Response of Soil and Foliar Application of Zn on the quality and productivity of Maize *(Zea mays* L.*)*

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Abstract**—** *The field experiment was carried out during Kharif, 2024 at Instructional FarmB1 Block (Agronomy), Rajasthan College of Agriculture, MPUAT, Udaipur. The experiment laid out under Factorial RBD design with three replications. The two factors were soil and foliar application of zinc sulphate heptahydrate. Soil application of zinc sulphate included 4 levels i.e. control, 6.25 kgha^{-1}, 12.5 kg ha^{-1} and 25 kgha^{-1} and 4 levels of foliar application i.e. control ,0.25% $ZnSO_4.7H_2O$, 0.50% $ZnSO_4$. $7H_2O$ and 0.75% $ZnSO_4.7H_2O$. The major challenge of was that how supply the balance diet to rural people and mitigate the problem of micronutrient deficiency in soil. Soil and foliar utilization of zinc increased significantly yield and Yield Attributes but the harvest index was found non-significant. The Protein content and chlorophyll content also increased significantly. The highest values were found with soil application of 25 kg $ZnSO_4.7H_2O$ and foliar application of 0.75% $ZnSO_4.7H_2O$ which was further at par with 12.5 kg $ZnSO_4.7H_2O$ and 0.5% $ZnSO_4.7H_2O$ respectively. Judicious soil and foliar application of zinc increase the Zinc status in soil as well as in grain of maize.*

***Keywords*— *Maize (Zea mays L.), Soil and foliar application, Yield attributes, Zinc sulphate, Quality parameters*.**

I. INTRODUCTION

Among cereal crops, maize (*Zea mays* L.) is considered the third most important cultivated grain worldwide owing to its improved adaptability to a wide spectrum of arid and semi-arid conditions (Shahzad *et al.*, 2020). It is a versatile crop that fits well in the existing cropping systems. The huge potential for export has added the demand for maize all over the world. Maize is a miracle crop called as "Queen of Cereals" due to high productiveness, easy to process, low cost than other cereals (Jaliya *et al.*, 2008). Maize grain has raised nutritive worth as it contains about 72% starch, 10% protein, 4.8% oil, 5.8% fiber and 3.0% sugar (Rafiq *et al.*, 2010).

In India, maize is cultivated on roughly 11.2 million hectares, with a record production estimated at 37.25 mt in 2024–25, and an average national yield of about 3.3 t ha^{-1} (Protect Our Livelihood, 2024). The crop serves multiple purposes: approximately 47% is used as poultry feed, 13% for livestock feed, 13% for direct human consumption, and the remaining 27% for industrial processing and exports.

Zinc is considered the most important micronutrient for normal and healthy plant growth (Tahir *et al*., 2018). It is a structural component or cofactor of various enzymes involved in many biochemical processes. In plants, it is involved in photosynthesis, carbohydrate metabolism, protein metabolism, pollen formation, auxin metabolism, maintenance of membrane integrity, and induction of tolerance against various stresses (Alloway, 2008). It is also essential for nitrogen metabolism and important for the stability of cytoplasmic ribosome's, cell division, as co factor to enzymes like dehydrogenase, proteinase and peptidase in the synthesis of tryptophan, a component of some proteins and a compound needed for production of growth hormones (auxin) such as indole acetic acid (Singh and Singh, 1981).

Plant response to Zn deficiency occurs in terms of decrease in membrane integrity, susceptibility to heat stress, decreased synthesis of carbohydrates, cytochromes nucleotide auxin and chlorophyll. Further, Zn-containing enzymes are also inhibited, which include alcohol dehydrogenase, carbonic anhydrase, Cu-Zn-superoxide dismutase, alkaline phosphatase, phospholipase, carboxypeptidase, and RNA polymerase. Depending on the zinc level, zinc deficiency status of plants can be classified as follows: less than 10 mg kg^{-1} definite zinc deficiency, between 10 and 20 mg kg^{-1} likely to be zinc deficient, more than 20 mg kg^{-1} Zn sufficient.

II. MATERIALS AND METHODS

2.1 Field location and materials:

The experiment was laid out during *kharif* season of 2024 at Instructional Farm B1 Block (Agronomy), Rajasthan College of agriculture, Udaipur, which is situated at 24º35' latitude and 73º42' longitude with an average altitude of 582.2 m above mean sea level. The region falls under agro-climatic zone-IVa of Rajasthan *i.e*. Sub-humid Southern Plain and Aravalli hill.

2.2 Experimental detail:

During the *kharif* of 2024, an experiment was conducted using a factorial randomized block design with three replications. In soil application four treatments were applied: S_1 (control) received no zinc, while S_2, S_3 and S_4 received zinc sulphate at rates of 6.25 kgha^{-1}, 12.5 kg ha^{-1} and 25 kgha^{-1}, respectively. The treatments of foliar application included F_1 (control) with no spray, F_2 with 0.25% $ZnSO_4.7H_2O$ solution, F_3 with 0.50% $ZnSO_4$. $7H_2O$and F_4 with 0.75% $ZnSO_4.7H_2O$concentration. Add lime @ half dose of $ZnSO_4.7H_2O$ as per treatment to avoid scotching effect. The recommended dose of nitrogen (120 kg/ha) was applied in three equal splits, the 1/3 dose as basal and the remaining 1/3 at knee stature stage and remaining 1/3 at 50 % tasseling stage as top dressing at the time of first irrigation through urea. The whole quantity of phosphorus (60 kg/ha) through SSP and potassium (30 kg/ha) through murate of potash was drilled as basal dose at 8-10 cm depth along with 1/3 dose of nitrogen before sowing. Zinc sulphate in the form of $ZnSO_4{\cdot}7H_2O$ was broadcast uniformly over the designated plots in soil application and foliar application was done at a critical crop growth stage (30, 45 and 60 DAS) using a using a knapsack sprayer to ensure uniform coverage of the foliage.

2.3 Determination methods

From the field, matured cobs from five tagged plants from each plot were plucked and counted. The average cobs plant^{-1} was worked out. These cobs were further taken to observe Length of cob, Number of grains cob^{-1}. The test weight was calculated for the 1000 seeds and measured in grams. Grain yield obtained from each net plot including the tagged plants was sun dried and recorded treatment wise and expressed as kg ha^{-1}. Stover yield was calculated by subtracting seed yield from respective biological yield of each plot and expressed as kg ha^{-1}. The un-threshed produce from net plot area including tagged plants after thorough sun drying was weighed for recording the biological yield and expressed as kg ha^{-1}. The ratio of economic yield (grain yield) to the biological yield was worked out and expressed in percentage as advocated by Donald and Hamblin (1976).

$$HI\ (\%) = [(\text{Economical yield})/\ (\text{biological yield})]*100 \quad (1)$$

Where,

Economical yield = Grain yield,

Biological yield = Grain yield + Stover yield

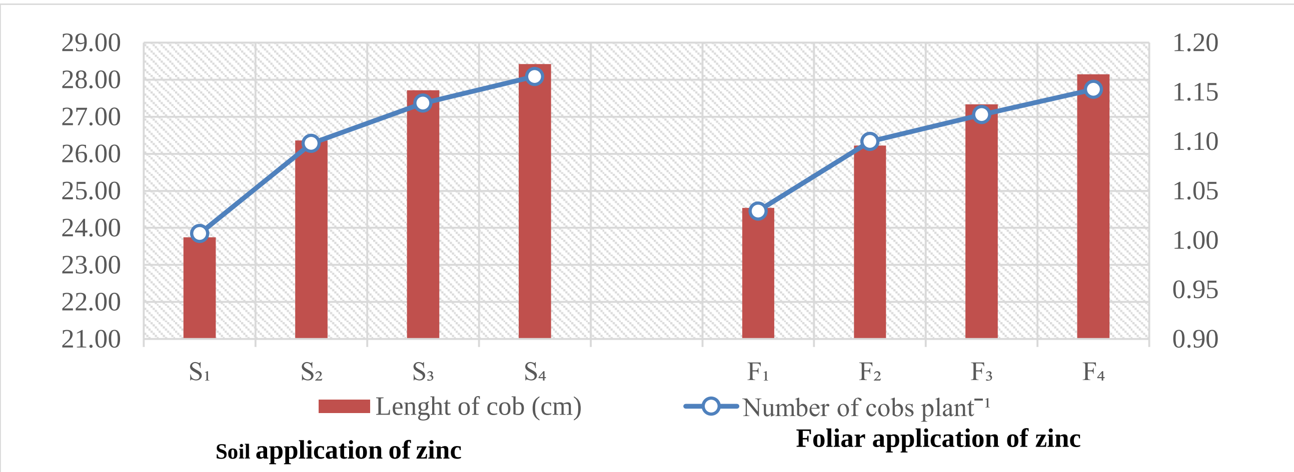
The crude protein content in grain was calculated by multiplying the nitrogen percentage in seed with a factor 6.25 as suggested by A.O.A.C. (1960). The result was expressed as per cent protein content on dry weight basis. The nitrogen content was determined by wet digestion of plant sample with H_2SO_4 and H_2O_2 estimated on colorimeter after development of color with Nessler's reagent (Snell and Snell, 1949). Chlorophyll content in leaves can be measured easily using a SPAD meter. Simply place a healthy, fully expanded leaf (avoiding the midrib) between the sensor clamps and press the button to get a SPAD reading. Take 3–5 readings per leaf and average them for accuracy. Higher SPAD values indicate more chlorophyll and usually better nitrogen status in the plant.

III. RESULTS AND DISCUSSION

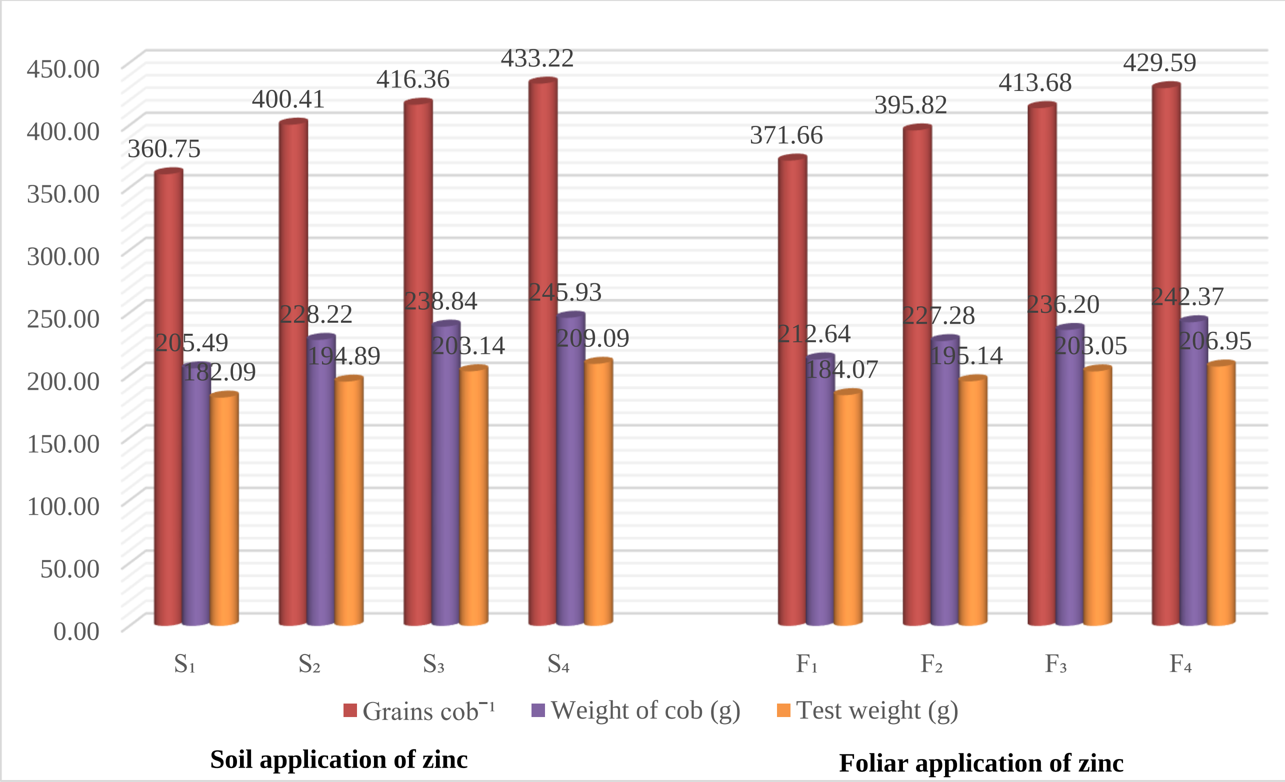
The findings of the present study shown in Table 1 clearly indicate that soil and foliar application of zinc, particularly at the rate of 25 kg $ZnSO_4.7H_2O$ ha^{-1} and 0.75 % $ZnSO_4$ significantly enhances the yield attributes of maize. These attributes include the number of cobs plant^{-1}, cob length, cob weight, number of grains cob^{-1} and test weight. The positive impact of zinc at this dosage can be attributed to its critical physiological and biochemical roles in plant systems. The maize crop fertilized with 25 kg $ZnSO_4.7H_2O$ ha^{-1} produced highest yield attributes *viz*., number of cobs plant^{-1}, length of cob, grains cob^{-1}, weight of cob and test weight of maize which was significantly higher over soil application of 6.25 kg $ZnSO_4.7H_2O$ ha^{-1} and control but remained at par with the soil application of 12.5 kg $ZnSO_4.7H_2O$ ha^{-1}.The superior performance at 25 kg $ZnSO_4.7H_2O$ ha^{-1} compared to the 6.25 kg ha^{-1} and control treatments suggests that zinc deficiency likely constrained growth and yield parameters in the lower-dosage and untreated plots. This is consistent with the findings of Prasad *et al*. (2014), who noted that soil-applied zinc significantly improved the cob length and grain weight in maize, mainly due to its effect on grain filling and nutrient translocation. In terms of foliar spray, the yield attributes *viz*., number of cobs plant^{-1}, length of cob, weight of cob, number of grains cob^{-1} and test weight of maize was significantly increased with foliar application of 0.75% $ZnSO_4.7H_2O$ over foliar application of 0.25% $ZnSO_4.7H_2O$ and control. The increased availability of zinc through foliar application likely improved photosynthetic efficiency and nutrient assimilation, leading to better cob development and grain quality.

TABLE 1
EFFECT OF SOIL AND FOLIAR APPLICATION OF ZINC ON YIELD ATTRIBUTES OF MAIZE

Treatment	Yield attributes				
	No. of cobs plant^{-1}	Length of cob (cm)	Grains cob^{-1} (g)	Weight of cob (g)	Test weight (g)
Soil application					
Control	1.01	23.74	360.75	205.49	182.09
6.25 kg $ZnSO_4$. $7H_2O$ ha^{-1}	1.10	26.36	400.41	228.22	194.89
12.5 kg $ZnSO_4$. $7H_2O$ ha^{-1}	1.14	27.71	416.36	238.84	203.14
25 kg $ZnSO_4$. $7H_2O$ ha^{-1}	1.17	28.42	433.22	245.93	209.09
SEm±	0.02	0.52	7.71	4.54	3.52
C.D. at 0.05	0.05	1.50	22.26	13.10	10.18
Foliar application					
Control	1.03	24.54	371.66	212.64	184.07
0.25% foliar spray of $ZnSO_4$. $7H_2O$	1.10	26.22	395.82	227.28	195.14
0.50% foliar spray of $ZnSO_4$. $7H_2O$	1.13	27.33	413.68	236.20	203.05
0.75% foliar spray of $ZnSO_4$. $7H_2O$	1.15	28.15	429.59	242.37	206.95
SEm±	0.02	0.52	7.71	4.54	3.52
C.D. at 0.05	0.05	1.50	22.26	13.10	10.18



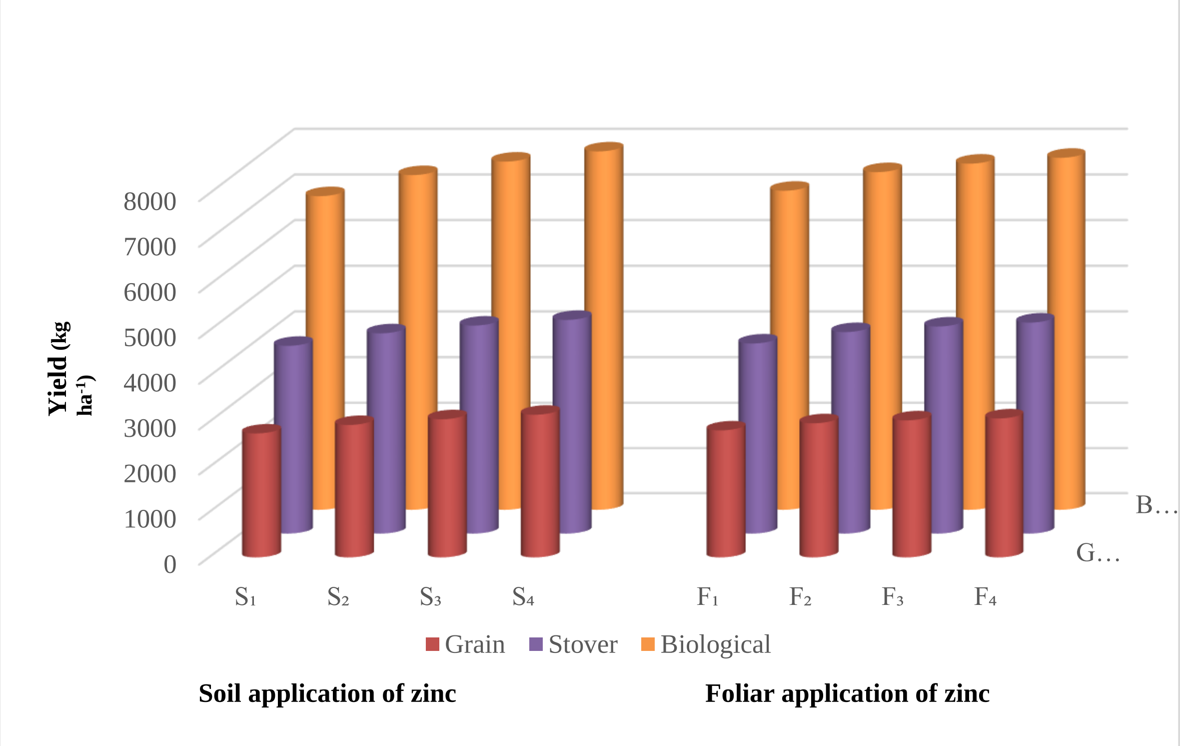
GRAPH 1 (A): Effect of foliar and soil application of zinc on length of cob and number of cobs plant^{-1} of maize



GRAPH 1 (B): Effect of foliar and soil application of zinc on grains cob^{-1}, weight of cob and test weight of maize

TABLE 2
EFFECT OF SOIL AND FOLIAR APPLICATION OF ZINC ON YIELD OF MAIZE

Treatment	Yield (kg ha^{-1})			Harvest index (%)
	Grain	Stover	Biological	
Soil application				
Control	2749	4143	6892	39.90
6.25 kg $ZnSO_4.7H_2O$ ha^{-1}	2937	4417	7354	39.93
12.5 kg $ZnSO_4.7H_2O$ ha^{-1}	3063	4586	7649	40.07
25 kg $ZnSO_4.7H_2O$ ha^{-1}	3162	4710	7872	40.17
SEm±	53	75	107	0.47
C.D. at 0.05	153	218	309	NS
Foliar application				
Control	2817	4194	7011	40.18
0.25% foliar spray of $ZnSO_4.7H_2O$	2975	4444	7418	40.11
0.50% foliar spray of $ZnSO_4.7H_2O$	3038	4566	7605	39.95
0.75% foliar spray of $ZnSO_4.7H_2O$	3081	4652	7733	39.82
SEm±	53	75	107	0.47
C.D. at 0.05	153	218	309	NS



GRAPH 2: Effect of foliar and soil application of zinc on yield of maize

The table 2 shows that maximum grain, Stover and biological yield was recorded under soil application of 25 kg $ZnSO_4.7H_2O$ ha^{-1} which was significantly higher over soil application of 6.25 kg $ZnSO_4.7H_2O$ ha^{-1} and control but remained at par with the soil application of 12.5 kg $ZnSO_4.7H_2O$ ha^{-1}. The significant increase in grain, Stover and biological yield with the soil application of 25 kg $ZnSO_4.7H_2O$ ha^{-1} was to the extent of 7.65, 6.65, 7.05 and 15.00, 13.69, 14.21 per cent over soil application of 6.25 kg $ZnSO_4.7H_2O$ ha^{-1} and control, respectively. The foliar application of 0.25, 0.50 and 0.75% $ZnSO_4.7H_2O$ significantly increased grain and Stover yield over control by 5.59, 7.86, 9.37 and 5.96, 8.88, 10.92 per cent, respectively. The foliar application of 0.75% $ZnSO_4.7H_2O$ significantly increased biological yield by 4.24 and 10.29 over foliar application of 0.50 and 0.25% $ZnSO_4.7H_2O$ and control, respectively but remained at par with foliar application of 0.50% $ZnSO_4.7H_2O$ during experimentation. Different levels of foliar application of zinc could not bring significant improvement in harvest index of maize over control. This increase is attributed to zinc pivotal role in various physiological and biochemical processes within the plant system. Recent studies corroborate these findings. For instance, Ariraman *et al.* (2022) observed that soil application of zinc at 20–25 kg ha^{-1} significantly improved maize grain yield, Stover yield and overall biomass, highlighting zinc's role in enhancing nutrient uptake and utilization efficiency.

The data on chlorophyll content at 50 DAS and protein content in grain of maize as by soil and foliar application of zinc to maize crop are presented in Table 3. The study reveals that the soil application of zinc at 25 kg $ZnSO_4.7H_2O$ ha^{-1} significantly increased chlorophyll content at 50 DAS and protein content in maize grains. These enhancements can be attributed to zinc's critical involvement in photosynthesis, enzyme activation, and protein synthesis. The maize crop fertilized with 25 kg $ZnSO_4.7H_2O$ ha^{-1} recorded highest chlorophyll content in maize at 50 DAS which was significantly higher over soil application of 6.25 kg $ZnSO_4.7H_2O$ ha^{-1} and control but remained at par with the soil application of 12.5 kg $ZnSO_4.7H_2O$ ha^{-1}. Foliar spray of 0.75% $ZnSO_4.7H_2O$ significantly increased chlorophyll content in maize recorded at 50 DAS over foliar spray of 0.50, 0.25% $ZnSO_4.7H_2O$ and control. Zinc is known to influence chlorophyll biosynthesis by enhancing the activity of carbonic anhydrase and other enzymes critical for photosynthetic function. Increased chlorophyll content directly contributes to higher photosynthetic rates, better assimilate production, and ultimately improved crop performance (Liu *et al.,* 2021). Soil application of 25 kg $ZnSO_4.7H_2O$ ha^{-1} significantly improved protein content in grain by 3.60 and 11.57 per cent over soil application of 6.25 kg $ZnSO_4.7H_2O$ ha^{-1} and control, respectively but remained at par with the soil application of soil application of 12.5 kg $ZnSO_4.7H_2O$ ha^{-1}. The protein content in grain was significantly increased with foliar application of 0.75% $ZnSO_4.7H_2O$ over foliar application of 0.25% $ZnSO_4.7H_2O$ and control by 4.77 and 8.95 per cent, respectively. Zinc contributes to protein synthesis by stabilizing ribosomal structure and facilitating enzymatic activity involved in nitrogen metabolism. Foliar zinc enhances N assimilation efficiency, which directly boosts grain protein content (Luo *et al.,* 2021).

TABLE 3
EFFECT OF SOIL AND FOLIAR APPLICATION OF ZINC ON QUALITY PARAMETERS OF MAIZE.

Treatment	Quality parameters		
	Nitrogen content in Grain (%)	Chlorophyll content (SPDA value)	Protein content (%)
Soil application			
Control	1.45	45.57	9.04
6.25 kg $ZnSO_4$. $7H_2O$ ha^{-1}	1.56	47.89	9.73
12.5 kg $ZnSO_4$. $7H_2O$ ha^{-1}	1.59	49.18	9.94
25 kg $ZnSO_4$. $7H_2O$ ha^{-1}	1.61	49.71	10.08
SEm±	0.02	0.54	0.11
C.D. at 0.05	0.05	1.56	0.32
Foliar application			
Control	1.48	43.72	9.24
0.25% foliar spray of $ZnSO_4$. $7H_2O$	1.54	46.72	9.61
0.50% foliar spray of $ZnSO_4$. $7H_2O$	1.58	49.57	9.87
0.75% foliar spray of $ZnSO_4$. $7H_2O$	1.61	52.34	10.07
SEm±	0.02	0.54	0.11
C.D. at 0.05	0.05	1.56	0.32

IV. CONCLUSION

The result concluded that soil and foliar application of zinc sulphate heptahydrate significantly increase yield attributes which include the number of cobs $plant^{-1}$, cob length, cob weight, number of grains cob^{-1} and test weight. The highest values were recorded in 25 kg $ZnSO_4$. $7H_2O$ ha^{-1} and 0.75% foliar spray of $ZnSO_4$. $7H_2O$. The maximum grain, Stover and biological yield was recorded under soil and foliar application of 25 kg $ZnSO_4.7H_2O$ ha^{-1} and 0.75% $ZnSO_4$ which was significantly higher over soil application of 6.25 kg $ZnSO_4.7H_2O$ ha^{-1} and 0.25% $ZnSO_4.7H_2O$ ha^{-1} but remain at par with 12.5 kg $ZnSO_4.7H_2O$ ha^{-1} and 0.50% $ZnSO_4$. . The harvest index increased non significantly in soil and foliar application. The quality parameters increased significantly from control to 25 kg $ZnSO_4.7H_2O$ ha^{-1} in soil application and control to .75% $ZnSO_4$. $7H_2O$ in foliar application

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