNA processing. Zinc also plays a vital role in protein-protein interactions, particularly through structures like the zinc-finger motif found in transcription factors. Within chloroplasts, zinc serves as a cofactor for carbonic anhydrase, which helps increase the concentration of CO_2, aiding in photosynthesis. Moreover, zinc-dependent enzymes are integral to various aspects of genetic expression, including RNA and DNA polymerases, splicing factors, histone deacetylases, and RNA-editing enzymes in organelles like mitochondria and chloroplasts.

The importance of zinc in genetic processes highlights its critical role in plant life. When plants experience zinc deficiency, it adversely affects their growth and development. For instance, in C4-plants, zinc deficiency can reduce net photosynthesis by interfering with the activity of carbonic anhydrase, which is essential for CO2 fixation. Overall, ensuring an adequate supply of zinc is essential for optimal plant health and productivity. About half of the world's agricultural soil lacks enough zinc, which leads to lower crop yields and less nutritious fruits, seeds, and other foods. This deficiency is a big problem globally. Normally, soil contains only about 0.1 to 2.0 mg of zinc per kilogram, which is far less than the 60 mg per kilogram that plants need. To help plants grow better, we need to add more zinc to the soil. One promising solution is using zinc nanoparticles as fertilizers. These tiny particles are expected to absorb 15–20 times more zinc than traditional zinc salts. Zinc salts dissolve more easily in water, which can cause them to be washed away, taking valuable nutrients with them. But nanoparticles are less soluble, so they stay in the soil longer, providing plants with the zinc they need to thrive.

Materials and Methods
Experimental details
I) Field experiment

The present research work entitled, "Effect of foliar application of Nano zinc on nutrient uptake, yield and quality of wheat on zinc deficient and sufficient soils of Inceptisol" was conducted at the PGI Research Farm, Department of Soil Science and Agricultural Chemistry, Mahatma Phule Krishi Vidyapeeth, Rahuri during *Rabi* season 2022. Two types of soils were selected, one with low available nitrogen, low available phosphorus, very high available potassium, and was deficient in zinc and another was also the same as the first soil type in macronutrients but sufficient in zinc. (Table 1).

Table 1: Initial properties of field experiment soils on Zn deficient and Zn sufficient

Sr. No.	Parameter	Value	
		Zn deficient	**Zn sufficient**
I	**Texture**	**Clay**	**Clay**
II	**Chemical properties**		
1.	pH (1: 2.5)	8.24	8.20
2.	EC (1:2.5) (dSm^{-1})	0.35	0.38
3.	Organic carbon ($g\ kg^{-1}$)	4.9	5.4
4.	Calcium carbonate (%)	6.80	7.87
III	**Macronutrients**		
1.	Available N ($kg\ ha^{-1}$)	159	166
2.	Available P ($kg\ ha^{-1}$)	10.83	12.78
3.	Available K ($kg\ ha^{-1}$)	467	490
IV	**DTPA micronutrients ($mg\ kg^{-1}$)**		
1.	Fe	4.61	4.60
2.	Mn	8.30	9.80
3.	Zn	0.54	0.67
4.	Cu	1.35	1.52

Experiment consisting of eight treatments and three replications in Randomized Block Design (RBD). The treatments comprised of T_1: Absolute control, T_2: General Recommended Dose of Fertilizer (GRDF), T_3: GRDF + Soil application of $ZnSO_4.7H_2O$ @ 20 kg ha^{-1}, T_4: GRDF + Two foliar sprays of $ZnSO_4.7H_2O$ @ 0.50%, T_5: GRDF + Two foliar sprays of Nano zinc @ 0.10%, T_6: GRDF + Two foliar sprays of Nano zinc @ 0.15%, T_7: GRDF + Two foliar sprays of chelated zinc @ 0.15% and T_8: GRDF + Two foliar sprays of chelated zinc @ 0.20% were sprayed at 20 and 40 DAS. The variety of Wheat (*Triticum aestivum* L.) Phule samadhan was sown under general recommended dose of fertilizers (120:60:40 kg ha^{-1} $N:P_2O_5:K_2O$ + 10 t ha^{-1} FYM) was applied urea, diammonium phosphate and muriate of potash, respectively. 50 percent of nitrogen was applied as basal dose. Remaining 50 percent of nitrogen was applied at 21 and 45 days after sowing. Soil application of $ZnSO_4.7H_2O$ (20 kg ha^{-1}) was carried out at the time of sowing. The foliar applications of $ZnSO_4.7H_2O$ @ 0.50%, Nano zinc @ 0.10%, Nano zinc @ 0.15% and chelated zinc @ 0.20% were sprayed at 20 and 40 DAS.

Soil and plant analysis

Soil samples were processed and analyzed for pH and electrical conductivity (1:2.5) using glass electrode pH meter and EC meter, respectively. Organic carbon (g kg^{-1}) was estimated by Wet oxidation method (Nelson and Sommer, 1982) [10], available N by alkaline permanganate method (Subbiah and Asija, 1956) [16], available P by Olsen method (Watanabe and Olsen, 1965) [11] and available K by Neutral normal ammonium acetate method (Jackson, 1973) [4]. For DTPA micronutrients (Fe, Mn, Zn and Cu), soil samples extracted by 0.005 *M* DTPA method (pH-7.3) (Lindsay and Norvell, 1978) [6]. Finely ground grain and straw samples were digested with di-acid mixture ($H_2O_2:H_2SO_4$ 1:1) for total N by Kjeldahl method and total micronutrients (Fe, Mn, Zn and Cu) atomic absorption spectrophotometry (AAS) and for total P and K digested with ($HNO_3:HClO_4$ 9:4) and analyzed by Vanado-Molybdate yellow colour in HNO_3 and Flame photometer, respectively.

Statistical analysis

The data obtained was analyzed as per the methods described by Panse and Sukhatme (1985) [12].

Results and Discussion
Effect of foliar application on different sources of zinc on soil properties after harvest
Available macronutrients in zinc deficient soil

This data presented in table 2 under zinc deficient soil, available nitrogen content in soil was found significantly higher (170 kg ha^{-1}) in treatment T_2 (General Recommended Dose of Fertilizers) over T_1, T_3, T_4, T_5, T_6, T_7 and T_8 treatments, the available phosphorus content in soil was found significantly higher (13.24 kg ha^{-1}) in treatment T_2 (General Recommended Dose of Fertilizers) over T_1, T_3, T_5 and T_6 treatments, while treatments T_7 and T_8 (13.05 and 12.68 kg ha^{-1}, respectively) were at par with treatment T_2. Available potassium content in soil was found significantly higher (497 kg ha^{-1}) in treatment T_2 (GRDF) over T_1, T_3, T_4, T_5, T_6, and T_8 treatments, while treatment T_7 (496 kg ha^{-1}) was at par with treatment T_2.

The concurrent utilization of traditional fertilizers alongside nano fertilizers resulted in an augmented quantity of accessible macronutrients within the soil. Rajonee *et al.* (2016) [13] noted that the slow-release characteristics of nano fertilizers led to higher levels of available nitrogen in post-harvest soil when compared to conventional fertilizers in the context of *Ipomoea aquatic* (kalmi). Furthermore, Astaneh *et al.* (2021) [1] observed that the application of nano chelated nitrogen fertilizers resulted in increase in phosphorus content and also increase in potassium content as compared to conventional urea fertilizer.

Table 2: Effect of foliar application of different sources of zinc on soil available macronutrients in zinc deficient under wheat crop

Tr. No	Treatment	Soil available macronutrients (kg ha^{-1})		
		N	P	K
T_1	Absolute control	137	8.72	440
T_2	General Recommended Dose of Fertilizers (GRDF)	170	13.24	497
T_3	GRDF + Soil application of $ZnSO_4.7H_2O$ @ 20 kg ha^{-1}	166	11.67	478
T_4	GRDF + Two foliar sprays of $ZnSO_4.7H_2O$ @ 0.50% at 20 and 40 DAS	165	13.05	482
T_5	GRDF + Two foliar sprays of Nano zinc @ 0.10% at 20 and 40 DAS	168	11.04	490
T_6	GRDF + Two foliar sprays of Nano zinc @ 0.15% at 20 and 40 DAS	169	11.67	491
T_7	GRDF + Two foliar sprays of chelated zinc @ 0.15% at 20 and 40 DAS	167	12.68	496
T_8	GRDF + Two foliar sprays of chelated zinc @ 0.20% at 20 and 40 DAS	168	13.05	478
	S.Em±	0.40	0.29	1.73
	CD at 5%	1.22	0.89	5.21
	Initial	159	10.83	467

Available macronutrients in zinc sufficient soil

The data presented in table 3 under zinc sufficient soil, the available nitrogen content in soil was found significantly higher (191 kg ha^{-1}) in treatments T_4 (GRDF + Two foliar sprays of $ZnSO_4.7H_2O$ @ 0.50% at 20 and 40 DAS) and T_7 (GRDF + Two foliar sprays of chelated zinc @ 0.15% at 20 and 40 DAS) over T_1, T_2, T_3, T_5, T_6 and T_8 treatments. The available phosphorus content in soil was found significantly higher (12.90 kg ha^{-1}) in treatment T_2 (General Recommended Dose of Fertilizers) over T_1, T_3, T_4, T_5, T_6, T_7 and T_8 treatments. Available potassium content in soil was found significantly higher (497 kg ha^{-1}) in treatment T_5 (GRDF + Two foliar sprays of Nano zinc @ 0.10% at 20 and 40 DAS) over T_1, T_2, T_3, T_4, T_6, T_7 and T_8 treatments.

The application of nano fertilizers has been found to boost certain biogeochemical processes, specifically the nitrification process, which results in an increased availability of nitrogen within the soil. Nano fertilizers release humic acid and root exudates gradually as nutrients are released, subsequently elevating the nitrogen content. This nitrogen serves as a food source for soil microorganisms, as reported by Vande and Arai (2019) [19]. The application of nano fertilizer via foliar spraying is expected to not only diminish soil pollution but also augment soil fertility by enhancing the chemical attributes of the soil. This phenomenon can likely be attributed to the enhancement of nitrogen mineralization in the soil, potentially stemming from the addition of zinc, which may have further contributed to the observed improvements, Similar results was also reported by Grunes (1959) [2], it also same for phosphorus and potassium availability in the soil may have increased as a results of biomass being incorporated into the soil by crops, the results are in conformity with the findings of Miao *et al*. (2010) [8].

Table 3: Effect of foliar application of different sources of zinc on soil available macronutrients in zinc sufficient under wheat crop

Tr. No	Treatment	Soil available macronutrients (kg ha^{-1})		
		N	P	K
T_1	Absolute control	149	10.18	459
T_2	General Recommended Dose of Fertilizers (GRDF)	181	12.90	508
T_3	GRDF + Soil application of $ZnSO_4.7H_2O$ @ 20 kg ha^{-1}	180	12.20	503
T_4	GRDF + Two foliar sprays of $ZnSO_4.7H_2O$ @ 0.50% at 20 and 40 DAS	191	12.54	517
T_5	GRDF + Two foliar sprays of Nano zinc @ 0.10% at 20 and 40 DAS	185	12.22	538
T_6	GRDF + Two foliar sprays of Nano zinc @ 0.15% at 20 and 40 DAS	186	12.37	519
T_7	GRDF + Two foliar sprays of chelated zinc @ 0.15% at 20 and 40 DAS	191	12.61	508
T_8	GRDF + Two foliar sprays of chelated zinc @ 0.20% at 20 and 40 DAS	187	12.11	504
	S.Em±	0.94	0.09	0.4
	CD at 5%	2.88	0.27	1.22
	Initial	166	12.78	490

Available DTPA micronutrients in zinc deficient in soil

The data presented in table 4 under zinc deficient soil, available iron content in soil was found significantly higher (4.28 mg kg^{-1}) in treatments T_2 (General Recommended Dose of Fertilizers) over T_1, T_3, T_4, T_5, T_6, T_7 and T_8 treatments. Initially, soil was sufficient in available Fe hence post harvest status showed deficient in all the soils under treatment. Available manganese (mg kg^{-1}) was found significantly higher (8.49 mg kg^{-1}) in treatment T_4 (GRDF + Two foliar sprays of $ZnSO_4.7H_2O$ @ 0.50% at 20 and 40 DAS) over T_3 treatment, while treatments T_1, T_2, T_5, T_6, T_7 and T_8 (8.25, 8.25, 8.25, 8.23, 8.17 and 8.19 mg kg^{-1}, respectively) was at par with treatment T_4. Initially, soil was deficient in available zinc under zinc deficient soil, but post-harvest status showed slightly higher status in treatment, which received zinc through $ZnSO_4$ through soil application as compared to the rest of the foliar treatments under study. Available zinc was found significantly higher (0.56 mg kg^{-1}) in treatment T_3 (GRDF + Soil application of $ZnSO_4.7H_2O$ @ 20 kg ha^{-1}) over T_1, T_2, T_4, T_6, T_7 and T_8 treatments, while treatment T_5 (0.52 mg kg^{-1}) was at par with treatment T_3. Available copper content in soil was found non significantly at harvest of wheat.

Table 4: Effect of foliar application of different sources of zinc on soil available DTPA micronutrients in zinc deficient under wheat crop

Tr. No.	Treatment	Soil available micronutrients (mg kg^{-1})			
		Fe	Mn	Zn	Cu
T_1	Absolute control	4.07	8.25	0.46	1.34
T_2	General Recommended Dose of Fertilizers (GRDF)	4.28	8.25	0.48	1.39
T_3	GRDF + Soil application of $ZnSO_4.7H_2O$ @ 20 kg ha^{-1}	4.16	8.32	0.56	1.35
T_4	GRDF + Two foliar sprays of $ZnSO_4.7H_2O$ @ 0.50% at 20 and 40 DAS.	4.13	8.49	0.46	1.36
T_5	GRDF + Two foliar sprays of Nano zinc @ 0.10% at 20 and 40 DAS.	4.12	8.25	0.52	1.31
T_6	GRDF + Two foliar sprays of Nano zinc @ 0.15% at 20 and 40 DAS.	4.02	8.23	0.48	1.35
T_7	GRDF + Two foliar sprays of chelated zinc @ 0.15% at 20 and 40 DAS.	4.15	8.17	0.51	1.34
T_8	GRDF + Two foliar sprays of chelated zinc @ 0.20% at 20 and 40 DAS.	4.16	8.19	0.49	1.37
	S.Em±	0.02	0.06	0.012	0.01
	CD at 5%	0.07	0.20	0.038	NS
	Initial	4.61	8.30	0.54	1.35

According to Jassim *et al*. (2019) [5], the utilization of nano fertilizers has been observed to enhance the availability of essential micronutrients such as zinc (Zn), iron (Fe) and manganese (Mn) in the soil following the harvest of rice crop. Additionally, Sahar *et al.* (2020) [15] concluded that the application of nano NPK fertilizers led to an increase in the availability of micronutrients in the soil after the harvest of soybean crops.

Available DTPA Micronutrients in Zinc Sufficient in Soil

The data presented in table 5 under zinc sufficient soil, available iron content in soil was found significantly higher (4.30 mg kg^{-1}) in treatment T_2 (General Recommended Dose of Fertilizers) over T_1, T_3, T_4, T_5, T_6, T_7 and T_8 treatments. Initially, the soil contained a sufficient amount of available iron (Fe); however, the post-harvest analysis indicated a deficiency of iron in all the soils subjected to treatment. Available manganese content in soil was found significantly higher (8.82 mg kg^{-1}) in treatment T_2 (General Recommended Dose of Fertilizers), while treatments T_1, T_3, T_4, T_5, T_6, T_7 and T_8 (8.64, 8.69, 8.60, 8.56, 8.62, 8.58 and 8.66 mg kg^{-1}, respectively) were at par with treatment T_3. Available zinc content in soil were sufficient and it was found significantly higher (0.65 mg kg^{-1}) in treatment T_3 **(**GRDF + Soil application of $ZnSO_4.7H_2O$ @ 20 kg ha^{-1}) over T_1, T_3, T_4, T_5, T_6, T_7 and T_8 treatments, while treatment T_3 (0.65 mg kg^{-1}) was at par with treatment T_3.

At the outset, the soil possessed a proportionate supply of available zinc in the context of zinc-sufficient soil. Nevertheless, the post-harvest evaluation revealed a slightly elevated zinc status in treatments that received zinc from various sources, both via soil application and foliar application, as examined in the study and available copper (mg kg^{-1}) was found significantly higher (1.70 mg kg^{-1}) in treatment T_2 (General Recommended Dose of Fertilizers) over T_1 treatment, while treatments T_3, T_4, T_5, T_6, T_7 and T_8 (1.51, 1.46, 1.64, 1.62, 1.49 and 1.57 mg kg^{-1}, respectively) were at par with treatment T_2.

Thirunavukkarasu and Subramanian (2015) [18] demonstrated that the slow-release mechanism of nano fertilizers has the capacity to improve the nutrient status of soil by mitigating leaching loss, fixation, atmospheric losses, and microbial conversion. These findings align with similar results reported by Rani *et al*. (2019) [14] and Meena *et al*. (2021) [7]. After application of nano zinc on leaves, there may have an increase in the mineralization of native iron and zinc, which led to better microbial activity in the soil due to gradual release of humic acid and root exudates and an increase in soil available iron and zinc. Similar results have also been reported by Mirzapor and Khashgoltermanesh (2013) [9], Hassanpouraghdam and Vojad (2020) [3].

Table 5: Effect of foliar application of different sources of zinc on soil available DTPA micronutrients in zinc sufficient under wheat crop

Tr. No.	Treatment	Soil available micronutrients (mg kg^{-1})			
		Fe	Mn	Zn	Cu
T_1	Absolute control	4.09	8.64	0.60	1.41
T_2	General Recommended Dose of Fertilizers (GRDF)	4.30	8.82	0.64	1.70
T_3	GRDF + Soil application of $ZnSO_4.7H_2O$ @ 20 kg ha^{-1}	4.29	8.69	0.65	1.51
T_4	GRDF + Two foliar sprays of $ZnSO_4.7H_2O$ @ 0.50% at 20 and 40 DAS.	4.17	8.60	0.61	1.46
T_5	GRDF + Two foliar sprays of Nano zinc @ 0.10% at 20 and 40 DAS.	4.16	8.56	0.62	1.64
T_6	GRDF + Two foliar sprays of Nano zinc @ 0.15% at 20 and 40 DAS.	4.11	8.62	0.61	1.62
T_7	GRDF + Two foliar sprays of chelated zinc @ 0.15% at 20 and 40 DAS.	4.26	8.58	0.62	1.49
T_8	GRDF + Two foliar sprays of chelated zinc @ 0.20% at 20 and 40 DAS.	4.26	8.66	0.60	1.57
	S.Em±	0.03	0.10	0.01	0.07
	CD at 5%	0.09	0.31	0.03	0.21
	Initial	4.60	9.80	0.67	1.52

Conclusion

It can be concluded that, the application of General Recommended Dose of Fertilizers (120:60:40 kg ha^{-1} $N:P_2O_5:K_2O$ + 10 t ha^{-1} FYM) along with soil application of $ZnSO_4.7H_2O$ @ 20 kg ha^{-1} found beneficial under Zn deficient soil for increase in maintaining the Zn status in zinc deficient soil of Inceptisol. However, under zinc sufficient soil, the treatment of GRDF + Two foliar sprays of nano zinc (0.15%) found at par. Application of General Recommended Dose of Fertilizers (120:60:40 kg ha^{-1} $N:P_2O_5:K_2O$ + 10 t ha^{-1} FYM) along with Two foliar sprays of nano zinc @ 0.15% found beneficial for increase in available nutrient status of soil. However, the treatment of GRDF + Two foliar sprays of nano zinc (0.10%) found at par.

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