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EFFECT OF APPLICATION METHODS AND FORMS OF ZINC ON YIELD ATTRIBUTES OF MAIZE CROP

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ABSTRACT

A field experiment was conducted during the *rabi* season of 2025-26 at the College Farm, College of Agriculture, Professor Jayashankar Telangana Agricultural University (PJTAU), Rajendranagar, Hyderabad, to evaluate the effect of different application methods and forms of zinc on the yield attributes and yield of maize (*Zea mays* L.). The experiment was laid out in a Randomized Block Design (RBD) with seven treatments and three replications under zinc-deficient sandy loam soil. The treatments comprised foliar application of zinc sulphate ($ZnSO_4$) and nano zinc through knapsack and drone sprayers, with and without basal application of chelated zinc (50%). Foliar sprays were applied at 35 and 50 days after sowing. The results revealed that zinc application significantly improved cob weight, cob length, cob girth, kernel rows per cob, kernels per row, cob yield, and stover yield, whereas the number of cobs per plant remained unaffected. The highest cob yield (9.81 t ha^{-1}) and stover yield (10.03 t ha^{-1}) were recorded with basal application of chelated zinc (50%) combined with foliar application of nano zinc @ 4 mL L^{-1} through drone spraying, which was statistically on par with basal chelated zinc (50%) combined with $ZnSO_4$ @ 2 g L^{-1} through drone spraying. Drone-based foliar application proved superior to conventional knapsack spraying, demonstrating greater efficiency in nutrient delivery and enhanced crop productivity. Thus, the combined application of basal chelated zinc and foliar nano zinc through drone spraying can be recommended for improving maize productivity under zinc-deficient conditions.
***Keywords*:** Maize, drone spraying, nano zinc, zinc sulphate, chelated zinc, yield attributes, cob yield.

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops worldwide due to its high yield potential, wide adaptability, and multiple uses in human food, animal feed, and various industrial products. In India, maize is cultivated extensively and plays a significant role in ensuring food and nutritional security as well as supporting the poultry and processing industries. However, achieving higher productivity requires balanced nutrient management, particularly the adequate supply of micronutrients such as zinc (Zn). (Balakrishna and Subramanian, 2012).

Zinc is an essential micronutrient involved in numerous physiological and biochemical processes, including enzyme activation, protein synthesis, chlorophyll formation, photosynthesis, carbohydrate metabolism, and auxin production. Zinc deficiency is widespread in many agricultural soils, especially in intensively cultivated areas, leading to reduced plant growth, poor nutrient uptake, lower grain yield, and inferior grain quality. Maize is highly sensitive to zinc deficiency, making timely and efficient zinc application crucial for improving crop productivity and zinc use efficiency (Suganya *et al*., 2020).

Among the different methods of zinc fertilization, foliar application has gained importance because it enables rapid nutrient absorption and minimizes losses associated with soil application. Conventional foliar spraying using knapsack sprayers is commonly adopted by farmers however, it requires high labour input, large spray volumes, and increases operator exposure to agrochemicals. Recent advances in precision agriculture have introduced unmanned aerial vehicles (UAVs) or drones as an efficient alternative for foliar nutrient application. Drone spraying offers advantages such as uniform droplet deposition, reduced spray volume, faster field coverage, lower labour requirement, and improved operational efficiency (Chen *et al*., 2021).

Although drone-based spraying is increasingly being adopted in agriculture, limited information is available regarding its effectiveness for foliar zinc application using different zinc sources in maize. Therefore, the present study was undertaken to evaluate the performance of different zinc forms applied through drone and conventional knapsack spraying on spray characteristics, zinc uptake, growth, yield, and economics of rabi maize.

Materials and Methods

Experimental Site

The field experiment was conducted during the rabi season of 2025-26 at College Farm, College of Agriculture, Professor Jayashankar Telangana Agricultural University (PJTAU), Rajendranagar, Hyderabad, Telangana, India. The experimental site is located at 17°32′21″ N latitude, 78°41′04″ E longitude, at an altitude of 559 m above mean sea level, and falls under the Southern Telangana Agro-Climatic Zone. The soil of the experimental field was sandy loam in texture.

Experimental Design and Treatment Details

The experiment was laid out in a randomized block design with 7 treatments and 3 replications. The test crop used was maize hybrid DHM-206 with a spacing of 60 x 20 cm. The crop was grown under zinc-deficient soil conditions, and foliar zinc sprays were applied at 35 and 50 days after sowing (DAS) according to the treatment schedule.

The treatments comprised: T_1 - Untreated control (recommended dose of NPK, no Zn); T_2 - $ZnSO_4$ @ 2 g L^{-1} through knapsack sprayer; T_3 - $ZnSO_4$ @ 2 g L^{-1} through drone sprayer; T_4 - Nano zinc @ 4 mL L^{-1} through knapsack sprayer; T_5 - Nano zinc @ 4 mL L^{-1} through drone sprayer; T_6 - Basal application of chelated zinc (50%) + $ZnSO_4$ @ 2 g L^{-1} through drone sprayer; and T_7 - Basal application of chelated zinc (50%) + nano zinc @ 4 mL L^{-1} through drone sprayer.

Characteristics of Spraying Devices

Drone parameters

The UAV used in the study was the AGRICOPTER AG 365 (Marut Drone Tech Pvt. Ltd., Hyderabad), equipped with four XR11002 VP extended-range flat-fan nozzles having a 110° spray angle. The drone was operated at a flight height of 2.5 m above the crop canopy with a flight speed of 4.0 m s^{-1}, spray volume of 40 L ha^{-1}, spray width of 4 m, and discharge rate of 60%. The UAV was powered by two 6-cell LiPo batteries (22,000 mAh each).

Knapsack sprayer parameters

Foliar zinc application was carried out using a knapsack sprayer with a hollow cone nozzle. The knapsack sprayer had a loading capacity of 20 litres and spraying height 20 to 30 cm above the crop canopy.

Observations

In all the 7 treatments randomly, 5 plants were selected in each replication and tagged for recording observations. The yield parameters like length and girth of the cob, weight of the cob, number of rows/cob, number of grains/row, were recorded.

Results and Discussion

Yield parameters

Number of Cobs Plant^{-1}

The number of cobs plant^{-1} was not significantly influenced by different application methods and forms of zinc (Table 01). However, the highest number of cobs plant^{-1} (1.54) was recorded with basal application of chelated zinc (50%) + nano zinc @ 4 mL L^{-1} through drone sprayer (T_7), followed by basal application of chelated zinc (50%) + $ZnSO_4$ @ 2 g L^{-1} through drone sprayer (T_6) (1.47). The lowest value (1.17) was recorded in the untreated control (T_1). The non-significant variation indicates that cob initiation is predominantly governed by the genetic potential of the hybrid, while zinc nutrition mainly influences cob development rather than cob number. Similar findings were reported by Tahir *et al.* (2009). However, Satdev *et al.* (2020) observed significant variation in this trait under nano-zinc application.

Cob Weight (g)

Cob weight was significantly influenced by zinc application methods and forms (Table 01) and illustrated in Fig.1. The maximum cob weight (219.06 g) was recorded with T_7, which was statistically on par with T_6 (213.89 g). Among the foliar treatments without basal zinc, nano zinc through drone sprayer (T_5) produced a cob weight of 193.83 g, followed by $ZnSO_4$ through drone sprayer (T_3) (193.36 g). The lowest cob weight (119.25 g) was observed in the untreated control (T_1). Increased cob weight under T_7 and T_6 may be attributed to improved zinc availability, enhanced photosynthetic activity and efficient translocation of assimilates to developing cobs. Similar results have been reported by Darwish *et al.* (2002), Gobarah *et al.* (2006) and Rana *et al.* (2013).

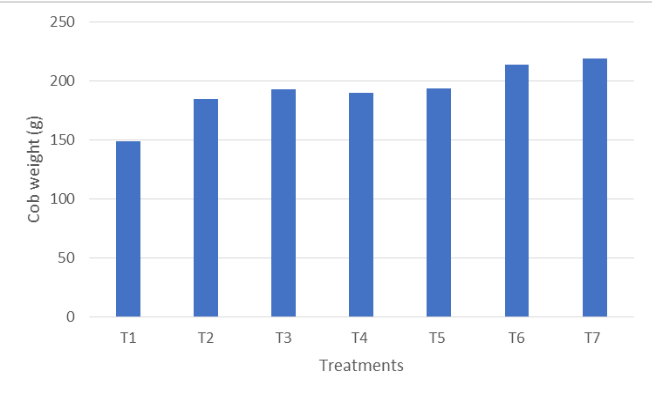

Fig. 1: Cob weight of maize crop influenced by application methods and forms of zinc

Cob Length (cm)

Significant differences were observed in cob length due to zinc treatments (Table 01) and illustrated in Fig.2. The longest cobs were recorded with T_7 (21.15 cm), which was statistically comparable with T_6 (20.99 cm). Drone application of nano zinc (T_5) recorded a cob length of 18.62 cm, whereas the untreated control (T_1) recorded the shortest cobs (13.40 cm). Enhanced zinc nutrition promoted better reproductive growth, resulting in improved cob elongation and grain-bearing capacity. Similar observations have been reported by Shankar *et al.* (2016), Satdev *et al.* (2020) and Vijay *et al.* (2022).

Cob Girth (cm)

Cob girth differed significantly among treatments (Table 01) and illustrated in Fig.2. The highest cob girth was recorded with T_7 (14.70 cm) and was statistically at par with T_6 (14.57 cm). The untreated control recorded the lowest cob girth (12.35 cm). Improved cob girth under zinc-applied treatments could be due to enhanced cell division, carbohydrate accumulation and better kernel development resulting from improved zinc nutrition. Similar findings were reported by Uma *et al.* (2019) and Satdev *et al.* (2020).

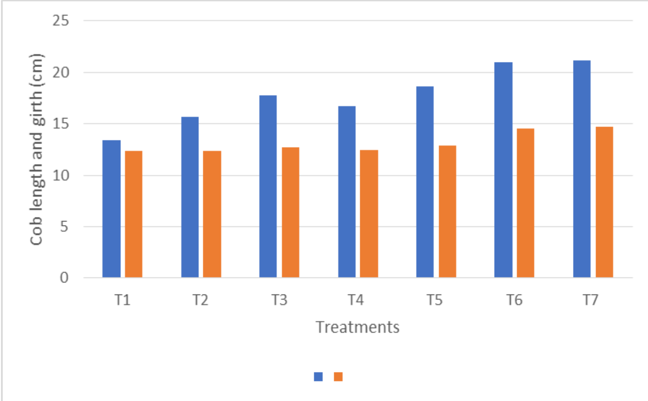

Fig. 2: Cob length (cm) and Cob girth (cm) of maize crop

Number of Kernel Rows Cob^{-1}

Application methods and forms of zinc significantly influenced the number of kernel rows cob^{-1} (Table 01). The highest number of kernel rows cob^{-1} was recorded with T_7 (16.51), followed by T_6 (16.10), both being significantly superior to the untreated control (13.53). Improved zinc nutrition during reproductive growth favoured better cob development and increased kernel row formation through enhanced assimilate supply. Similar findings have been reported by Amar *et al.* (2000) and Khurana *et al.* (2002), Innocent *et al.* (2018) and Salakinkop *et al.* (2019).

Number of Kernels Row^{-1}

The number of kernels row^{-1} was significantly influenced by zinc application (Table 01). T_7 recorded the highest number of kernels row^{-1} (36.10), which was statistically comparable with T_6 (34.46). Among foliar treatments, T_5 (30.52) and T_3 (30.27) produced more kernels than the corresponding knapsack applications. The untreated control recorded the lowest value (23.98). Better pollen viability, grain set and assimilate translocation under adequate zinc supply might have contributed to the increased number of kernels. Similar observations have been reported by Elmore and Abendorth (2006), Gobarah *et al.* (2006), Esfandiari *et al.* (2016), Dambale *et al.* (2018), Doolette *et al.* (2018) and Anusuya *et al.* (2019).

Cob Yield and Stover Yield

Cob yield and stover yield were significantly influenced by different application methods and forms of zinc (Table 01) and illustrated in Fig.3. The highest cob yield (9.81 t ha^{-1}) and stover yield (10.03 t ha^{-1}) were recorded with T_7, which were statistically on par with T_6 (9.53 and 9.83 t ha^{-1}, respectively). Among the foliar zinc treatments, T_5 recorded a cob yield of 8.01 t ha^{-1}, followed by T_3 (7.62 t ha^{-1}), T_4 (7.40 t ha^{-1}) and

T_2 (7.00 t ha^{-1}). The untreated control produced the lowest cob yield (6.46 t ha^{-1}) and stover yield (7.19 t ha^{-1}). The higher yields under T_7 and T_6 may be attributed to improved zinc availability through basal and foliar application, enhanced droplet deposition by drone spraying, higher photosynthetic efficiency, improved nutrient uptake and better partitioning of assimilates towards reproductive organs. Similar findings were reported by Mohsin *et al.* (2014), Choudhary *et al.* (2022) and Vijay *et al.* (2022).

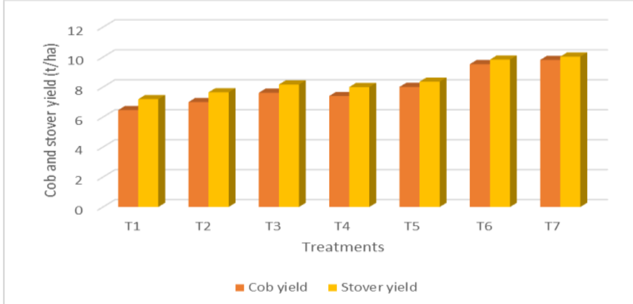

Fig. 3: Cob and Stover yield (t/ha) of maize crop

Table 01. Yield attributes of maize crop as influenced by application methods and forms of 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}	Cob yield (t ha^{-1})	Stover yield (t ha^{-1})
T1 : Untreated Control (RDF of NPK, No Zn)	1.17	149.25	13.40	12.35	13.53	23.98	6.46	7.19
T2 : $ZnSO_4$ @2g/L through Knapsack sprayer (35 and 50 DAS)	1.30	184.74	15.68	12.40	13.64	26.40	7.00	7.65
T3 : $ZnSO_4$ @2g/L through Drone sprayer (35 and 50 DAS)	1.40	193.36	17.74	12.71	14.08	30.27	7.62	8.17
T4 : Nano Zinc @4ml/L through Knapsack sprayer (35 and 50 DAS)	1.39	190.05	16.70	12.46	13.94	28.89	7.40	8.00
T5 : Nano Zinc @4ml/L through Drone sprayer (35 and 50 DAS)	1.42	193.83	18.62	12.86	14.18	30.52	8.01	8.36
T6 : Basal application of Chelated Zinc (50%) + $ZnSO_4$ @2g/L through Drone sprayer (35 and 50 DAS)	1.47	213.89	21.00	14.57	16.10	34.46	9.53	9.83
T7 : Basal application of Chelated Zinc (50%) + Nano Zinc @4ml/L through Drone sprayer (35 and 50 DAS)	1.54	219.06	21.15	14.70	16.51	36.10	9.81	10.03
SEm±	0.08	8.15	0.81	0.54	0.66	1.34	0.41	0.43
CD (p=0.05)	NS	25.11	2.51	1.68	2.06	4.14	1.28	1.34

Conclusion

The study demonstrated that the method of zinc application and the source of zinc significantly influenced the yield attributes and yield of maize. Basal application of chelated zinc (50%) combined with foliar application of nano zinc @ 4 mL L^{-1} through drone spraying (T_7) produced the highest cob weight, cob dimensions, kernel number, cob yield (9.81 t ha^{-1}) and stover yield (10.03 t ha^{-1}), and was comparable to basal chelated zinc + $ZnSO_4$ through drone spraying (T_6). Drone-based foliar application proved to be more effective than conventional knapsack spraying, indicating its potential as an efficient and precise nutrient delivery system. Therefore, the combined application of basal chelated zinc and foliar nano zinc through drone spraying can be recommended for improving maize productivity under zinc-deficient soil conditions.

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