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Exploring the Role of Zinc in Maize (*Zea Mays* L.) through Soil and Foliar Application

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Abstract Maize (*Zea mays* L.) is considered as high nutrient demanding crop and needs balanced nutrition. It is also regarded sensitive to zinc deficiency. Zinc is mostly deficient in soils and application of zinc fertilizer is required to explore its full potential. Crop species and even cultivars within species vary in their Zn requirement. A field experiment was conducted during spring 2011 at Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan to evaluate the comparative efficacy of Zn uptake and grain yield in three maize hybrids (Pioneer-32 F 10, Monsanto-6525 and Hycorn-8288) through the application of Zn in the form of $ZnSO_4$. The $ZnSO_4$ treatments comprised; soil application at the time of sowing @ 12 kg ha^{-1}, foliar application at vegetative stage (9 leaf stage) @ 1% $ZnSO_4$ solution and foliar application at reproductive stage (anthesis) @ 1% $ZnSO_4$ solution and one treatment was kept as a control. The experimental results showed substantial difference in yield and yield contributing parameters such as plant population at harvest, number of grains per cob, biological yield, grain yield and harvest index. Statistically maximum grain yield (8.76t ha^{-1}) was obtained with foliar spray of $ZnSO_4$ at 9-leaf stage (Zn_2) in case of Monsanto-6525. Foliar spray of $ZnSO_4$ increased 38% and soil application gave 23.7% more grain yield than control treatment. Foliar spray of $ZnSO_4$ at 9-leaf stage in Monsanto-6525 hybrid produced higher grain yield and net field benefit. Thus foliar application of Zn fertilizers has a positive effect on economic and biological yield of maize crop.

Keywords Maize Hybrids, Zinc, Foliar Application, Yield

1. Introduction

Amongst the cereals, maize is a rich source of essential nutrients needed by both human beings and animals. In Pakistan, it ranks 3rd largest cereal crop after wheat and rice, respectively, on hectare basis. But its average grain yield of 3558 tons ha^{-1}during the year 2010-11[5] (Federal Bureau of Statistics, 2010-11) is too low as compared to other developed countries growing maize [6] (FAO statistics, 2010). There are many factors that limit the maize yield but nutrient deficiency is considered the most deleterious one. Overall crop nutrition play vital role in plant development. Crop nutrition comprised of macronutrients and micronutrients with major role of macro ones, but the micronutrients (Zn, B, Co, Mn, Mo, Cu, Ni and Fe), even being required in smaller amounts are of equally vital for plant growth and development [3] (Davies, 1997). It is due to the fact that micronutrients not only enhance the grain yields but involved in improvement of the quality in terms of grain nutrients [11] (Johnson *et al*., 2005). We can pursue the role of micronutrients in balanced combinations for getting optimal productions. Especially the uses of specific mineral nutrients have become crucial for better plant growth [17] (Marshner, 1995) which can be supplemented as a chemical fertilizer in intensive cropping areas.

Zinc is most crucial amongst the micronutrients that take part in plant growth and development due to its catalytic action in metabolism of almost all crops [8] (George and Schmitt, 2002). Deficiency of Zn in soil causes deficiency in crops and altogether this has become problem all over the world with acute zinc deficiency ranges in arid to semi-arid regions of the world [22] (Rashid and Ryan, 2004). Trend of Zn deficiency have been detected in crop varieties as compared to old ones [2] (Cakmak *et al*., 2001).The genetic differences among crop varieties and species for up taking Zn could be promising approach to Zn problem which invites the selection of proper genotypes.

Moreover, the proper method of nutrient application can be another approach for better uptake and utilization of Zn. Amongst the different methods; the foliar spray of micronutrients is efficient for enhancement of crop productivity [24] (Savithri *et al.,* 1999). This way of nutrient application is an easy and simple method for improvement of plant nutritional condition, as stated for maize and wheat [4], [9] (Erenoglu *et al.,* 2002; Grzebisz *et al.,* 2008). Reasons for effectiveness of foliar spray are simple due to its direct application to the leaves [1] (Baloch *et al.,* 2008).

However, micronutrients can be applied directly into the soil as well. Soil applied Zn is effective in enhancing the grain yield whereas Zn concentration in grain improves via foliar spray of Zn fertilizer. Based on particular studies, [18] Mortvedt *et al.* (1991) is of the view that soil and foliar applications of zinc enhances the yield of crops whereas [30] Yilmaz *et al.* (1998) have also concluded that increased Zn uptake and accumulation in crop grain has been found with both of the soil and foliar application.

Keeping in view the systematic studies on zinc application methods and different potentials of maize cultivars to take up zinc, a study was conducted in order to assess the growth response and yield potential of maize hybrids under varying levels of zinc application and to find out appropriate stage of zinc application.

2. Materials and Methods

The study to assess the performance of four methods of Zn application i.e Control (no Zn application) (Zn_0), Soil application at sowing @ 12 kg ha^{-1}(Zn_1), Foliar application at vegetative phase (9 leaf stage) @ 1% $ZnSO_4$ solution (Zn_2) and Foliar application at reproductive phase (anthesis) @ 1% $ZnSO_4$ solution (Zn_3), on three different hybrid varieties of maize namely Pioneer-32 F 10 (H_1), Monsanto-6525 (H_2) and Hycorn-8288 (H_3) was conducted at Agronomic Research Area, University of Agriculture, Faisalabad (184 meters elevation, 31º N latitude and 73º longitude) during 2011-2012. Soil samples were collected before sowing and after harvest of maize from experimental area in order to have a view of physico-chemical properties of soil with special reference to zinc (Table 1 & 2). The electrical conductivity (EC) of soil samples were measured by digital Equiptronics conductivity meter, Nitrogen (N) and Phosphorus (P) were estimated by using spectrophotometer, Potassium (K) in the soil was determined by flame photometer with K-filter. Total Zinc in soils were determined by HF-HCl dissolution method [19].

The experiment was laid out in randomized complete block design (RCBD) with factorial arrangements having three replications with net plot size of 2.8 m ×5 m. Maize hybrids (viz. Pioneer-32 F 10, Monsanto-6525 and Hycorn-8288) were sown on 4th February, 2011 as spring crop. Sowing was done with the help of single row hand drill at 70 cm spaced rows using seed rate of 30 kg ha^{-1}. Fertilizers at the rate of 250 and 125 kg ha^{-1}N and P_2O_5 respectively were applied. All of phosphorous and half of the nitrogen were applied at the time of sowing in the form of DAP (Diammonium Phosphate) and Urea while remaining half of nitrogen was applied in two splits i.e at five leaf stage and other at tasseling stage. $ZnSO_4$ solution of 1% was prepared from 21% Zinc sulphate salt. Foliar spray of 1% $ZnSO_4$ was applied as per treatment and soil application of $ZnSO_4$ @ 12 kg ha^{-1} was accomplished at the time of sowing.

Table 1. Soil physical and chemical analysis before sowing the crop

Soil Properties	Value	Status
Soil Texture	-	Clay loam
Soil pH	8.2	Alkaline
EC (dSm^{-1})	0.27	Normal
OM (%)	0.73	Low
Total N (%)	0.0457	Low
Total P (mg/kg)	4.5	Very low
Total K (mg/kg)	174.5	Sufficient
Total Zn (mg/kg)	0.65	Deficient

Subsequent irrigations were applied, whenever needed to the crop. Thinning was done at 3-4 leaf stage in order to maintain plant to plant distance of 20 cm. Crop was kept weed free and insect pest were also controlled with proper application of chemicals. The crop was harvested manually after its maturity on 24th of June 2011 and data collected was analyzed statistically by using Fisher's Analysis of Variance Technique and least significant difference (LSD) test at 5% probability level was applied to compare the treatments' means [25] (Steel *et al.*, 1997) using the computer statistical program MSTAT-C.

Table 2. Soil chemical analysis for nutrient concentration and organic matter percentage after harvest of the crop

Treatments	pH	EC (dSm^{-1})	OM (%)	Total N (%)	Total P (mg/kg)	Total K (mg/kg)	Total Zn (mg/kg)
Zn_o H_1	8.1	1.43	0.67	0.044	4.1	176.6	0.56
Zn_o H_2	7.7	1.33	0.68	0.046	4.3	175.8	0.64
Zn_o H_3	8.2	1.48	0.72	0.048	4.8	171.5	0.59
Zn_1 H_1	8.0	1.34	0.71	0.042	4.5	165.4	0.67
Zn_1 H_2	7.9	1.42	0.68	0.046	4.0	171.8	0.67
Zn_1 H_3	8.2	1.51	0.61	0.045	4.3	169.2	0.65
Zn_2 H_1	7.9	1.40	0.62	0.043	4.1	168.3	0.61
Zn_2 H_2	8.3	1.23	0.66	0.041	5.1	169.4	0.64
Zn_2 H_3	7.7	1.51	0.73	0.046	4.6	157.6	0.61
Zn_3 H_1	8.1	1.22	0.65	0.045	4.2	167.0	0.58
Zn_3 H_2	8.2	1.32	0.68	0.046	4.1	174.5	0.65
Zn_3 H_3	7.9	1.38	0.69	0.046	4.7	166.6	0.62

3. Results and Discussion

3.1. Plant Height

The data pertaining to effect of $ZnSO_4$ application on different maize hybrids (Table 3) revealed that there was significant difference in plant height among all the maize hybrids at maturity. Maximum plant height (191.22 cm) was observed in Pioneer-32F 10, followed by Monsanto-6525 (172.29 cm). Hycorn-8288 gained minimum plant height (159.51 cm). Different treatments of $ZnSO_4$ application have no significant difference in the plant height. Interaction between maize hybrids and $ZnSO_4$ treatments was also found non-significant to plant height at maturity.

Growth behavior of the crop plant is reflected by the final height of the plants at maturity. In our study, the results showed that $ZnSO_4$ application exhibited no significant effect on plant height of maize. Our results are in close conformity with those reported by [23] who found that application of zinc had no effect on plant height in rice crop. Our findings are in contradiction with [31] who reported that zinc application methods (soil and foliar) significantly affect the plant height. However, different maize hybrids showed significant difference in plant height at maturity, which could be attributed to the genetic makeup of plant. These results are in accordance with [7] who reported that zinc efficient cultivars of maize significantly differed in plant height. The reason of non-significant effects of $ZnSO_4$ could be attributed to genetic potential of hybrids. Therefore the different hybrids could depict difference in plant height within themselves without having any influence of $ZnSO_4$.

3.2. Number of Plants (m^{-2})

The data pertaining to number of plants (m^{-2}) at final harvest is presented in the Table 4, showed that effect of $ZnSO_4$ application on plant population was also found significant. Maximum number of plants (6.61) was observed under Zn_3 (foliar application at anthesis) which is statistically at par with Zn_2 (foliar application at 9 leaf stage) and Zn_1 (soil application at sowing) have the plant population (6.56) and (6.46) respectively. While minimum plant population (6.36) was observed under Zn_0 where no $ZnSO_4$ was applied. The results showed that foliar application of $ZnSO_4$ increased the plant population per unit area at harvest. Similarly, maize hybrids had significant effect on plant population at harvest. Maximum numbers of plants (6.77) were produced by Pioneer-32F 10 while minimum number of plants (6.06) was observed in Hycorn-8288. The interaction was found non-significant.

Number of plants per unit area is an important trait contributing towards the final grain yield. The results indicated that foliar application of $ZnSO_4$ increased the plant population per unit area at harvest. This increase in plant population might be due to synergistic effect of nitrogen that correlates with Zn foliar application because substantial translocation of zinc takes place from the older leaves to the younger ones during grain development phase. These results confirm the findings of [27] who reported that foliar application of zinc greatly affected plant growth and production. This trend might be due to the ability of Zn to synthesize plant growth regulators such as auxins, which play an important role in cell enlargement and elongation in meristems. The significant effect of different hybrids on plant population per unit area at harvest can be attributed to uniform use of seed in all the hybrids.

Table 3. Effect of $ZnSO_4$ application on the plant height (cm) of maize hybrids. Values represent mean of three replications. Capital letters reflect significant difference ($p<0.05$) between maize hybrids.

Treatment	Zn_o	Zn_1	Zn_2	Zn_3	Mean
Pioneer-32F 10	184.88	194.93	194.66	190.40	191.22 A
Monsanto-6525	172.40	171.96	168.46	176.35	172.29 B
Hycorn-8288	156.21	162.43	152.29	167.10	159.51 C
Mean	171.16	176.44	171.80	177.95	
LSD value for	Hybrid=10.50				

Table 4. Effect of $ZnSO_4$ application on plant population at harvest (m^{-2}) of maize hybrids. Values represent mean of three replications. Capital letters reflect significant difference ($p<0.05$) between maize hybrids and zinc treatments.

Treatment	Zn_o	Zn_1	Zn_2	Zn_3	Mean
Pioneer-32F 10	6.55	6.83	6.86	6.83	6.77 A
Monsanto-6525	6.67	6.55	6.57	6.86	6.66 A
Hycorn-8288	5.86	6.00	6.24	6.14	6.06 B
Mean	6.36 B	6.46 AB	6.56 A	6.61 A	
LSD value for	Hybrid=0.15	Zinc=0.17			

3.3. Grain Rows per Cob

Maize hybrids had significant difference in number of grain rows per cob as evident from (Table 5). All treatments of $ZnSO_4$ application showed non-significant effect on number of grain rows per cob but the effect of hybrids was significant. Maximum numbers of rows (15.47) were observed in Monsanto-6525 whereas the Pioneer-32F 10 (13.37) and Hycorn-8288 (12.35) could not differ within each and another statistically. The interaction between $ZnSO_4$ treatments and different hybrids was found to be non-significant for number of grain rows per cob.

Number of grain rows per cob directly affects the number of grains per cob and ultimately grain yield of maize. The result trends of our study showed that foliar application of $ZnSO_4$ at anthesis produced the maximum number of grains per cob. The significant influence of $ZnSO_4$ in increasing the number of grains per cob is different in different maize hybrids, which might be due to fact that it activates several plant enzymes that are involved in carbohydrate metabolism, protein synthesis and pollen formation differently in different maize hybrids [8].

3.4. Grains per Cob

The data presented in (Table 6) clearly depicts that the interaction between $ZnSO_4$ treatments and maize hybrids for the number of grains per cob was found to be significant. Maximum number of grains per cob (506.22) was noted with foliar spray of $ZnSO_4$ at anthesis (Zn_3) in case of Monsanto-6525, which was however statistically at par with same foliar spray in case of Pioneer-32F10 where 396.05 numbers of grains per cob were produced. Moreover, individual effects of $ZnSO_4$ application and hybrids were also found significant.

The number of grains per cob was however considered as a most sensitive element of maize yield structure to environmental influences. Application of $ZnSO_4$ significantly increased the number of grain per cob in all treatments. These results are in accordance with the findings of [31] who reported that soil application of zinc significantly increased the number of grains per cob. The conclusions drawn by [10], [25], [13] and [29] are also in agreement with the results of our study.

3.5. 1000-grain Weight

Although different treatments of $ZnSO_4$ have no significant effect on 1000-grain weight. However, (Table 7) revealed that different hybrids had significant effect on 1000-grain weight. The data showed that Pioneer-32 F10 produced significantly more 1000-grain weight (280.78 g), which was statistically at par with Hycorn-8288 (280.42 g). While minimum 1000-grain weight (258.88 g) was attained by the H_2 (Monsanto-6525). The interaction between $ZnSO_4$ treatments and hybrid was also found to be non-significant for 1000-grain weight.

Table 5. Effect of $ZnSO_4$ application on number of grain rows per cob of maize hybrids. Values represent mean of three replications. Capital letters reflect significant difference ($p<0.05$) between maize hybrids.

Treatment	Zn_o	Zn_1	Zn_2	Zn_3	Mean
Pioneer-32F 10	12.67	13.44	13.86	13.53	13.37 B
Monsanto-6525	16.11	14.97	15.89	14.89	15.47 A
Hycorn-8288	11.78	12.33	11.94	13.33	12.35 B
Mean	13.52	13.58	13.90	13.92	
LSD value for	Hybrid=1.32				

Table 6. Effect of $ZnSO_4$ application on number of grains per cob of maize hybrids. Values represent mean of three replications. Capital letters reflect significant difference ($p<0.05$) between maize hybrids and zinc treatments. The small letter shows significant difference ($p<0.05$) between interactions of hybrids and zinc treatments.

Treatment	Zn_o	Zn_1	Zn_2	Zn_3	Mean
Pioneer-32F 10	277.53 de	431.44 ab	380.58 bcd	396.05 abc	371.40 B
Monsanto-6525	498.11 a	483.89 ab	482.00 ab	506.22 a	492.56 A
Hycorn-8288	196.56 e	286.22 cde	248.86 e	307.00 cde	259.66 C
Mean	324.06 B	400.52 A	370.48 AB	403.09 A	
LSD value for	Hybrid = 56.6	Zinc = 65.4	H×Z =113.2		

Table 7. Effect of $ZnSO_4$ application on 1000-grain weight (g) of maize hybrids. Values represent mean of three replications. Capital letters reflect significant difference ($p<0.05$) between maize hybrids.

Treatment	Zn_o	Zn_1	Zn_2	Zn_3	Mean
Pioneer-32F 10	276.67	292.50	263.47	290.50	280.78 A
Monsanto-6525	253.00	256.33	257.50	268.67	258.88 B
Hycorn-8288	269.00	291.50	274.67	286.50	280.42 A
Mean	266.22	280.11	265.21	281.89	
LSD value for	Hybrid=16.32				

The yield potential of any variety is always determined by the mean grain weight and this trait is the most important yield-contributing factor for deciding the potential of maize hybrids. The trend of 1000-grain weight opposes to the rank established for number of grains per cobs (Table 6) in different maize cultivars. Data presented in Table 7 showed that the Pioneer-32 F10 and Hycorn-8288 hybrids although remained statistically at par but produced significantly higher 1000-grain weight as compared to Monsanto-6525. However, the $ZnSO_4$ application could not depict any influence on 1000-grain weight. Furthermore, this yield factor shows slightly stronger dependence on number of grains status under each zinc application treatment than genetic variation. Our results are in close agreement with those reported by [14] that zinc had no significant effect on thousand-grain weight in maize. However, these results are opposite to the findings of [28] who reported that yield-contributing components of maize were significantly increased by the application of zinc.

3.6. Biological Yield

The interaction between $ZnSO_4$ and hybrids was found to be significant for biological yield as depicted in (Table 8). Foliar spray of $ZnSO_4$ at anthesis stage (Zn_3) produced maximum biological yield (21.48 t ha^{-1}) in case of Pioneer-32 F10 while the control plots (Zn_0) produced the minimum biological yield (9.25 t ha^{-1}) in Hycorn-8288. Interestingly, various $ZnSO_4$ treatments and the hybrids also showed significant results in producing biological yield.

Biological yield indicates the relative growth rate of plants as considered to net assimilation rate. Our study demonstrated that foliar spray of $ZnSO_4$ at anthesis produced the maximum biological yield in case of Pioneer-32 F10 hybrid. The better influence of foliar spray especially at anthesis stage might be due to Zn action in pollen formation. These results are in line with the findings of [16] and [12] who also claimed that foliar application of micronutrients is more efficient method as compare to ground fertilization and zinc should be applied as foliar spray to maize plant grown in zinc deficient soils; otherwise zinc deficiency would reduce the water use efficiency and ultimately the total yield of crop, as application of zinc increased the vegetative growth that increase the water use efficiency. But its effects are opposite on harvest index (Table 10).

3.7. Grain Yield

Similarly, the interaction between $ZnSO_4$ treatments and hybrids was also found significant for grain yield (Table 9) where maximum grain yield (8.76t ha^{-1}) was obtained with foliar spray of $ZnSO_4$ at 9 leaf stage (Zn_2) in case of Monsanto-6525 and it differed significantly with other hybrids. Furthermore, the study demonstrated that grain yield in different $ZnSO_4$ treatments and maize hybrids individually, were also found significant.

Grain yield is an ultimate end product of many yield-contributing components, physiological and morphological processes taking place in plants during growth and development. Maximum grain yield was obtained with foliar spray of $ZnSO_4$ at 9 leaf stage in case of Monsanto-6525 which can be attributed to the maximum number of grain rows per cob, number of grains per cob and grain weight per cob. Zinc is an important micronutrient needed by the maize plant and its deficiency especially during the grain filling stage reduces the grain yield and efficiency of plants [15]. The results are also in agreement with the findings of [20] who reported that foliar application of $ZnSO_4$ at 5-leaf stage significantly increased the grain yield of maize hybrid. These results are also in consonance with those reported by [9] who showed that foliar application of $ZnSO_4$ is better to increase the grain yield of maize hybrids.

Table 8. Effect of $ZnSO_4$ application on biological yield (t ha^{-1}) of maize hybrids. Values represent mean of three replications. Capital letters reflect significant difference ($p<0.05$) between maize hybrids and zinc treatments. The small letter shows significant difference ($p<0.05$) between interactions of hybrids and zinc treatments.

Treatment	Zn_o	Zn_1	Zn_2	Zn_3	Mean
Pioneer-32F 10	13.33 cd	16.10 b	17.24 b	21.48 a	17.04 A
Monsanto-6525	13.19 cde	13.52 c	11.19 def	16.17 b	13.52 B
Hycorn-8288	9.25 f	9.82 f	11.10 ef	9.78 f	9.99 C
Mean	11.92 B	13.15 B	13.18 B	15.81 A	
LSD value for	Hybrid = 1.1	Zinc = 1.27	H×Z = 2.2		

Table 9. Effect of $ZnSO_4$ application on grain yield (t ha^{-1}) of maize hybrids. Values represent mean of three replications. Capital letters reflect significant difference ($p<0.05$) between maize hybrids and zinc treatments. The small letter shows significant difference ($p<0.05$) between interactions of hybrids and zinc treatments.

Treatment	Zn_o	Zn_1	Zn_2	Zn_3	Mean
Pioneer-32F 10	4.63 f	6.94 d	7.60 bc	6.02 e	6.30 B
Monsanto-6525	6.72 d	7.29 c	8.76 a	7.95 b	7.68 A
Hycorn-8288	3.72 g	4.40 f	4.50 f	3.79 g	4.10 C
Mean	5.02 D	6.21 B	6.96 A	5.92 C	
LSD value for	Hybrid =0.17	Zinc = 0.20	H×Z = 0.35		

Table 10. Effect of $ZnSO_4$ application on harvest index (%) of maize hybrids. Values represent mean of three replications. Capital letters reflect significant difference ($p<0.05$) between maize hybrids and zinc treatments. The small letter shows significant difference ($p<0.05$) between interactions of hybrids and zinc treatments.

Treatment	Zn_o	Zn_1	Zn_2	Zn_3	Mean
Pioneer-32F 10	36.21 f	43.52 def	44.24 cde	28.28 g	38.06 B
Monsanto-6525	51.27 bc	54.03 b	78.37 a	49.19 bcd	58.52 A
Hycorn-8288	40.22 ef	44.82 cde	41.09 ef	38.80 ef	41.23 B
Mean	42.57 C	47.45 B	54.57 A	38.76 C	
LSD value for	Hybrid = 3.73	Zinc = 4.31	H×Z = 7.47		

3.8. Harvest Index

The interactive effects of $ZnSO_4$ treatments and maize hybrids were found significant for harvest index (Table 10). Zn_2 treatment i.e. foliar spray of $ZnSO_4$ at 9-leaf stage produced maximum value of harvest index (78.37%) in Monsanto-6525. While Zn_3 i.e. foliar spray of $ZnSO_4$ at anthesis gave the minimum value of harvest index (28.28%) in Pioneer-32 F10 hybrid. Statistically, the different maize hybrids showed significant difference in harvest index. Similar trend was also observed in harvest index, while considering different $ZnSO_4$ treatments.

Harvest index shows the physiological efficiency of plants to convert the fraction of photo-assimilates to grain yield. Obviously higher the harvest index is, greater will be the grain yield of crop. Maximum value of harvest index (78.37%) in case of Monsanto-6525 was obtained when $ZnSO_4$ was applied at 9 leaf stage. The results advocated that foliar application of $ZnSO_4$ at 9 leaf stage increased the proportion of grain yield in Monsanto hybrid while, in Pioneer-32 F10 and Hycorn-8288 soil application of $ZnSO_4$ gave maximum harvest index. The observed trend suggest seemingly higher response of maize vegetative organs as compare to reproductive organs to foliar application of $ZnSO_4$.

4. Conclusions

The experimental results indicated that Monsanto-6525 and Pioneer-32F 10 produced 80% and 50% higher grain yield, respectively than Hycorn-8288 hybrid. Moreover, foliar application of $ZnSO_4$ at 9-leaf (vegetative stage) gave 12% more grain yield than soil applied and 38% higher than control. Consequently, type of maize cultivars, method and time of zinc fertilization have strong influence on maize yield and yielding components. Foliar application of zinc fertilizer at reproductive stage has lower influence on maize grains yield as compare to early foliar application at vegetative stage or soil application.

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