INFLUENCE OF NANO ZINC FOLIAR APPLICATION ON YIELD ATTRIBUTES, YIELD AND ECONOMICS OF SWEET CORN (Zea mays L. saccharata)

ABSTRACT

Field experiment was conducted at College farm, College of Agriculture, Rajendranagar, Hyderabad during *rabi* season of 2022 on zinc deficient soils to evaluate the effect of nano zinc on growth, yield and quality of sweet corn. The study included 9 treatments with 3 forms of Zn fertilizer *viz*., $ZnSO_4$, Zn EDTA and nano Zn. Results of the study indicated that foliar application of Zn EDTA at 5 g L^{-1} produced significantly highest yield parameters, cob yield (15.5 t ha^{-1}), fodder yield (20.4 t ha^{-1}) and B:C ratio of 2.11 followed by basal application of $ZnSO_4$ at 25 kg ha^{-1}. Nano Zinc foliar applications at 2 ml L^{-1} and 3ml L^{-1}produced comparatively lower yields but were significantly higher than control. Treatments with foliar spray of nano zinc at 4ml L^{-1} produced statistically better results than the lower doses (2 ml L^{-1} and 3 ml L^{-1}).

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

1. INTRODUCTION

Cereals are the grain crops grown in greater quantities and serve as staple food sources worldwide in their natural, unprocessed, whole grain form. Cereals are a rich source of vitamins, minerals, carbohydrates, fats, oils and protein.

Maize or corn is the third most important cereal crop after rice and wheat in India. 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} Indiastat [1]. Sweet corn (*Zea mays* L. *saccharata*) is a specialty maize species which accounts for 8 and 25% of the world's area and production respectively.

Sweet corn has sugar content greater than 25% at milking stage. Sweet corn kernels generally contain 16-20%, sugar, 2.2-4.5% of proteins, 1.2–2.7 % of fats, 3–20 % of starch, 1.0 – 1.9 % of cellulose, 6.7 to 8 mg of vitamin C per 100 g, small amounts of vitamins A, B_1, B_2 and mineral components Bercht [2].

Zinc plays a prominent role in the growth and development of sweet corn. It is essential for the production of growth hormones (auxins) such as indoleacetic acid and is involved in the transport of sugars and other nutrients throughout the plant. 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. About 50% of Indian soils are deficient in available Zn Singh and Abrol [3]. 96–99 per cent of conventional soil applied zinc is fixed into different insoluble forms within a week of application. Hence nano form of zinc is expected to alleviate the problem of Zn deficiency in sweet corn.

Currently, nanotechnology is becoming increasingly significant in the field of agriculture, focusing on particles with dimensions ranging from 1 to 100 nm. Nano fertilizers possess distinctive physicochemical characteristics and have the capability to improve plant metabolism Giraldo [4]. These nano fertilizers or nano encapsulated nutrients release nutrients gradually, thereby regulating plant growth and enhancing targeted activities DeRosa [5]. Therefore, the present study aimed to investigate the efficacy of nano zinc on the growth and yield of sweet corn.

2. MATERIAL AND METHODS

A field experiment was conducted in the rabi season of 2022 on sandy clay loam soils at College farm, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, 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 (158.31 kg ha^{-1}), high in phosphorus (48.7 kg ha^{-1}) and potassium (452.6 kg ha^{-1}) and low in available zinc (0.49 mg kg^{-1}). Crop is supplied with supplemental irrigation as there was no rain during the crop growth period. Throughout the crop growth period, the mean weekly maximum and minimum temperatures were recorded as 29.6°C and 16.0°C, respectively Fig. 1. Sufficient irrigation was provided

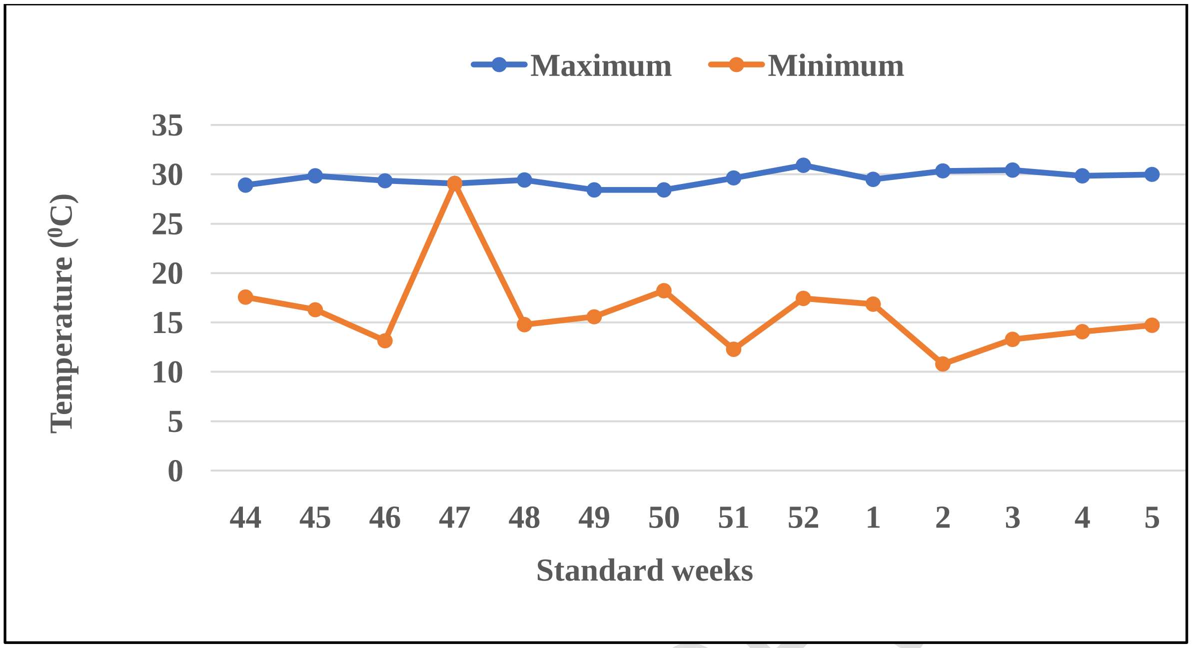

Fig. 1. Weekly maximum and minimum temperatures (°C) during the crop growth period

The experimental layout included nine zinc management practices, arranged in a randomized block design with three replications. Treatments included in the experiment were as follows,

Chart 1 : List of treatments used for the study

T1	:	Control
T2	:	100 % basal application of Zn
T3	:	75% basal application of Zn + Foliar spray with Nano Zn at 2 ml L^{-1} (20 DAS)
T4	:	50% basal application of Zn + Foliar spray with Nano Zn at 2 ml L^{-1} (45 DAS)
T5	:	75% basal application of Zn + Foliar spray with Nano Zn at 3 ml $^{L-1}$ (20 DAS)
T6	:	50% basal application of Zn + Foliar spray with Nano Zn at 3 ml L^{-1} (45 DAS)
T7	:	75% basal application of Zn + Foliar spray with Nano Zn at 4 ml L^{-1} (20 DAS)
T8	:	50% basal application of Zn + Foliar spray with Nano Zn at 4 ml L^{-1} (45 DAS)
T9	:	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). Zinc sulphate is the most commonly used source around the world and is available in both the crystalline monohydrate and heptahydrate form. Synthetic chelate are special types of complexed micronutrients generally formed by combining a chelating agent such as Ethylene Diamine Tetra-acetic Acid (EDTA) with a metal ion and the stability of the metal-chelate complex determines the availability of the metal to plants Mousavi [6]. Urea, single superphosphate (SSP), and muriate of potash (MOP) were utilized as sources of nitrogen (N), phosphorus (P), and potassium (K), respectively, as soil application. 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.

The experimental data obtained were subjected to statistical analysis using the ANOVA procedure, and the results were presented using alphabet notations following analysis by DMRT Gomez and Gomez [7].

3. RESULTS AND DISCUSSION

3.1 Yield parameters

The various Zn fertilization treatments imposed on sweet corn exhibited significant effect on yield parameters *viz*., cob weight, cob length, cob girth and number of kernels per row (Table 1). Highest values for the parameters were obtained from the foliar spray of Zn EDTA at 5 g L^{-1} at 20 and 45 DAS (T9) which was significantly superior over the next best treatment *i.e*., 100 % basal application of Zn (T2).

It was observed that 100 % basal application of Zn (T2) was on par with T7 *i.e*., 75% basal application of Zn + Foliar spray with Nano Zn at 4 ml L^{-1} (20 DAS) which was numerically superior over T8 (50% basal application of Zn + Foliar spray with Nano Zn at 4 ml L^{-1} at 45 DAS). Treatments with nano Zn foliar application at 2 ml L^{-1} and 3 ml L^{-1} manifested significantly lower yield parameters. These results are in accordance with Doolette [8] and Anusuya [9], where application of Zn EDTA produced significantly higher yield parameters in wheat and rice respectively.

No fertilizer treatment (T1) recorded significantly lower yield parameters over the other treatments. Number of cobs per plant and number of kernel rows per cob were not influenced by Zn fertilization treatments, possibly due to their inherent genetic regulation (Table 1).

Table 1. Yield parameters of sweet corn at as influenced by foliar application of nano zinc

Treatments	No. of cobs $plant^{-1}$	Cob weight (g)	Cob length (cm)	Cob girth (cm)	No. of kernel rows cob^{-1}	No. of kernels row^{-1}
T1 : Control	1.4	245	16.31	13.40	15.4	31.5
T2 : 100 % basal application of Zn	1.7	326	19.73	16.42	17.5	39.4
T3 : 75% basal application of Zn + Foliar spray with Nano Zn at 2 ml L^{-1} (20 DAS)	1.4	284	17.98	14.81	15.8	35.1
T4 : 50% basal application of Zn + Foliar spray with Nano Zn at 2 ml L^{-1} (45 DAS)	1.5	279	17.92	14.79	16.4	34.8
T5 : 75% basal application of Zn + Foliar spray with Nano Zn at 3 ml L^{-1} (20 DAS)	1.5	285	18.07	14.92	16.3	35.9
T6 : 50% basal application of Zn + Foliar spray with Nano Zn at 3 ml L^{-1} (45 DAS)	1.6	287	18.01	14.85	16.5	35.7
T7 : 75% basal application of Zn + Foliar spray with Nano Zn at 4 ml L^{-1} (20 DAS)	1.5	322	19.69	16.36	17.6	39.2
T8 : 50% basal application of Zn + Foliar spray with Nano Zn at 4 ml L^{-1} (45 DAS)	1.4	296	19.24	15.98	16.9	38.7
T9 : Zn EDTA spray at 5g L^{-1} (20 and 45 DAS)	1.6	340	21.41	17.82	17.9	42.8
S Em (+)	0.14	10.60	0.54	0.45	1.4	1.1
CD (5%)	NS	31.76	1.60	1.33	NS	3.20

3.2. Yield

Pattern similar to that of yield parameters was noticed for both green cob yield and green fodder yield (Table 2). Treatment T9 (Zn EDTA spray at 5g L^{-1} at 20 and 45 DAS) demonstrated the most significant results, with green cob and green fodder yields higher than T2 by 1.2 t ha^{-1} and 1.9 t ha^{-1} respectively. These findings align with those of Naik [10].

Zn promotes the release of growth promoting hormones in plants which may be due to the fact that zinc has an effect on building up the natural auxin (IAA) and consequently activating the cell division and enlargement El-Tohamy, and El-Greadly [11]. Hence all the Zn treated plants exhibit better growth, which thereby promotes the development of yield parameters, consequently contributing to higher yields.

Higher yield parameters of T9 over T2 may be because the organic molecules in Zn chelates facilitate the passage of zinc through the cell membranes, increasing the absorption rate and overall efficiency of zinc uptake. Soil-applied zinc sulphate can interact with other soil nutrients, particularly phosphorus, forming insoluble complexes that reduce zinc availability to plants. While, foliar applications minimize such interactions, ensuring better zinc uptake and utilization. Foliar spray of chelate Zn allows for more precise and targeted application compared to conventional soil-applied fertilizer. Due to enhanced yield parameters, yield obtained is higher in T9. Similar findings were obtained by Rezaei [12], where higher numbers of bolls per plant and boll weight in cotton were obtained with foliar application of chelate Zn compared to conventional Zn fertilizer. Findings of the investigation by Tahir [13] were in conformity with the present study.

On the other hand, foliar application of Nano Zn with 2 ml L^{-1} and 3 ml L^{-1} led to statistically lower cob and fodder yields, ranging from 12.5 to 12.9 t ha^{-1} and 16.1 to 16.6 t ha^{-1}, respectively. The reduced yields may be due to inadequate supply of Zinc, as the product contains only 1% Zn. Lower concentration of Zn in plant causes deficiency affecting production of growth hormones (auxins) such as indoleacetic acid and transport of sugars, nutrients throughout the plant leading to lower plant height, dry matter accumulation which in turn affects the development of yield promoting parameters adversely. Goud [14] also obtained similar outcome in their research. Number of cobs per ha and harvest index of the crop were not significantly affected by Zn fertilization (Table 2).

Table 2. Green cob yield, fodder yield and harvest index of sweet corn as influenced by foliar application of nano zinc

Treatments	YIELD			
	No. of cobs ha^{-1}	Green cob yield (t ha^{-1})	Green fodder yield (t ha^{-1})	Harvest index (%)
T1 : Control	87016	11.4	14.6	43.8
T2 : 100 % basal application of Zn	89746	14.3	18.5	43.6
T3 : 75% basal application of Zn + Foliar spray with Nano Zn at 2 ml L^{-1} (20 DAS)	88523	12.7	16.3	43.8
T4 : 50% basal application of Zn + Foliar spray with Nano Zn at 2 ml L^{-1} (45 DAS)	89412	12.5	16.1	43.7
T5 : 75% basal application of Zn + Foliar spray with Nano Zn at 3 ml L^{-1} (20 DAS)	89680	12.9	16.6	43.7
T6 : 50% basal application of Zn + Foliar spray with Nano Zn at 3 ml L^{-1} (45 DAS)	88654	12.6	16.4	43.5
T7 : 75% basal application of Zn + Foliar spray with Nano Zn at 4 ml L^{-1} (20 DAS)	88741	14.1	18.2	43.7
T8 : 50% basal application of Zn + Foliar spray with Nano Zn at 4 ml L^{-1} (45 DAS)	89547	13.3	17.9	42.6
T9 : Zn EDTA spray at 5g L^{-1} (20 and 45 DAS)	89817	15.5	20.4	43.5
S Em (+)	3536	0.4	0.5	1.8
CD (5%)	NS	1.1	1.5	NS

3.2 Economics

Zinc fertilization had a significant impact on the economics of sweet corn production. It becomes evident that the highest cost of cultivation was associated with treatment T9 (Zn EDTA spray at 5g L^{-1} (20 and 45 DAS), followed by T7 *i.e.*, 75% basal application of Zn + Foliar spray with Nano Zn at 4 ml L^{-1} at 20 DAS (Table 3). Despite the higher cultivation cost for T9, this expense was compensated by the substantial increase in yields, as indicated by the elevated values of economic indicators such as gross returns (Rs. 1,24,000 ha^{-1}), net returns (Rs. 63,873 ha^{-1}). However the highest B:C ratio was observed for T2 (100% basal application of Zn), attributed to its higher yields and lower cost of cultivation. On the other hand, nano fertilization n resulted in comparatively lower returns possibly due to the higher cost of the product, labor charges and lower yields.

Table 3. Economics of sweet corn as influenced by foliar application of nano zinc

Treatments	COC	Gross returns	Net returns	B:C ratio
T1 : Control	53,427	91200	37,773	1.71
T2 : 100 % basal application of Zn	54,302	114400	59,098	2.11
T3 : 75% basal application of Zn + Foliar spray with Nano Zn at 2 ml L^{-1} (20 DAS)	57,297	101600	44,303	1.77
T4 : 50% basal application of Zn + Foliar spray with Nano Zn at 2 ml L^{-1} (45 DAS)	56,829	100000	43,171	1.76
T5 : 75% basal application of Zn + Foliar spray with Nano Zn at 3 ml L^{-1} (20 DAS)	57,656	103200	45,544	1.79
T6 : 50% basal application of Zn + Foliar spray with Nano Zn at 3 ml L^{-1} (45 DAS)	57,188	100800	43,612	1.76
T7 : 75% basal application of Zn + Foliar spray with Nano Zn at 4 ml L^{-1} (20 DAS)	58,031	112800	54,769	1.94
T8 : 50% basal application of Zn + Foliar spray with Nano Zn at 4 ml L^{-1} (45 DAS)	57,563	106400	48,837	1.85
T9 : Zn EDTA spray at 5g L^{-1} (20 and 45 DAS)	60,127	124000	63,873	2.06

4. CONCLUSION

Based on the results of the above discussed study, foliar application of Zn EDTA proved to be beneficial in terms of yields. Even though the product is expensive, it's higher nutrient content, precise supply of the nutrient and better uptake enhances the yields making Zn EDTA cost effective. Foliar sprays of nano Zn provided yields numerically lower than basal application of Zn due to inadequate concentration of the micronutrient. Based on the economics, basal application is the best treatment, foliar applications of nano Zn and Zn chelate can be recommended during emergency deficiency corrections and when basal application of conventional Zn is ineffective due to high pH or high organic matter where applied Zn becomes unavailable.

REFERENCES

1. Most Comprehensive e-resource for Socio-Economic Statistical Data India (indiastat.com) 2022.

2. Brecht JK, Sargent SA, Hochmuth RC, Tervola RS. Post-harvest quality of supersweet (sh2) sweet corn cultivars. *Proceedings of Flavours State Horticulture Sciences*, 1990; 111: 734-738.

3. Singh MV, Abrol IP. Transformation and availability of zinc in alkali soils. *Fertilizer news*. 1986; 37: 17-27.

4. Giraldo JP, Landry MP, Faltermeier SM, McNicholas TP, Iverson NM, Boghossian AA, Reuel NF, Hilmer AJ, Sen F, Brew JA, Strano MS. Plant nanobionics approach to augment photosynthesis and biochemical sensing. *Nature materials*. 2014; 13(4): 400-408.

5. DeRosa MC, Monreal C, Schnitzer M, Walsh R, Sultan Y. Nanotechnology in fertilizers. *Nature nanotechnology*. 2010; 5(2): 91-91.

6. Mousavi SR, Galavi M, Rezaei M. Zinc (Zn) importance for crop production—a review. *International Journal of Agronomy and Plant Production*. 2013; 4(1): 64-68.

7. Gomez KA, Gomez AA. Statistical procedures for agricultural research. *John wiley & sons*. 1984 Feb 17.

8. Doolette CL, Read TL, Li C, Scheckel KG, Donner E, Kopittke PM, Schjoerring JK, Lombi E. Foliar application of zinc sulphate and zinc EDTA to wheat leaves: differences in mobility, distribution, and speciation. *Journal of Experimental Botany*. 2018; 69(18): 4469–4481.

9. Anusuya N, Ravichandran V, Sritharan N. Influence of zinc sulphate and zinc EDTA on grain zinc, growth and yield parameters, of rice genotypes. *Madras Agricultural Journal*. 2019; 106: 160-164.

10. Naik SK, Das DK. Relative performance of chelated zinc and zinc sulphate for lowland rice (*Oryza sativa* L.). *Nutrient Cycling in Agroecosystems*.2008; 81: 219-227.

11. El-Tohamy WA, NHM El-Greadly. 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*. 2007; 1: 249-299.

12. Rezaei M, Abbasi H. Foliar application of nanochelate and non-nanochelate of zinc on plant resistance physiological processes in cotton (*Gossipium hirsutum* L.). *Iranian Journal of Plant Physiology*. 2014; 4(4): 1137-1144.

13. Tahir M, Fiaz N, Nadeem MA, Khalid F, Ali M. Effect of different chelated zinc sources on the growth and yield of maize (Zea mays L.). *Soil and Environment*. 2009; 28(2): 179-183.

14. Goud G, Sudhakar KS, Pasha ML, Madhavi A. Evaluation of the Foliar Application of Nano Urea on the Performance of Rabi Sunflower (*Helianthus annuus* L.). *International Journal of Environment and Climate Change*. 2022; 12(11): 2700-2706.