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Effect of Nano-Zinc on Uptake of Nitrogen, Phosphorus, Potassium and Zinc by Maize (*Zea mays* L.)

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ABSTRACT: The valuable insights into the potential benefits and challenges associated with using Nano-Zinc in increasing the efficiency of nutrient utilization by maize, particularly nitrogen, phosphorus, potassium, and zinc, which are crucial for plant growth and development in the specific context of the semi-arid tropics of Maharashtra. A field experiment was conducted during *rabi* 2022 on Instructional Farm, PGI, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra). The experiment was laid out in randomized block design with three replications and eight treatments. The experiment consists of two foliar applications of Nano-Zinc oxide at vegetative stage (30 DAS) and flowering stage (45 DAS). Treatment involving GRDF (General recommended dose of fertilizer) + Two foliar application of Nano-Zinc oxide @ 800 ppm was recorded highest uptake of nitrogen in grain, stover and total of (94.85, 71.77 and 166.93 kg ha^{-1}), phosphorus (27.20, 20.43 and 47.72 kg ha^{-1}), potassium (39.33, 112.66 and 152.27 kg ha^{-1}) and zinc (165.50, 85.45 and 250.95 g ha^{-1}) This treatment is significantly at par with GRDF + Two foliar application of Nano-Zinc oxide @ 600 ppm, which is followed by the treatment GRDF + Two foliar application of Nano-Zinc oxide @ 400 ppm and GRDF + Two foliar application of Chelated Zinc @ 2000 ppm.

Keywords: Nano-Zinc oxide, nitrogen, phosphorus, potassium, Chelated Zinc, GRDF.

INTRODUCTION

Agricultural productivity in the semi-arid tropics of Maharashtra faces multifaceted challenges, including water scarcity, variable climatic conditions, and nutrient-deficient soils. In the pursuit of sustainable and efficient agricultural practices, researchers are increasingly exploring innovative solutions (Biradar *et al.*, 2023), and nanotechnology holds promise in addressing some of these challenges (Verma *et al.*, 2023). Nanotechnology, with its ability to manipulate materials at the nanoscale, offers a novel approach to enhance nutrient availability and uptake by plants (Badawi, *et al.*, 2022). Nano-Zinc, in particular, has shown promise in improving nutrient absorption and mitigating nutrient stress in various crops. Nevertheless, the specific impact of Nano-Zinc on maize in the semi-arid tropics remains an area warranting detailed investigation. One such avenue of exploration is the application of Nano-Zinc and its potential impact on the uptake of crucial nutrients by maize. The third-most important cereal crop in the world after rice and wheat is maize (*Zea mays* L.). Belonging to the grass family Gramineae (2n = 20) and the tribe maydeae, maize is often referred to as a "miracle crop" and the "queen of grains" due to its remarkable productivity (lkramullah *et al*., 2011). Fertilizers play a vital role in agricultural production, contributing to approximately 35-40% of crop productivity (Biradar *et al.*, 2023). Unlike conventional urea fertilizer, which ceases nutrient release after 10-12 days, zeolite-based nano fertilizers have the ability to release nutrients, especially NO_3^- -N, for more than 50 days. This indicates that nano fertilizers can be employed to regulate the smart release of nutrients in accordance with crop requirements. Nanoparticles exhibit higher reactivity due to their specific surface area, thicker responsive regions, or enhanced reactivity on molecular surfaces. These characteristics enhance the absorption of fertilizers and pesticides delivered at the nano scale (Anon., 2009). Studies have demonstrated the potential benefits of nano-particles in promoting seedling growth and development in plants (Zhu *et al*., 2008). Zinc plays a critical role in various metabolic reactions in plants, serving as an essential component of numerous enzymes. It contributes significantly to plant disease resistance, photosynthesis, cell wall integrity, protein synthesis, pollen formation (Gurmani *et al*., 2012) and enhances the activity of antioxidant enzymes and chlorophyll levels in plant tissues (Sbartai *et al*., 2011). Following nitrogen (N), phosphorus (P) and potassium (K), zinc (Zn) is currently regarded as the fourth most significant nutrient that limits production in India. There is a significant yield loss due to Zn deficiency in 50% of the soils used to grow maize in India alone (Singh, 2010). Zinc is a crucial component in the generation of biomass. (Kaya and Higgs 2002). In terms of micronutrient deficiencies, Zn and manganese (Mn) deficiency make plants more vulnerable to drought stress (Khan *et al*., 2003). Maize, stands out as a critical staple crop, providing food security and livelihoods for a significant population in the region. However, the region's unique agro-climatic conditions necessitate innovative approaches to address nutrient deficiencies and enhance crop yields. Nano-Zinc, with its potential to improve nutrient uptake, emerges as a promising avenue worthy of exploration.

MATERIAL AND METHODS

The field experiment has been conducted during *rabi* 2022 on Instructional Farm, PGI, MPKV, Rahuri to assess the effect of Nano-Zinc on growth, yield and quality of maize (*Zea mays* L.). There were eight treatments laid out in randomized block design (RBD) with three replications. The experiment consists of eight treatments *viz*., T_1: Recommended dose of fertilizer (Control); T_2: GRDF (General recommended dose of fertilizer); T_3: T_2 + Two foliar application of water; T_4: T_2+ Two foliar application of $ZnSO_4$ @ 5000 ppm; T_5: T_2 + Two foliar application of Chelated Zinc @ 2000 ppm; T_6: T_2 + Two foliar application of Nano-Zinc oxide @ 400 ppm; T_7: T_2 + Two foliar application of Nano-Zinc oxide @ 600 ppm; T_8: T_2 + Two foliar application of Nano-Zinc oxide @ 800 ppm.

A. Nitrogen uptake

Nitrogen content was estimated by modified Micro-Kjeldhal's method as outlined by Jackson (1973) and expressed in percentage. Nitrogen uptake (kg ha^{-1}) by crop was calculated for each treatment separately using the following formula.

Nitrogen uptake (kg ha^{-1}) = Nitrogen concentration (%) × Dry matter (q ha^{-1})

B. Phosphorus uptake

Phosphorus content in the digested plant sample was estimated by Vanadomolybdate phosphoric yellow colour method in nitric acid medium and the colour intensity was measured at 660 nm wave length as outlined by Jackson (1973). It is calculated using the following formula.

Phosphorus uptake (kg ha^{-1}) = Phosphorus concentration (%) × Dry matter (q ha^{-1})

C. Potassium uptake

Potassium in the plant samples digest was estimated by atomizing the diluted acid extract in a flame photometer as described by Jackson (1973). It is calculated using the following formula.

Potassium uptake (kg ha^{-1}) = Potassium concentration (%) × Dry matter (q ha^{-1})

D. Zinc uptake

Zinc in plant digested sample was determined by using Atomic Absorption Spectrophotometer and expressed uptake in g kg^{-1}

$$\text{Zinc uptake (g ha}^{-1}\text{)} = \frac{\text{Zinc concentration (mg kg}^{-1}\text{)} \times \text{Dry matter (q ha}^{-1}\text{)}}{100}$$

RESULTS AND DISCUSSION

A. Nitrogen uptake (kg ha^{-1})

The data concerning the grain, stover and total uptake of nitrogen in maize, which was influenced by the foliar application of different zinc sources are presented in the Table 1. The mean values for grain uptake, stover uptake and the total uptake amounted to 84.81, 64.19 and 149.02 kg ha^{-1}, respectively.

The T_8 treatment, receiving GRDF + Two foliar applications of Nano-Zinc oxide at 800 ppm, demonstrated significantly higher nitrogen uptake in grain, stover and total (94.85, 71.77and 166.93 kg ha^{-1}, respectively). This was at par with GRDF + Two foliar applications of Nano-Zinc oxide at 600 ppm (92.01, 69.62 and 161.73 kg ha^{-1}, respectively). Following closely were GRDF + Two foliar application of Nano-Zinc oxide @ 400 ppm) and GRDF + Two foliar application of chelated zinc @ 2000 ppm) with their respective nitrogen uptake values (89.66, 67.85, 157.51 kg ha^{-1} and 87.13, 65.93, 153.14 kg ha^{-1}). In contrast, the Recommended dose of fertilizer (Control) exhibited lower uptake levels (66.44, 50.28 and 116.74 kg ha^{-1}, respectively).

The possible reason for this could be the utilization of zinc in its nano form, which enhances nutrient uptake by plants. The small size of nano particles facilitates their rapid penetration through the plant cell membrane. The increased nutrient uptake observed with the foliar application of ZnOnano fertilizer can be attributed to its higher nutrient content and resulting higher yields in both grains and stover. The conclusion drawn by Alzreejawi and Al-Juthery (2021); Rajesh *et al.* (2021); Tondey *et al*. (2021).

B. Phosphorus uptake (kg ha^{-1})

The data regarding the grain, stover and total uptake of phosphorus by maize, which was influenced by different sources of zinc applied through foliar application are presented in the Table 1. The mean values for grain uptake, stover uptake and the total uptake amounted to 23.81, 18.19 and 42.04 kg ha^{-1}, respectively.

The highest phosphorus uptake in maize, including grain, stover and total, was significantly observed in the treatment involving GRDF + Two foliar applications of Nano-Zinc oxide at 800 ppm (27.20, 20.43 and 47.72

kg ha^{-1}). This was at par with treatments involving GRDF + Two foliar applications of Nano-Zinc oxide at 600 ppm (26.80, 19.91 and 46.74 kg ha^{-1}), GRDF + Two foliar applications of Nano-Zinc oxide at 400 ppm (25.18, 19.12 and 44.30 kg ha^{-1}) and GRDF + Two foliar applications of Chelated Zinc at 2000 ppm (24.96, 18.97 and 43.95 kg ha^{-1}). In contrast, Recommended dose of fertilizer (Control) exhibited significantly lower phosphorus uptake levels (18.21, 15.18 and 33.40 kg ha^{-1}).

The application of higher sources of foliar Zn resulted in significant increases in phosphorus content in both the shoots and grains of maize. This can be attributed to the stimulation of P transporters by Zn and the increased active loading of Zn^{2+} into the apoplastic xylem. Interestingly, this synergistic effect did not contradict the antagonistic effect of P on Zn uptake. These results were in conformity with the findings of Noufal *et al*. (2021); Tondey *et al*. (2021).

C. Potassium uptake (kg ha^{-1})

The data on the uptake of potassium in maize, including grain, stover and total uptake, which were influenced by the application of various zinc sources via foliar application are presented in Table 2. On average, the grain uptake was 34.22 kg ha^{-1}, the stover uptake was 103.16 kg ha^{-1} and the total uptake after harvest was 137.47 kg ha^{-1}.

The highest potassium uptake in maize, encompassing grain, stover and total, was significantly observed in the treatment involving GRDF + Two foliar applications of Nano-Zinc oxide at 800 ppm (39.33, 112.66 and 152.27 kg ha^{-1}). This was at par with the treatment involving GRDF + Two foliar applications of Nano-Zinc oxide at 600 ppm (37.91, 110.18 and 148.19 kg ha^{-1}), followed by GRDF + Two foliar applications of Nano-Zinc oxide at 400 ppm (36.82, 107.42and 144.24 kg ha^{-1}) and GRDF + Two foliar applications of Chelated Zinc at 2000 ppm (36.57, 105.84 and 142.49 kg ha^{-1}). Conversely, Recommended dose of fertilizer (Control) exhibited significantly lower potassium uptake levels (25.91, 87.16 and 113.09 kg ha^{-1}).

The higher dosage of zinc resulted in an increased uptake of potassium by maize. This effect can be attributed to the synergistic interaction between zinc and potassium, which enhances the availability and uptake of potassium. Similar findings were reported in previous studies conducted by Tondey *et al*. (2021).

D. Zinc uptake (g ha^{-1})

The data concerning the uptake of zinc in maize, encompassing grain, stover and the total uptake, all of which were influenced by the application of various zinc sources via foliar application are presented in the Table 2. On average, the grain uptake was 147.06 g ha^{-1}, the stover uptake was 74.79 g ha^{-1} and the total uptake reached 222.03 g ha^{-1}.

The application of GRDF + Two foliar of Nano-Zinc oxide at 800 ppm resulted in a notably higher zinc uptake by maize grain, stover and the total recorded of (165.50, 85.45 and 250.95 g ha^{-1}). This was at par with the treatment involving GRDF + Two foliar applications of Nano-Zinc oxide at 600 ppm, which yielded (160.69, 81.57 and 242.26 g ha^{-1}). Following closely was the treatment of GRDF + Two foliar applications of Nano-Zinc oxide at 400 ppm, producing (155.86, 79.62 and 235.48 g ha^{-1}) and GRDF + Two foliar applications of Chelated Zinc at 2000 ppm, resulting in (149.70, 75.87 and 225.57 g ha^{-1}). In contrast, Recommended dose of fertilizer (Control) exhibited significantly lower zinc uptake, recording (128.89, 65.20 and 194.09 g ha^{-1}).

Table 1: Grain, stover and total uptake of nitrogen and phosphorus by maize as influenced by foliar application of various zinc sources.

Tr. No.	Treatments	N (kg ha^{-1})			P (kg ha^{-1})		
		Grain	Stover	Total	Grain	Stover	Total
T_1	Recommended dose of fertilizer (Control)	66.44	50.28	116.74	18.21	15.18	33.40
T_2	GRDF (General recommended dose of fertilizer)	81.47	61.65	143.31	22.33	16.62	39.02
T_3	T_2 + Two foliar application of water	82.62	62.50	145.18	22.47	17.20	39.69
T_4	T_2 + Two foliar application of $ZnSO_4$ @ 5000 ppm	84.31	63.92	147.63	23.38	18.13	41.53
T_5	T_2 + Two foliar application of Chelated Zinc @ 2000 ppm	87.13	65.93	153.14	24.96	18.97	43.95
T_6	T_2 + Two foliar application of Nano-Zinc oxide @ 400 ppm	89.66	67.85	157.51	25.18	19.12	44.30
T_7	T_2 + Two foliar application of Nano-Zinc oxide @ 600 ppm	92.01	69.62	161.73	26.80	19.91	46.74
T_8	T_2 + Two foliar application of Nano-Zinc oxide @ 800 ppm	94.85	71.77	166.93	27.20	20.43	47.72
	S.E.(m) ±	3.42	2.55	5.98	0.96	0.73	1.69
	C.D at 5 %	10.39	7.75	18.14	2.91	2.22	5.15
	General mean	84.81	64.19	149.02	23.81	18.19	42.04

Table 2: Grain, stover and total uptake of potassium and zinc by maize as influenced by foliar application of various zinc sources.

Tr. No.	Treatments	K (kg ha^{-1})			Zn (g ha^{-1})		
		Grain	Stover	Total	Grain	Stover	Total
T_1	Recommended dose of fertilizer (Control)	25.91	87.16	113.09	128.89	65.20	194.09
T_2	GRDF (General recommended dose of fertilizer)	31.77	99.21	131.16	133.34	68.56	201.90
T_3	T_2 + Two foliar application of water	32.19	100.81	133.06	138.57	69.89	208.46
T_4	T_2 + Two foliar application of $ZnSO_4$ @ 5000 ppm	33.27	102.01	135.34	143.98	72.22	216.20
T_5	T_2 + Two foliar application of Chelated Zinc @ 2000 ppm	36.57	105.84	142.49	149.70	75.87	225.57
T_6	T_2 + Two foliar application of Nano-Zinc oxide @ 400 ppm	36.82	107.42	144.24	155.86	79.62	235.48
T_7	T_2 + Two foliar application of Nano-Zinc oxide @ 600 ppm	37.91	110.18	148.19	160.69	81.57	242.26
T_8	T_2 + Two foliar application of Nano-Zinc oxide @ 800 ppm	39.33	112.66	152.27	165.50	85.45	250.95
	S.E.(m) ±	1.13	3.49	5.55	5.94	3.21	9.61
	C.D at 5 %	3.45	10.59	16.85	18.02	9.74	29.16
	General mean	34.22	103.16	137.47	147.06	74.79	222.03

The findings revealed a greater efficiency in zinc absorption with the use of ZnO nanoparticle treatments, attributed to the increased availability of surface area created by the nanoparticles. As a result, maize plants were able to accumulate higher levels of zinc in their tissues. This enhanced uptake and accumulation of zinc in both seeds and leaves could be attributed to the application of ZnO nanoparticles, which outperformed the traditional $ZnSO_4$ treatment. The study emphasizes the significant potential of nano zinc fertilizers in improving plant zinc nutrition. The results obtained were consistent with the findings of Rameshraddy *et al*. (2017); Poornima and Koti (2019); Noufal *et al*. (2021); Mahesh *et al*. (2022).

CONCLUSIONS

The enhanced efficiency in zinc absorption is achieved through the utilization of ZnO nanoparticle treatments, owing to the augmented availability of surface area facilitated by the nanoparticles. Consequently, maize plants demonstrated an increased capacity to accumulate higher concentrations of zinc in their tissues. This heightened uptake and accumulation of N, P, K and zinc in both seeds and leaves can be ascribed to the application of ZnO nanoparticles, surpassing the effectiveness of the conventional $ZnSO_4$ treatment. The study underscores the noteworthy potential of nano zinc fertilizers in enhancing plant zinc nutrition.

FUTURE SCOPE

1. Investigate how different maize varieties respond to Nano-Zinc application. Assess varietal differences in nutrient uptake, growth parameters, and yield to tailor Nano-Zinc recommendations based on specific maize genotypes adapted to semi-arid conditions.
2. Explore the molecular and genetic mechanisms underlying Nano-Zinc's influence on nutrient uptake in maize. Investigate gene expression patterns, signaling pathways, and the interplay of Nano-Zinc with specific transporters and receptors involved in nutrient absorption.

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Conflict of Interest. None.

REFERENCES

Alzreejawi, S. A. and Al-Juthery, H. W. (2021). Effect of foliar application of nano nutrients and amino acids as a complementary nutrition on quantity and quality of maize grains. In *Iop Conference Serie, Earth and Environmental Science*, *735*, 012-060.

Anonymous (2009). www.copenhagenconsensus.com.

Badawi, M. A., S. E. Seadh, W. A. E. Abido and Israa S. T. A. El-Sadik (2022). Effect of Spraying with Nano-Zinc and Mineral Npk Levels on Productivity and Grains Quality of Maize, *J. of Plant Production*, Mansoura Univ., *13*(12), 869-874.

Biradar, B., Jayadev, H. M., Halli, H. M., & Sannagoudar, M. S. (2023). Mapping of soil test-based spatial fertilizer recommendations for paddy and maize using GIS, GPS and STCR approaches in a micro-watershed of Karnataka, India. *Current Science (00113891)*, *124*(10), 1160-1166.

Biradar, B., Surve, U. S., Solanke, A. V., Gorantiwar, S. D., Patil, V. S., Patil, M. R., ... & Gupta, G. (2023). In-situ trash management and irrigation methods for enhancing soil fertility of sugarcane (*Saccharum officinarum* L.) in semi-arid region of India. *Ann. Agric. Res. New Series*, *44*(1), 99-105.

Gurmani, A. R., Khan, S. U., Andaleep, R., Waseem, K. and Khan, A. (2012). Soil Application of Zinc Improves Growth and Yield of Tomato. *International Journal of Agriculture and Biology*, *14*(1).

Ikramullah and Hussain, Iftikhar and Noor, Muhammad and Kausar, Mohammad and Shah, Nawaz and Khalil, H. and Noor, Mansha and Shah, M. (2011). Heterotic Effects for Yield and Protein Content in White Quality Protein Maize. *Sarhad Journal of Agriculture, 27*(3).

Jackson, M. L. (1973). Soil chemical analysis. Prentice-Hall of India, Pvt. Ltd., New Delhi, India. pp. 111-204.

Kaya, C. and Higgs, D. (2002). Response of tomato (*Lycopersicom esculentum*) culture at low zinc. *Scientia Horticulture, 93,* 53-64.

Khan, H. R., Mcdonald, G. K. and Rengel, Z. (2003). Zinc fertilization improves water use efficiency, grain yield and seed Zn content in chickpea. *Plant Soil, 249,* 389–400.

Mahesh, R. H., Dayal, A., Nasakar, J. and Sharan, E. A. (2022). Effect of particle size and concentration of zinc oxide nanoparticles on growth, yield and yield attributing traits of maize (*Zea mays* L.). *International Journal of Noval Research and Development, 7*.

Noufal, E., Farid, I., Attia, M. A., Ahmed, R. and Abbas, M. (2021). Effect of traditional sources of Zn and ZnO-nano-particles foliar application on productivity and P-uptake of maize plants grown on sandy and clay loam soils. *Environment, Biodiversity and Soil Security, 5*, 59-72.

Poornima, R. and Koti, R. V. (2019). Effect of nano zinc oxide on growth, yield and grain zinc content of sorghum (*Sorghum bicolor*). *Journal of Pharmacognosy and Phytochemistry, 8*(4), 727-731.

Rajesh, H., Yadahalli, G., Chittapur, B. M., Halepyati, A. S. and Hiregoudar, S. (2021). Growth, yield and economics of sweet corn (*Zea mays* L. *Saccarata*) as influenced by foliar sprays of nano fertilisers. *Journal of Farm Sciences, 34*(4), 381-385.

Rameshraddy, Pavithra, G. J., Rajashekar Reddy, B. H., Salimath, M., Geetha, K. N. and Shankar, A. G. (2017). Zinc oxide nano particles increases Zn uptake, translocation in rice with positive effect on growth, yield and moisture stress tolerance. *Indian Journal of Plant Physiology, 22*, 287-294.

Verma, R., Dwivedi, G. K., Singh, J. P., Singh, A. P., Tamta, N., & Kumar, A. (2023). Characterization of synthesized zinc oxide nanoparticles and their effect on growth, productivity and zinc use efficiency of wheat and field pea in the Indian Himalayan foothills. *Current Science, 124*(11), 1319-1328.

Sbartai, H., Djebar, M. R., Rouabhi, R., Sbartai, I., and Berrebbah, H. (2011). Antioxidative response in tomato plants *Lycopersicon esculentum* L. roots and leaves to zinc. *American-Eurasian Journal of Toxicological Sciences, 3*(1), 41-46.

Singh, M. V. (2010). Micronutrient nutritional problems in soil of Indian and improvement for human and animal health. *Indian Journal of Fertilisers, 5*(4), 11-56.

Tondey, M., Kalia, A., Singh, A., Dheri, G. S., Taggar, M. S., Nepovimova, E. and Kuca, K. (2021). Seed priming and coating by nano-scale zinc oxide particles improved vegetative growth, yield and quality of fodder maize (*Zea mays*). *Agronomy, 11*(4), 729.

Zhu, H., Han. J., Xiao, J. Q. and Jin, Y. (2008). Uptake, translocation and accumulation of manufactured iron oxide nanoparticles by pumpkin plants. *Journal of Environmental Monitoring, 10,* 713-717.

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