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Impact of different Sources of Zinc on Yield, Yield Components and Nutrient Uptake of Sweetcorn

Monika Peddapuli[1]*, B. Venkateswarlu[2] and V. Sai Surya Gowthami[3]

[1]M.Sc. Scholar, (Ag.), Department of Agronomy, Agricultural College, Bapatla (Andhra Pradesh), India.
[2]Professor and Head, Department of Agronomy, Agricultural College, Bapatla (Andhra Pradesh), India.
[3]Ph.D. Scholar, Department of Agronomy, Agricultural College, Bapatla (Andhra Pradesh), India.

(Corresponding author: Monika Peddapuli)*
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ABSTRACT: Micronutrient malnutrition has been widespread both in developing and developed countries affecting about 2 billion people. In contrast, most of the cereal based crops are fundamentally deficient in micronutrients. Food fortification is widely acknowledged as an effectual approach to enhance micronutrient status in population. Agronomic fortification of cereals is a rapid and effective method to enrich the cereals with the micronutrients particulary zinc. A field experiment was conducted during *kharif*, season of 2020-21 at Agricultural College Farm, Bapatla. The experiment was laid out in simple Randomised Block Design with nine treatments and replicated thrice. Among different sources of zinc, soil application of 10 kg ha^{-1} Zn EDTA + foliar application of nano zinc @ 250 ppm at 20 & 40 DAS along with RDF recorded significantly highest green cob yield (12,638 kg ha^{-1}), stover yield (7590 kg ha^{-1}), number of seed rows cob^{-1} (16.84), number of seeds row^{-1} (32.57), cob length (22.44 cm), girth (18.87 cm), weight of cob with husk (254.80 g) and without husk (201.8 g) and seed yield per cob (124.86 g) as compared to rest of the treatments and lowest was noticed in control. The highest zinc and nitrogen uptake by the plant at harvest was noticed in the plots treated with RDF along with soil application of 10 kg ha^{-1} Zn EDTA + foliar application of nano zinc @ 250 ppm at 20 & 40 DAS treatment and the lowest was observed in control.

Keywords: Nutrient Uptake, Nano Zinc, Cob Girth and Stover Yield.

INTRODUCTION

Maize is one of the widely grown cereal crop on account of its multiple functions as a human food and animal feed (Xia *et al*., 2019). Being an exhaustive crop, maize requires both major and micro nutrients especially zinc for obtaining good yields (Lawson *et al*., 2015). Among the different kinds of corn, sweetcorn gained much importance for human consumption in metropolitan areas owing to its taste. The nutrient composition of sweet corn is very important for human health and diet (Swapna *et al*., 2020). The sugar content in normal corn ranges from 2-5% which is less in comparison to sweetcorn at milk stage where the sugar content is in the range of 25-30%. Further, its demand for the fresh sweetcorn in hotels and also as raw materials for industrial products like dextrin, starch syrup, dextrose has potentiality gained significance both in local and global markets (Michell, 2000). Sweet corn consumption has increased considerably worldwide. Sweet corn is produced for human consumption either as a fresh or a processed product (Prasanthi *et al*., 2017).

Intensive agriculture involving modern technologies with the introduction of high yielding sweetcorn and the repeated use of high analysis fertilizers has finally lead to deficiency of micro nutrients particularly zinc (Ray *et al*., 2016). Subsequently, in the intensively cultivated areas, micro-nutrient deficiency has evolved as an alarming situation.

Zn deficiency is a well-documented problem in food crops, causing decreased crop yields and nutritional quality (Cakmak, 2008). Generally, the regions in the world with Zn deficient soils are also characterized by widespread Zn deficiency in humans. According to WHO report on the risk factors responsible for development of illnesses and diseases, Zn deficiency rank 11th among the 20 most important factors in the world and 5th among the 10 most important factors in developing countries (Anon., 2002).

Half of our Indian soils are deficient in zinc, resulting in lower yields of major food crops (Cakmak, 2009) further affecting livestock health. Apart from livestock human beings who consume the food grown in this zinc deficient soils also suffer from zinc malnutrition. A recent study revealed that annually 5,00,000 children of below 5 years age die due to zinc and iron deficiencies (Akhtar, 2013). Similarly, a rare medical disorder *viz*., "*Acrodermatitis enteropathica*" also determines the deficiency of the intestinal absorption of Zn (Regina *et al*., 2018). To surmount the zinc malnutrition several strategies have been developed in the form of fortification, supplementation, bio fortification and Zinc fertilization.

The several approaches to increase the concentration of micronutrients in foods, includes nutrient fortification, supplementation programmes, conventional breeding and genetic engineering (Siwela *et al*., 2020). They are necessary to diagnose and manage the problem of micronutrient malnutrition. However, these approaches appear to be expensive and are not easily accessible by those living in the developing countries (Gupta *et al*., 2020). Conventionally, though $ZnSO_4$ is the only reliable source, many other sources of zinc fertilizer are available now. Soils with high fixation and adsorption reactions, prefer chelating agents such as Ethylene diamine tetra acetic acid (EDTA), which increases the availability of zinc besides other trace elements in the soil solution (Stacey *et al.*, 2007). A study showed that application of EDTA mitigated the toxic effects of excessive copper accumulation on *Corchorus capsularis* (Saleem *et al*., 2020) Chelated forms, metal ions remain inert and are easily available to plant. Similarly, zinc oxide nanoparticles also hold a promise as novel fertilizer nutrients for crops because they enhance productivity, nutrient use efficiency and impart tolerance to biotic as well as abiotic stresses, thus fortifying edible plant parts with zinc (Dimkpa *et al*., 2020). An appropriate method of Zn application also assumes significance for its efficient uptake and utilization. Hence, the present investigation was carried out to assess the impact of different sources of zinc on yield, yield components and nutrient uptake of sweetcorn.

MATERIALS AND METHODS

A field experiment was conducted during *kharif* season of 2020-21 at Agricultural College Farm, Bapatla. The soil of the experimental site was sandy clay in texture, neutral in reaction (6.86) and low in organic carbon (0.35%) and available nitrogen (210 kg ha^{-1}), medium in available phosphorus (23.0 kg ha^{-1}) and medium in available potassium (258 kg ha^{-1}). DTPA extractable zinc was 0.42 mg kg^{-1} and was found deficient. A total rainfall of 525.5 mm was received during the crop growth period in 25 rainy days. Sugar-75, a sturdy and vigorously performing hybrid variety of sweetcorn, released by Syngenta company was used in the current experimentation.

The experiment was laid out according to randomized block design comprising of nine treatments and replicated thrice. The treatments comprised T_1: Control (RDF), T_2: RDF + $ZnSO_4$ @ 25 kg ha^{-1} (Soil application), T_3: RDF + $ZnSO_4$ @ 0.5 % foliar spray at 20 & 40 DAS, T_4: RDF + Zn EDTA @ 10 kg ha^{-1} (Soil application), T_5: RDF + Zn EDTA @ 0.5 % (Foliar spray) at 20 and 40 DAS, T_6: RDF + Nano ZnO @ 250 ppm at 20 & 40 DAS (Foliar spray), T_7: RDF + Nano ZnO @ 500 ppm at 20 & 40 DAS (Foliar spray), T_8: RDF + $ZnSO_4$ @ 25 kg ha^{-1} (Soil) + Nano ZnO @ 250 ppm at 20 & 40 DAS (Foliar spray) and T_9: RDF + Zn EDTA @ 10 kg ha^{-1} (Soil) + Nano ZnO @ 250 ppm at 20 & 40 DAS (Foliar spray). Recommended dose of 180:60:50 NPK kg ha^{-1} were applied to all the treatments. $1/3^{r\ d}$ Urea was applied as basal at the time of sowing, $1/3^{rd}$ at knee high stage and $1/3^{rd}$ at the time of tasseling. Entire dose of single super phosphate and muriate of potash were applied in single dose as basal. Micronutrient $ZnSO_4$ was applied as basal and foliar application as per the treatments.

RESULTS AND DISCUSSION

A. Yield Parameters

The difference among treatments due to fortification of sweetcorn with zinc could not reach the level of significance with respect to number of cobs $plant^{-1}$. Cob length and girth registered significantly higher values (22.44 cm and 18.87 cm) with T_9 (RDF + Zn EDTA 10 kg ha^{-1} (Soil) + Nano ZnO @ 250 ppm at 20 and 40 DAS as foliar spray). While the lowest cob length (15.67 cm) and girth (13.77 cm) was registered in control.

Significantly the highest number of seed rows cob^{-1} (16.84) and seeds row^{-1} (32.57) were recorded in soil application of zinc EDTA @ 10 kg ha^{-1} + foliar spray of nano zinc @ 250 ppm at 20 & 40 DAS which was observed to be on a par with T_8 (RDF + $ZnSO_4$ @ 25 kg ha^{-1} (Soil) + Nano ZnO @ 250 ppm at 20 & 40 DAS (Foliar spray)) and T_7 (RDF + Nano ZnO @ 500 ppm at 20 & 40 DAS (Foliar spray)) treatments. Significantly the lowest number of seed rows per cob (11.16) and seeds per row (20.10) were observed in control treatment.

Soil application of zinc EDTA @ 10 kg ha^{-1} + foliar spray of nano zinc @ 250 ppm at 20 & 40 DAS along with RDF has registered higher cob weight with husk (254.80 g) and without husk (201.8 g) and was comparable with T_8 (RDF + $ZnSO_4$ @ 25 kg ha^{-1} (Soil) + Nano ZnO @ 250 ppm at 20 & 40 DAS (Foliar spray)) and T_7 (RDF + Nano ZnO @ 500 ppm at 20 & 40 DAS (Foliar spray)) treatments only. Control treatment (T_1) recorded the lowest cob weight with husk (203.40 g) and without husk (140.20 g).

Among the various treatments tested, 100-kernel weight was not significantly influenced however, 100-kernel weight and seed yield cob $^{-1}$ attained their highest (22.8 and 124.9 g cob^{-1}) and lowest values (20.3 and 48.31 g cob^{-1}) with the soil application of zinc EDTA @ 10 kg ha^{-1} + foliar spray of nano zinc @ 250 ppm at 20 & 40 DAS (T_9) and control respectively.

Combined application of zinc as soil and foliar spray increased the availability of zinc to the plant from both soil (soil application) and leaves, due to the direct intake of Zn by the foliar application which might be the reason for the increased yield attributes. This proper and timely availability of zinc might have improved the uptake of nitrogen during the growth of sweetcorn and eventually enhanced yield attributes. Similar findings were reported by Potarzycki and Grzebisz (2009); Siddiqui *et al*. (2009) in which they noticed that Zn application showed a positive influence in improving nitrogen fertilizer productivity. In addition to this, zinc is also engaged in many enzymatic processes and catalytic reactions which increase the growth of the plant, thus leading to the development of higher yield attributing parameters. These results were in good accordance with those of Kenbaev and Sade (2002); Hussain and Yasin (2004); Jakhar *et al*. (2006).

B. Green Cob Yield

Significantly the highest green cob yield (12,638 kg ha^{-1}) was registered from the treatment with soil application of Zn EDTA @ 10 kg ha^{-1} + two foliar sprays of nano zinc @ 250 ppm at 20 & 40 DAS along with RDF. Whereas, the lowest green cob yield (8009 kg ha^{-1}) was noticed in the control.

C. Stover Yield

Zinc application had a beneficial influence on plant metabolism, physiological process and plant growth, and better translocation of carbohydrates from source to sink which ultimately lead to more yield.

Table 1: Number of cobs $plant^{-1}$, Cob length, Cob girth, Number of seed rows cob^{-1} and Number seeds row^{-1} of sweetcorn as influenced by zinc fertilization.

Treatments	Number of cobs $plant^{-1}$	Cob length	Cob girth	Number of seed rows cob^{-1}	Number of seeds row^{-1}
T_1: Control (RDF)	1.32	15.67	13.77	11.16	20.10
T_2: RDF + $ZnSO_4$ @ 25 kg ha^{-1} (Soil application)	1.74	18.49	16.37	13.98	25.81
T_3: RDF + $ZnSO_4$ @ 0.50% at 20 and 40 DAS (Foliar spray)	1.65	17.76	15.53	12.88	23.70
T_4: RDF + Zn EDTA @ 10 kg ha^{-1} (Soil application)	1.77	18.58	16.49	14.25	26.00
T_5: RDF + Zn EDTA @ 0.5% (Foliar spray) at 20 and 40 DAS	1.69	17.84	15.68	13.01	23.91
T_6: RDF + Nano ZnO @ 250 ppm at 20 and 40 DAS (Foliar spray)	1.70	18.28	16.21	13.92	25.62
T_7: RDF + Nano ZnO @ 500 ppm at 20 and 40 DAS (Foliar spray)	1.83	21.63	18.38	15.99	31.62
T_8: RDF + $ZnSO_4$ @ 25 kg ha^{-1} (Soil) + Nano ZnO @ 250 ppm at 20 and 40 DAS (Foliar spray)	1.86	22.28	18.65	16.48	32.07
T_9 : RDF + Zn EDTA 10 kg ha^{-1} (Soil) + Nano ZnO @ 250 ppm at 20 and 40 DAS (Foliar spray)	1.88	22.44	18.87	16.84	32.57
SEm±	0.12	0.67	0.58	0.55	1.16
CD (p=0.05)	NS	2.04	1.75	1.66	3.51
CV (%)	12.07	6.08	6.00	6.64	7.49

Table 2: Cob weight (g) (with husk and without husk), 100-kernel weight and Seed yield cob^{-1} of sweetcorn as influenced by zinc fertilization.

Treatments	Cob weight (with husk)	Cob weight (without husk)	100-kernel Weight	Seed yield cob^{-1}
T_1: Control (RDF)	203.40	140.20	20.3	48.3
T_2: RDF + $ZnSO_4$ @ 25 kg ha^{-1} (Soil application)	219.83	170.17	22.0	78.9
T_3: RDF + $ZnSO_4$ @ 0.50% at 20 and 40 DAS (Foliar spray)	212.90	159.90	20.7	58.5
T_4: RDF + Zn EDTA @ 10 kg ha^{-1} (Soil application)	222.77	174.30	22.1	81.5
T_5: RDF + Zn EDTA @ 0.5% (Foliar spray) at 20 and 40 DAS	214.43	161.43	20.8	60.5
T_6: RDF + Nano ZnO @ 250 ppm at 20 and 40 DAS (Foliar spray)	216.23	165.23	21.0	74.7
T_7: RDF + Nano ZnO @ 500 ppm at 20 and 40 DAS (Foliar spray)	248.97	195.97	22.4	108.7
T_8: RDF + $ZnSO_4$ @ 25 kg ha^{-1} (Soil) + Nano ZnO @ 250 ppm at 20 and 40 DAS (Foliar spray)	252.47	199.47	22.6	116.4
T_9 : RDF + Zn EDTA 10 kg ha^{-1} (Soil) + Nano ZnO @ 250 ppm at 20 and 40 DAS (Foliar spray)	254.80	201.80	22.8	124.9
SEm±	8.19	7.06	0.98	5.40
CD (p=0.05)	24.78	21.37	NS	16.34
CV (%)	6.24	7.02	7.83	11.18

Table 3: Green cob yield (kg ha^{-1}) and Stover yield (kg ha^{-1}) of sweetcorn as influenced by zinc fertilization.

Treatments	Green cob yield (kg ha^{-1})	Stover yield (kg ha^{-1})
T_1: Control (RDF)	8,009	5,004
T_2: RDF + $ZnSO_4$ @ 25 kg ha^{-1} (Soil application)	9,517	6,296
T_3: RDF + $ZnSO_4$ @ 0.50% at 20 and 40 DAS (Foliar spray)	9,306	6,008
T_4: RDF + Zn EDTA @ 10 kg ha^{-1} (Soil application)	9,566	6,350
T_5: RDF + Zn EDTA @ 0.5% (Foliar spray) at 20 and 40 DAS	9,313	6,166
T_6: RDF + Nano ZnO @ 250 ppm at 20 and 40 DAS (Foliar spray)	9,439	6,282
T_7: RDF + Nano ZnO @ 500 ppm at 20 and 40 DAS (Foliar spray)	12,017	7,369
T_8: RDF + $ZnSO_4$ @ 25 kg ha^{-1} (Soil) + Nano ZnO @ 250 ppm at 20 and 40 DAS (Foliar spray)	12,371	7,373
T_8: RDF + Zn EDTA @ 10 kg ha^{-1} (Soil) + Nano ZnO @ 250 ppm at 20 and 40 DAS (Foliar spray)	12,638	7,590
S.Em ±	421.96	331.04
CD (P = 0.05)	1277.03	1001.86
CV (%)	7.14	8.83

Increase in yield with application of Zn was also noticed by Kumar and Bohra (2014); Chand and Susheela (2017); Kumar and Salakinkop (2018). Application of nano zinc oxide might have activated the enzymes by fusing with the chlorophyll formation in sweetcorn plants and increased growth harmone production like tryptophan. This increased production is the main place to store carbohydrates. In plant, carbohydrates are in grains that eventually led to an increased number of seeds per plant as a source, and storage carbohydrates, and increased the yield of sweetcorn. Similar increase in yield by the application of nano zinc oxide particles is reported by Ashrafi *et al*. (2013); Satdev *et al*. (2020).

The highest stover yield (7,590 kg ha^{-1}) of sweetcorn was obtained with RDF + soil application of Zn EDTA @ 10 kg ha^{-1} along with the two foliar sprays of nano zinc @ 250 ppm at 20 & 40 DAS (T_9). T_9 treatment was comparable with T_8 *i.e.* RDF + soil application of zinc sulphate @ 25 kg ha^{-1} + two foliar sprays of nano zinc @ 250 ppm at 20 and 40 DAS (19,554 and 7,373 kg ha^{-1}) and T_7 *i.e.* two foliar sprays of nano ZnO @ 500 ppm at 20 and 40 DAS along with RDF (19,498 and 7,369 kg ha^{-1}). The lowest value was noticed in control (5,004 kg ha^{-1}).

Maize is a fast growing crop with vigorous growth habit, lengthy stem with more number of leaves. This robust growth associated with taller plants, maximum number of leaves, increased dry matter production and higher green fodder might be the probable reason for remarkably elevated stover yield (Amanullah *et al*., 2009). Zinc fertilization resulted in early growth of seedling and superior nutrition which further enhanced dry matter accumulation in maize thus increasing stover yield (Shakoor *et al*., 2018). Increase in stover yield by the foliar application of nano zinc oxide in the present study can be attributed to significant increase in dry matter in plants which in turn mainly attributed to increase in growth factors like plant height. Current findings are in accordance with results of Uma *et al*. (2019).

D. Nitrogen Uptake

Significantly, highest nitrogen uptake by the plant at harvest was recorded in treatment T_9 *i.e*. soil application of Zn EDTA @ 10 kg ha^{-1} along with the two foliar sprays of nano zinc @ 250 ppm at 20 & 40 DAS (127.60 kg ha^{-1}) and was on a par with T_8 *i.e.* RDF + soil application of zinc sulphate @ 25 kg ha^{-1} + two foliar sprays of nano zinc @ 250 ppm at 20 and 40 DAS (126.33 kg ha^{-1}) and T_7 *i.e.* two foliar sprays of nano ZnO @ 500 ppm at 20 and 40 DAS along with RDF (119.96 kg ha^{-1}). The lowest uptake of nitrogen by the plant was noticed in control treatment *i.e.* T_1 (70.83 kg ha^{-1}).

Current findings are in close agreement with the results reported by Fan *et al*. (2012) and Wu (2013) who demonstrated the effectiveness of chitosan nanoparticles in enhancing the uptake of nutrients, thus increasing the nutrients concentration significantly such as nitrogen in the plants compared to control. Zinc improves the cationic exchange capacity of roots, which further increased the surface absorption of other essential nutrients, specifically nitrogen which was also one of the reason for higher protein content.

E. Zinc Uptake

At harvest, significantly the highest uptake of zinc in T_9 treatment *i.e*. soil application of Zn EDTA @ 10 kg ha^{-1} along with the two foliar sprays of nano zinc @ 250 ppm at 20 & 40 DAS (257.31 g ha^{-1}) which stood statistically at par with the treatment T_8 *i.e.* RDF + soil application of zinc sulphate @ 25 kg ha^{-1} + two foliar sprays of nano zinc @ 250 ppm at 20 and 40 DAS (254.19 g ha^{-1}) and T_7 *i.e.* two foliar sprays of nano ZnO @ 500 ppm at 20 and 40 DAS along with RDF (245.48 g ha^{-1}). While the lowest zinc uptake by the plant (115.68 g ha^{-1}) was noticed in the treatment T_1 (Control).

Application of zinc both by soil and foliar spray improved the zinc availability and distribution near roots which in turn increased the zinc uptake by the roots and thus enhanced its accumulation in shoots (Zhang *et al*., 2013). These findings are in accordance with Zhang *et al*. (2013) who reported that zinc uptake by the plants can be increased by zinc application. These results are also confirmed by Harris *et al.* (2007) and Hossain *et al*. (2008). Also, the inherent small size and the associated large surface area of nanoscale ZnO fertilizer might have increased the uptake as reported earlier by Prasad *et al*. (2012).

Table 4: Nitrogen and Zinc uptake (kg ha^{-1}) by sweetcorn at harvest as influenced by zinc fertilization.

Treatments	Nitrogen uptake (kg ha^{-1})	Zinc uptake (kg ha^{-1})
T_1 : Control (RDF)	70.83	115.68
T_2 : RDF + $ZnSO_4$ @ 25 kg ha^{-1} (Soil application)	100.85	175.44
T_3 : RDF + $ZnSO_4$ @ 0.50% at 20 and 40 DAS (Foliar spray)	91.90	153.27
T_4 : RDF + Zn EDTA @ 10 kg ha^{-1} (Soil application)	102.35	176.76
T_5 : RDF + Zn EDTA @ 0.5% (Foliar spray) at 20 and 40 DAS	94.87	156.76
T_6 : RDF + Nano ZnO @ 250 ppm at 20 and 40 DAS (Foliar spray)	97.93	161.01
T_7 : RDF + Nano ZnO @ 500 ppm at 20 and 40 DAS (Foliar spray)	119.96	245.48
T_8 : RDF + $ZnSO_4$ @ 25 kg ha^{-1} (Soil) + Nano ZnO @ 250 ppm at 20 and 40 DAS (Foliar spray)	126.33	254.19
T_9 : RDF + Zn EDTA 10 kg ha^{-1} (Soil) + Nano ZnO @ 250 ppm at 20 and 40 DAS (Foliar spray)	127.60	257.31
SEm±	4.29	9.52
CD (p=0.05)	12.98	28.80
CV (%)	7.17	8.75

CONCLUSION

Soil application of Zn EDTA (10 kg ha^{-1}) along with the two foliar sprays of nano zinc (250 ppm) at 20 and 40 DAS was found to be more effective in improving yield attributes, cob and stover yield of sweetcorn. The highest zinc and nitrogen uptake by the plant at harvest was noticed in the plots treated with RDF along with soil application of 10 kg ha^{-1} Zn EDTA + foliar application of nano zinc @ 250 ppm at 20 & 40 DAS treatment and the lowest was observed in control.

FUTURE SCOPE

1. Long term experiments pertaining to study of effect of different sources of zinc application on sweetcorn.
2. Study on the effect of nano zinc oxide particles on the growth and yield of sweetcorn.
3. Comparative studies on Zn EDTA, $ZnSO_4$ and nano zinc oxide particles should be extended to various other cereals.

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