

EFFECT OF NANO ZINC ON GROWTH AND QUALITY OF SWEET CORN IN SOUTHERN TELANGANA ZONE, INDIA

Comment [x1]: Please, Change the title to: EFFECT OF ZINC SOURCE AND TYPE APPLICATION ON GROWTH AND QUALITY OF SWEET CORN IN SOUTHERN TELANGANA ZONE, INDIA

ABSTRACT

A field experiment was conducted at College farm, College of Agriculture, Rajendranagar, Hyderabad during *rabi* season of 2022. The objective was to assess the impact of nano zinc on the growth, yield and quality of sweet corn in soils deficient in zinc. The experiment encompassed 9 treatments with 3 forms of Zn fertilizer *viz.*, ZnSO₄, Zn EDTA and Nano Zn. Findings of the study revealed that foliar application of Zn EDTA at 5 g L⁻¹ recorded significantly highest values for growth, Zn uptake and quality parameters while basal application of ZnSO₄ at 25 kg ha⁻¹ was the next best treatment. Foliar application of Nano Zinc performed significantly superior over control; however, it was not comparable with the most effective treatment (T₉).

Key words: *chelate, nano fertilizer, sweet corn, zinc*

INTRODUCTION

Maize is the third most important cereal crop after rice and wheat in India. It is extensively grown in Karnataka, Telangana, Andhra Pradesh, Maharashtra, Bihar, Rajasthan and Madhya Pradesh. In India, maize is cultivated over an area of 99.6 lakh ha with an annual production of 33.72 Mt and average productivity of 3,387 kg ha⁻¹, while in Telangana State, it is grown in 4.12 lakh ha with total production of 2.23 Mt and productivity of 5,403 kg ha⁻¹ (India stat, 2022).

Sweet corn (*Zea mays L. saccharata*) is a specialty maize species that accounts for 8 and 25% of the world's area and production respectively. Sweet corn crops are harvested while their corn-ears have just attained the milky stage at 80- 90 DAS. Its kernels are tender and eaten as a vegetable in many cuisines worldwide. Sugar corn features a high-quality phyto-nutrition profile comprising of dietary fiber, minerals, vitamins and antioxidants.

Comment [x2]: Add reference, please

Zinc is essential for several physiological and enzymatic activities of the plant system, it involves in conversion of carbohydrates, proteins and chlorophyll synthesis and induces many catalytic functions. The crucial role played by the micronutrient makes its application and availability essential for the growth, yield and quality of produce in sweet corn.

Maize with its sensitivity to zinc deficiency in the soil, results in disorder called "white bud" manifested as white parallel bands between the midrib and margin of leaves. The magnitude of

zinc deficiency varies among soil types with reduction in crop yield and quality to the tune of 25-30%.

Comment [x3]: Add reference, please

Soil applied zinc is fixed into different insoluble forms within a week of application. Hence the application of nano scale zinc fertilizer is expected to alleviate the micronutrient deficiency and improve use efficiency. Nano fertilizers have unique physicochemical properties and the potential to enhance the plant metabolism (Giraldo *et al.*, 2014). They release the nutrients slowly that regulate the plant growth and boost the target activity (DeRosa *et al.*, 2010). Therefore, the present study was conducted to investigate the efficacy of nano zinc on the growth and quality of sweet corn.

Comment [x4]: Correct to: Zinc source and type application on.....corn., Please.

METHODOLOGY

Comment [x5]: Please, change to: Materials and Methods

The experiment was conducted in *rabi* season of 2022 on sandy clay loam soils at College farm, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural University, Hyderabad, India. The experimental site was located at 17° 19' 18" N latitude and 78° 24' 31" E longitude, within the Southern Telangana Agro Climatic Zone of Telangana State. The soil at the site was low in available nitrogen (168.3 kg N ha⁻¹), medium in phosphorus (48.7 kg P₂O₅ ha⁻¹) and high in potassium (495.7 kg K₂O ha⁻¹) and low in available zinc (0.49 mg kg⁻¹). Throughout the crop growth period, there was no rainfall and the mean weekly maximum and minimum temperatures were recorded as 29.6°C and 16.0°C, respectively. The experimental layout included nine zinc management practices, arranged in a randomized block design with three replications.

Comment [x6]: What the reference adopted to classify this soil?

Table 1. Details of treatments included in the experiment

T ₁	: Control
T ₂	: 100 % basal application of Zn
T ₃	: 75% basal application of Zn + Foliar spray with Nano Zn at 2 ml L ⁻¹ (20 DAS)
T ₄	: 50% basal application of Zn + Foliar spray with Nano Zn at 2 ml L ⁻¹ (45 DAS)
T ₅	: 75% basal application of Zn + Foliar spray with Nano Zn at 3 ml L ⁻¹ (20 DAS)
T ₆	: 50% basal application of Zn + Foliar spray with Nano Zn at 3 ml L ⁻¹ (45 DAS)
T ₇	: 75% basal application of Zn + Foliar spray with Nano Zn at 4 ml L ⁻¹ (20 DAS)
T ₈	: 50% basal application of Zn + Foliar spray with Nano Zn at 4 ml L ⁻¹ (45 DAS)
T ₉	: Zn EDTA spray at 5g L ⁻¹ (20 and 45 DAS)
Note	– 100 % basal application of Zn indicates 25 kg ha ⁻¹ ZnSO ₄

In this research, nano Zinc was administered using Nano-Zinc (liquid) produced by Indian Farmers Fertilizer Cooperative Limited (IFFCO). According to the manufacturer's claim, the nano zinc liquid contains 1% of Zn and was applied by spraying at a rate of 2- 4 ml per litre of water. Other sources of Zn were Zinc sulphate (36% Zn) and Zn EDTA chelate (12% Zn). Urea, single superphosphate (SSP) and muriate of potash (MOP) were applied to the soil as sources of nitrogen (N), phosphorus (P) and potassium (K), respectively. The complete dose of P was applied during sowing, while N and K were applied in three split doses at different phenophases of the crop.

Comment [x7]: Please, this rate what equal in mg/l or µg/l?

From each plot, five plants were selected randomly in the net plot periodical observations on growth characters were recorded while, leaf area and dry matter production were recorded using plants selected from the border rows.

Comment [x8]: Amount of each element per hectare

Crude protein (%): The 1g of oven dried and ground kernel was digested in Kelplus digestion unit and 10 ml distilled water was added to it which was used for distillation. Nitrogen evolved as ammonia was collected in a receiver containing boric acid (2%) solution and mixed indicator (Bromocresol green and methyl red). It was titrated against standard (0.02N) H₂SO₄ in an automatic titration unit to get crude protein percentage.

Comment [x9]: Reference of method , please.

Total Soluble Solids(%): 1 or 2 drops of sweetcorn kernel sap were placed onto the refractometer and the Total Soluble Solids (TSS) values displayed were recorded as TSS %.

Zinc uptake (mg kg⁻¹): Plant samples collected and dried were digested in di-acid mixture *i.e.*, HNO₃: HClO₄ in the proportion of 3:1. The di-acid digested plant samples were analysed for Zinc content using Inductively Coupled Plasma Optical Emission Spectroscopy method at the wavelength of 213.857 nm and the results were expressed in mg kg⁻¹ (Lindsay and Norvell, 1978).

The data obtained from various parameters under study was analyzed by the method of analysis of variance (ANOVA) as given by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Table 2. Plant height (cm) of sweet corn as influenced by foliar application of Nano Zinc

TREATMENT	Plant height (cm)			
	30 DAS	45 DAS	60 DAS	Harvest
T ₁ : Control	43.7	74.4	96.8	142.4
T ₂ : 100 % basal application of Zn	56.1	94.7	135.2	189.2
T ₃ : 75% basal application of Zn + Foliar spray with Nano Zn at 2 ml L ⁻¹ (20 DAS)	49.9	84.5	115.9	162.8
T ₄ : 50% basal application of Zn + Foliar spray with Nano Zn at 2 ml L ⁻¹ (45 DAS)	48.4	83.3	113.4	158.2
T ₅ : 75% basal application of Zn + Foliar spray with Nano Zn at 3 ml L ⁻¹ (20 DAS)	50.5	85.1	118.3	165.7
T ₆ : 50% basal application of Zn + Foliar spray with Nano Zn at 3 ml L ⁻¹ (45 DAS)	49.3	82.6	117.7	159.4
T ₇ : 75% basal application of Zn + Foliar spray with Nano Zn at 4 ml L ⁻¹ (20 DAS)	55.2	93.5	131.8	183.6
T ₈ : 50% basal application of Zn + Foliar spray with Nano Zn at 4 ml L ⁻¹ (45 DAS)	50.8	83.1	124.5	175.2
T ₉ : Zn EDTA spray at 5g L ⁻¹ (20 and 45 DAS)	60.9	104.0	150.7	205.2
S Em (±)	1.5	2.2	3.5	4.9
CD (5%)	4.5	7.4	10.6	14.8

Comment [x10]: Please, as below:
RESULTS AND DISCUSSION
1- Growth parameters

Please, you must put all the tables after the text of result and discussion.

Table 3. Number of leaves plant⁻¹ of sweet corn as influenced by foliar application of Nano Zinc

TREATMENT	Number of leaves plant ⁻¹			
	30 DAS	45 DAS	60 DAS	Harvest
T ₁ : Control	4.5	8.0	10.1	4.5
T ₂ : 100 % basal application of Zn	5.4	9.8	11.3	5.4
T ₃ : 75% basal application of Zn + Foliar spray with Nano Zn at 2 ml L ⁻¹ (20 DAS)	4.5	8.1	10.2	4.5
T ₄ : 50% basal application of Zn + Foliar spray with Nano Zn at 2 ml L ⁻¹ (45 DAS)	4.5	8.0	10.3	4.5
T ₅ : 75% basal application of Zn + Foliar spray with Nano Zn at 3 ml L ⁻¹ (20 DAS)	4.5	8.2	10.1	4.5
T ₆ : 50% basal application of Zn + Foliar spray with Nano Zn at 3 ml L ⁻¹ (45 DAS)	4.6	8.1	10.1	4.6
T ₇ : 75% basal application of Zn + Foliar spray with Nano Zn at 4 ml L ⁻¹ (20 DAS)	5.0	8.9	10.3	5.0
T ₈ : 50% basal application of Zn + Foliar spray with Nano Zn at 4 ml L ⁻¹ (45 DAS)	4.9	8.9	10.2	4.9
T ₉ : Zn EDTA spray at 5g L ⁻¹ (20 and 45 DAS)	5.6	9.9	12.1	5.6

S Em (\pm)	0.4	0.7	0.7	0.4
CD (5%)	NS	NS	NS	NS

Table 4. Dry matter production (kg ha⁻¹) of sweet corn as influenced by foliar application of Nano Zinc

TREATMENT	Dry matter production (kg ha ⁻¹)			
	30 DAS	45 DAS	60 DAS	Harvest
T ₁ : Control	216	3462	6012	7234
T ₂ : 100 % basal application of Zn	320	4876	8143	9651
T ₃ : 75% basal application of Zn + Foliar spray with Nano Zn at 2 ml L ⁻¹ (20 DAS)	259	4031	6851	8127
T ₄ : 50% basal application of Zn + Foliar spray with Nano Zn at 2 ml L ⁻¹ (45 DAS)	246	3913	6665	7998
T ₅ : 75% basal application of Zn + Foliar spray with Nano Zn at 3 ml L ⁻¹ (20 DAS)	263	4114	6925	8196
T ₆ : 50% basal application of Zn + Foliar spray with Nano Zn at 3 ml L ⁻¹ (45 DAS)	247	3923	6723	8043
T ₇ : 75% basal application of Zn + Foliar spray with Nano Zn at 4 ml L ⁻¹ (20 DAS)	294	4540	7591	8962
T ₈ : 50% basal application of Zn + Foliar spray with Nano Zn at 4 ml L ⁻¹ (45 DAS)	269	3907	7196	8642
T ₉ : Zn EDTA spray at 5g L ⁻¹ (20 and 45 DAS)	351	5312	8812	10403
S Em (\pm)	10	142	213	249
CD (5%)	29	427	639	746

Table 5. Leaf area plant⁻¹ (cm²) of sweet corn as influenced by foliar application of Nano Zinc

TREATMENT	Leaf area plant ⁻¹ (cm ²)			
	30 DAS	45 DAS	60 DAS	Harvest
T ₁ : Control	2147	3648	4031	4400
T ₂ : 100 % basal application of Zn	2956	4789	5458	5536
T ₃ : 75% basal application of Zn + Foliar spray with Nano Zn at 2 ml L ⁻¹ (20 DAS)	2481	4186	4632	4965
T ₄ : 50% basal application of Zn + Foliar spray with Nano Zn at 2 ml L ⁻¹ (45 DAS)	2373	4053	4453	4858
T ₅ : 75% basal application of Zn + Foliar spray with Nano Zn at 3 ml L ⁻¹ (20 DAS)	2428	4215	4696	5023
T ₆ : 50% basal application of Zn + Foliar spray with Nano Zn at 3 ml L ⁻¹ (45 DAS)	2400	4105	4519	4910

T ₇ : 75% basal application of Zn + Foliar spray with Nano Zn at 4 ml L ⁻¹ (20 DAS)	2708	4597	5142	5489
T ₈ : 50% basal application of Zn + Foliar spray with Nano Zn at 4 ml L ⁻¹ (45 DAS)	2687	4350	4986	5238
T ₉ : Zn EDTA spray at 5g L ⁻¹ (20 and 45 DAS)	3204	5202	5924	6046
S Em (±)	74	124	139	149
CD (5%)	220	373	417	447

Growth parameters viz., plant height (Table 2), leaf area (Table 3) and dry matter production (Table 4) were significantly influenced with ZnSO₄, Zn EDTA and NanoZn management treatments. Highest values for the parameters were recorded with Zn EDTA spray at 5g L⁻¹ (20 and 45 DAS) (T₉) followed by 100 % basal application of Zn (T₂) which was on par with 75% basal application of Zn + Foliar spray with Nano Zn at 4 ml L⁻¹ (20 DAS) (T₇). Control manifested least values for the parameters. While, number of leaves plant⁻¹ was not significantly impacted with the treatments (Table 5).

Zinc fertilizer has a positive effect on auxin biosynthesis which stimulates cell division and better absorption of other minerals, thus promotes internodal elongation and plant growth (El-Tohamy and El-Greadly, 2007; Cakmak, 2000). Significantly superior performance of Zn chelate foliar application over other treatments may be attributed to enhanced absorption rate as the organic molecules in chelates facilitate easier passage of zinc through the cell membranes. The findings from this study align with those of Darwish *et al.* (2002), Mahdi *et al.* (2012), Rana *et al.* (2013) and Lone *et al.* (2022).

Satdevet *et al.* (2020), Azamet *et al.* (2022) and Samui *et al.* (2022) reported significantly higher plant height in plants treated with nano fertilizers. However, results obtained in the present investigation are contrary to these findings which might be attributed to lower concentration of Zn (1% Zn) in the product (Kumar *et al.*, 2021) leading to inadequate supply to the plant.

Table 6. Zinc uptake of sweet corn as influenced by foliar application of Nano Zinc

TREATMENT	Zinc uptake (mg kg ⁻¹)			
	30 DAS	45 DAS	60 DAS	Harvest
T ₁ : Control	14.23	14.31	14.38	14.42
T ₂ : 100 % basal application of Zn	17.49	18.2	18.45	18.62
T ₃ : 75% basal application of Zn + Foliar spray with Nano Zn at 2 ml L ⁻¹ (20 DAS)	16.33	16.48	16.56	16.59

Comment [x11]: Please, the discussion must include % of increase or decrease..., or reduce,

Comment [x12]: Also, May be to amount of Zn applied, please be sure of this point.

T ₄ : 50% basal application of Zn + Foliar spray with Nano Zn at 2 ml L ⁻¹ (45 DAS)	15.76	15.83	16.33	16.47
T ₅ : 75% basal application of Zn + Foliar spray with Nano Zn at 3 ml L ⁻¹ (20 DAS)	16.64	16.76	16.81	16.86
T ₆ : 50% basal application of Zn + Foliar spray with Nano Zn at 3 ml L ⁻¹ (45 DAS)	15.72	15.8	16.51	16.63
T ₇ : 75% basal application of Zn + Foliar spray with Nano Zn at 4 ml L ⁻¹ (20 DAS)	17.02	17.13	17.21	17.24
T ₈ : 50% basal application of Zn + Foliar spray with Nano Zn at 4 ml L ⁻¹ (45 DAS)	15.73	15.81	16.84	16.91
T ₉ : Zn EDTA spray at 5g L ⁻¹ (20 and 45 DAS)	18.98	19.65	20.05	20.33
S Em (±)	0.47	0.48	0.52	0.56
CD (5%)	1.4	1.43	1.56	1.69

Zn uptake was recorded highest with T₉ (Zn EDTA spray at 5g L⁻¹ at 20 and 45 DAS) while the next superior treatment was 100 % basal application of Zn (T₂). T₂ was recorded to be on par with 75% basal application of Zn + Foliar spray with Nano Zn at 4 ml L⁻¹ (20 DAS) (T₇).

Foliar applications minimize nutrient interactions, ensuring better zinc uptake and utilization. The relatively lesser absorption of zinc in plants treated with nano zinc could be linked to the insufficient zinc concentration in the product as mentioned earlier (1% Zn), as well as the adequate supply of micronutrient from zinc sulphate (36%) and Zn EDTA (12%). The results are in consonance with Apoorva *et al.* (2017) and Goud *et al.* (2022).

Table 7. Quality parameters of sweet corn as influenced by foliar application of Nano Zinc

TREATMENT	TSS (%)	Crude protein (%)
T ₁ : Control	10.5	7.2
T ₂ : 100 % basal application of Zn	13.4	9.7
T ₃ : 75% basal application of Zn + Foliar spray with Nano Zn at 2 ml L ⁻¹ (20 DAS)	11.9	8.4
T ₄ : 50% basal application of Zn + Foliar spray with Nano Zn at 2 ml L ⁻¹ (45 DAS)	11.7	8.0
T ₅ : 75% basal application of Zn + Foliar spray with Nano Zn at 3 ml L ⁻¹ (20 DAS)	12.0	8.6
T ₆ : 50% basal application of Zn + Foliar spray with Nano Zn at 3 ml L ⁻¹ (45 DAS)	11.8	8.1
T ₇ : 75% basal application of Zn + Foliar spray with Nano Zn at 4 ml L ⁻¹ (20 DAS)	13.2	9.4

Comment [x13]: 2- Quality parameters

Also, put the text of discussion before the table, please.

T ₈ : 50% basal application of Zn + Foliar spray with Nano Zn at 4 ml L ⁻¹ (45 DAS)	12.2	8.7
T ₉ : Zn EDTA spray at 5g L ⁻¹ (20 and 45 DAS)	14.8	10.5
S Em (±)	0.4	0.3
CD (5%)	1.1	0.8

Zinc plays critical role in various physiological processes like enzyme activity, protein synthesis and carbohydrate metabolism, thereby manifesting significant influence on crude protein percent and TSS percent of sweetcorn. Hence, quality parameters exhibit a pattern similar to that of Zinc uptake.

CONCLUSION

Significantly highest plant growth, Zn uptake and quality parameters were recorded with Zn EDTA spray at 5g L⁻¹ (20 and 45 DAS) (T₉). The Nano Zinc foliar application resulted in significantly higher values over control, however, the increase was not comparable with the values registered in the most effective treatment. Nano Zinc can be recommended for emergency corrections when standard chelate products are unavailable.

REFERENCES

- Apoorva, M.R., Rao, P.C and Padmaja, G. 2017. Effect of zinc with special reference to nano zinc carrier on yield, nutrient content and uptake by rice (*Oryzasativa* L.). *International journal of current microbiology and applied sciences*. 6(8): 1057-1063.
- Azam, M., Bhatti, H.N., Khan, A., Zafar, L and Iqbal, M. 2022. Zinc oxide nano-fertilizer application (foliar and soil) effect on the growth, photosynthetic pigments and antioxidant system of maize cultivar. *Biocatalysis and Agricultural Biotechnology*. 42: 102343.
- Cakmak, I. 2000. Possible roles of zinc in protecting plant cells from damage by reactive oxygen species. *New Phytologist*. 146: 185-205.

- Darwish, D.S., El-G. El-Gharreib, M.A. El-Hawary and O.A. Rafft. 2002. Effect of some macro and micronutrients application on peanut production in a saline soil in El-Faiyum Governorate. *Egyptian Journal of Applied Sciences*. 17: 17-32
- DeRosa, M.C., Monreal, C., Schnitzer, M., Walsh, R and Sultan, Y. 2010. Nanotechnology in fertilizers. *Nature nanotechnology*. 5(2): 91-91.
- El-Tohamy, W.A and N. H. M. El-Greadly. 2007. Physiological responses, growth, yield and quality of snap bean in response to foliar application of yeast, vitamin E and zinc under sandy soil conditions. *Australian Journal of basic Applied Sciences*. 1: 249-299.
- Giraldo, J.P., Landry, M.P., Faltermeier, S.M., McNicholas, T.P., Iverson, N.M., Boghossian, A.A., Reuel, N.F., Hilmer, A.J., Sen, F., Brew, J.A and Strano, M.S. 2014. Plant nanobionics approach to augment photosynthesis and biochemical sensing. *Nature materials*. 13(4): 400-408.
- Gomez, K.A and Gomez, A.A. 1984. Statistical procedure for agricultural research. John Wiley and Sons, New York.
- Goud, G., Sudhakar, K.S., Pasha, M and Madhavi, A. 2022. Evaluation of the Foliar Application of Nano Urea on the Performance of Rabi Sunflower (*Helianthus annuus* L.). *International Journal of Environment and Climate Change*. 12(11): 2700-2706.
- Indiastat. Agriculture Production Statistical Database. 2022. <http://www.indiastat.com>
- Kumar, Y., Singh, T., Raliya, R and Tiwari, K.N. 2021. Nano fertilizers for sustainable crop production, higher nutrient use efficiency and enhanced profitability. *Indian Journal of Fertilisers*. 17(11): 1206-1214.
- Lone, A.H., Sheikh, T.A., Lone, B.A., Ahngar, T.A., Baba, Z.A., Bashir, M., Sheikh, M.A., Mir, M.S., Rashid, Z., Majid, S and Dar, Z.A. 2022. Performance of Sweet Corn Hybrids (*Zea mays saccharata*) as Influenced by Soil and Foliar Application of Zinc. *Journal of Experimental Agriculture International*. 44(12): 167-174.
- Mahdi, S.S., Hasan, B and Singh, L. 2012. Influence of seed rate, nitrogen and zinc on fodder maize (*Zeamays*) in temperate conditions of Western Himalayas. *Indian Journal of Agronomy*. 57 (1): 85-88.

Rana, D.S., Singh, B., Gupta, K., Dhaka, A.K and Arya, S. 2013. Response of fodder sorghum [*Sorghumbicolor* (L.) Moench] to zinc and iron. *ForageResearch*. 39 (1): 45-47.

Samui, S., Sagar, L., Sankar, T., Manohar, A., Adhikary, R., Maitra, S and Praharaj, S. 2022. Growth and productivity of rabi maize as influenced by foliar application of urea and nano-urea. *Crop Research*. 57(3): 136-140.

Satdev, V.J., Chavda, B.N and Saini, L.K. 2020. Effect of nanoZnO on growth and yield of sweet corn under South Gujarat condition. *International Journal of Chemical Studies*. 8(1).

UNDER PEER REVIEW