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Effect of different methods of zinc application on maize (*Zea mays* L.)

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Abstract

The present study was conducted at new developmental research farm of The University of Agriculture Peshawar-Pakistan. The aim of study was to find out impact of different methods of zinc (Zn) application to maize crop. The experiment was laid out in Randomized complete block (RCB) design replicated three times. In this experiment zinc was applied by two methods, soil, foliar and their combinations. Zinc at the rate of 5.0 and 2.5 kg ha^{-1} was applied in soil during sowing time while during silking stage two levels 1.0 and 0.5 kg Zn ha^{-1} was supplied as foliar application. Zinc in the form of zinc sulfate was applied in all methods whereas basal dose of nitrogen, phosphorus and potassium was applied at the rate of 120, 90 and 60 kg ha^{-1} respectively. The consequences after data collection showed that days to emergence were not affected significantly. The application of zinc via soil and foliar i.e. 5.0 and 0.5 kg ha^{-1} respectively significantly increased the ear length and ear weight. In the same way treatment combination 5.0 soil and 0.5 foliar kg Zn ha^{-1} increased grain and biological yield. The increasing Zn rates also enhanced thousand grain weight and number of grains per ear in a significant manner. Zn concentration and uptake of zinc by plant were non-significant. It was concluded from the results that application of Zn via soil and foliar combination increased growth rate and maize yield.

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Introduction

Maize (*Zea mays* L.) is a member of family Gramineae and is one of the most important cereal crop (Tollenat and Lee, 2002). Maize is one of the prominent cereal crop throughout the world and its total yield is more as compared to other cereal crops (FAO, 2011). It is also important regarding its nutritional value for humans, poultry and livestock (Nuss and Tanumihardjo, 2010). The grain yield production of maize in Pakistan is less than other regions. In this region the minimum yield is due to poor supply of water and nutrients not for cultivars response, because Pakistani soils are mostly calcareous and alkaline in reaction, less in organic matter and lacking or low in primary and secondary elements, specifically zinc (Zn) and the availability of Zn to crops is accustomed by these characteristics of soils (Sillanpaa, 1982).

Zn plays a vital role in plants integral system such as it plays roles in nitrogen metabolism and results in improving protein quality, it also plays a major role in protein synthesis and photosynthesis (Cakmak, 2008). Zinc is performing an important role in metabolic processes of plants (Rout and Das, 2003). Furthermore, Zn also concerned in formation of chlorophyll and also maximize the biosynthesis of carotenoids, chlorophyll and ultimately helpful for the photosynthetic mechanism of the plant. (Aravind and Prasad, 2003).

Maize is the most vulnerable crop to zinc deficiency. In the last decades Zn deficiency in soil crop system has been widely reported (Fageria *et al.,* 2002). Throughout the world it has been observed that zinc application increased grain yield (Harris *et al.,* 2007; Hossain *et al* 2008; Potarzycki and Grzebisz, 2009). The Zn fertilizers application increased maize production in China (Zou *et al.,* 2008). Maize was recognized by farmers as a crop of maximum output to Zn supply (Leach and Hameleers, 2011; Subedi and Ma, 2009).

Zinc deficit is a chief worldwide problem damaging cultivation of plant, and this difficulty is due to exacerbated in alkaline soils these soil types are mostly found in semi-arid and arid parts of the world (Cakmak, 2000).

Various technique of Zn applying to crops such as soil, foliar sprays and seed treated with Zn dusting, fertigation seed priming in nutrient solution and root dipping in the nutrient solution etc. Amongst these methods foliar spray of Zn is efficient technique. (Wilhelm *et al.*, 1988; Savithri *et al.*, 1999) and recently reported that foliar application is a uncomplicated method for quick improvement of plant nutritional status, of maize (Erenoglu *et al.*, 2002) and wheat (Grzebisz *et al.,* 2008) and the advantage of foliar supplementing of Zn, Mn, Cu, Fe and B, which contain rapid competence, rapid plant response, easy and taking away toxicity symptoms was due to accumulation of such nutrients to the soil have moreover been noted by Rimar *et al.,* (1996). Deficiency of Zn in wheat has been reported from various parts of the world, Pakistan soils are not exception to this. Almost 50% soil of the world which used for cereal production are Zn deficient (Gibbson, 2006). The quality of edible parts of plant and yield can be improve by Zn fertilizers.

Furthermore Zn uptake and utilization can be improve by applying different methods of application. Among the various techniques of application, the foliar methods of Zn is effective to increase crop production (Savithri *et al.,* 1999). This approach of nutrient supply is an easy and simple way to improve nutrients in plants (Erenoglu *et al.,* 2002; Grzebisz *et al.,* 2008) as reported in maize and wheat crop. The foliar spray is most effective because it directly apply on plant leaves (Baloch *et al.,* 2008). Foliar treatment is one of the essential technique of Zn fertilizer application. One of the study conducted by Thalooth *et al.*, (2006) reported that foliar application of Zn significantly enhanced all growth parameters of mung bean in Egypt. Leach and Hameleers, (2011) observed that Zn application increased starch percent in maize during harvest and increased the Zn concentration in grain twice (Peck *et al.,* 2008).

On the other hand micronutrients including Zn can also be apply via soil. Zn application in soil is effective in increasing the grain yield while foliar spray improves Zn accumulation in grains (Ehsanullah *et al.,* 2015).

The application of Zn via soil and foliar method increases crop yield (Mortvedt *et al.,* 1991). Both the soil and foliar application enhanced Zn concentration and uptake in crop grain (Yilmaz *et al.,* 1998). Khan *et al.,* (2006) stated application of mineral fertilizer enhanced Zn concentration in leaf, straw and grain of wheat crop. In addition to this crop growth and yield also affected by application methods of micronutrients. Malakouti, (2008) reported that quality and yield of crops is improved by soil and or foliar application of micronutrients.

Foliar application of micronutrients during tillering and booting phase may enhanced wheat yield (Arif *et al.,* 2006) whereas application of mineral fertilizers can increased Zn, Cu, Fe, and Mn accumulation in leaf, straw and grain of crop. The present study was carried out with the main objective of evaluating the most effective method of Zn application in order to gain maximum yield and to evaluate Zn uptake by maize crop.

Materials and methods

The present work was conducted at new developmental research farm, The University of Agriculture Peshawar, Pakistan in order to find out the effect of different methods of Zn application on maize crop. The experiment was carried out in RCB design with three replications.

The plot size was 5 x 3, plant to plant distance 20 cm and row to row distance was 70 cm. Maize seeds were sown with the help of drill. In the experiment Zn application was done by two methods i.e. soil application, foliar application and their combination. Zn in the form of zinc sulfate was used in all the treatments while basal dose of NPK 120, 90 and 60 kg ha^{-1} respectively were applied. Irrigation was regularly applied and all the cultural practices including weeding, thinning and hoeing were performed.

Table 1. The treatments applied in the following rates.

T_1	Control
	Soil Application
T_2	2.5 Kg Zn ha^{-1}
T_3	5.0 Kg Zn ha^{-1}
	Foliar Application
T_4	0.5 Kg Zn ha^{-1}
T_5	1.0 Kg Zn ha^{-1}
	Combinations
T_6	2.5 soil + 0.5 foliar (Kg Zn ha^{-1})
T_7	2.5 soil + 1.0 foliar (Kg Zn ha^{-1})
T_8	5.0 soil + 0.5 foliar (Kg Zn ha^{-1})
T_9	5.0 soil + 1.0 foliar (Kg Zn ha^{-1})

The following parameters were recorded during the field and laboratory investigations:-

- Days to emergence
- Ear length (cm)
- Ear weight (g)
- Grains ear^{-1}
- Thousand grains weight (g)
- Biological yield (kg ha^{-1})
- Grain yield (kg ha^{-1})
- Zinc concentration in plant (µg g^{-1})
- Zinc uptake by plant (g ha^{-1})

Plant Analysis

A leaf adjacent to the ear of the plant was taken from randomly selected plants in central two rows of each treatment plant for plant analysis. The samples oven dried at 70°C for 48 hrs and crushed electrical grinder and sieved. Samples were stored in polythene bags for nutrient analysis. Zinc in maize was determined in digested sample using Atomic absorption spectrophotometer (Perkin Elmer, 2380). In wet digestion 1g of plant sample was taken in a pyrex flask, 10mL of concentrated HNO_3 was added, kept overnight and then 4mL of concentrated $HCLO_4$ was added. The sample was digested on a plate and was filtered through Whatman 42 filter paper in to a 50mL flask (Walsh and Beaton, 1977).

Statistical Analysis

The data was statistically analyzed using analysis of variance appropriate for RCB design and the means was compared using LSD test at 0.05 significance level of probability (Steel and Terrie, 1984).

Results and discussions

A farm trail "Effect of different methods of Zinc application in maize" was carried out in new developmental research farm of the University of Agriculture, Peshawar, Pakistan in 2012.

Before conducting experiment different soil physico-chemical characteristics were determined. For this purpose soil samples from the depth of 0-15 and 15-30 cm were randomly collected from the field (Table 1).

Table 2. Physico-chemical properties of pre sowing soil.

Soil properties	Unit	Values
Sand	%	12.51
Clay	%	11.49
Silt	%	76.00
Soil texture	-	Silt loam
$pH_{(1:5)}$	-	8.40
$EC_{(1:5)}$	dSm^{-1}	0.21
Organic matter	%	0.67
AB-DTPA extractable Zn	mg kg^{-1}	0.90

Days to emergence

The results for days to emergence of maize are presented in (Fig. 1). Results showed days to emergence was non significantly affected by methods of Zn application. The treatments which received 5 kg Zn ha^{-1} took 6 days to emergence. The average days to emergence was 5.5.

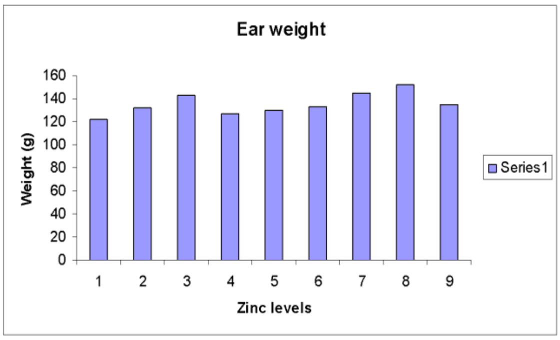

Fig. 1. Effect of different methods and levels of Zn application on Days to emergence of maize.

Ear length

The results regarding ear length showed that methods of Zn application significantly affecting ear length. The maximum ear length 22.07 cm was obtained from treatment combination 5.0 soil + 0.5 foliar whereas minimum ear length 14.17 cm noted in control. Soil application of Zn 5 kg ha^{-1} found to be significant while foliar Zn application 1.0 kg ha^{-1} was non-significant as compared to control. The highest ear length was noticed in treatment interaction (soil + foliar) than soil and foliar alone.

These results are similar with Lonov and lonovo, (1977) who conducted experiment on rice and stated that application of Zn promoted growth and panicle length.

Ear weight

The data of ear weight presented in Fig. 2 & 3. The results exhibited that ear weight was significantly affected by Zn application techniques. The highest ear weight 152 g was detected in treatment interaction (5.0 soil + 0.5 foliar) while lowest ear weight 122 g was noticed in control. The application of Zn in soil 5 kg ha^{-1} showed maximum ear weight than foliar application 1.0 kg ha^{-1}. Similar findings were reported by Khasragi and Yarnia, (2014) who noticed greater ear weight by using Zn soil and foliar way. The increased in ear weight was due to Zn soil and foliar supply (Drissi *et al.,* 2015).

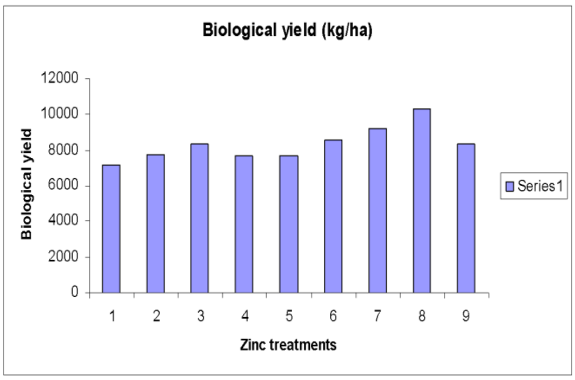

Fig. 2. Effect of different methods and levels of Zn application on biological yield.

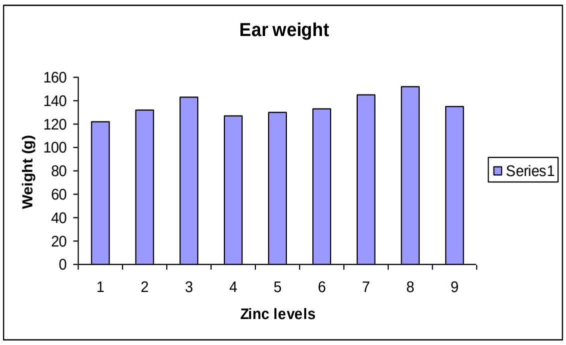

Fig. 3. Effect of different methods and levels of Zn application on ear weight.

Grains ear-1

The results for number of grains per ear are shown in Fig. 4. The findings showed that number of grains per ear was significantly affected by Zn fertilization. The maximum grains per ear 445.3 was obtained from treatment interactions (5.0 soil + 0.5 foliar) whereas minimum grains per ear was found in control. Zn applied by soil application yield maximum number of grains than foliar spray. This might be due to increase in Zn rate which results in sufficient uptake and availability of Zn to plants (Umar *et al.* 2005). The number of grains per cob in all the treatments were increased by Zn application in the form of $ZnSO_4$ (Ehsanullah *et al.,* 2015). These findings are smililar with results of Zeb and Arif, (2008) who observed that number of grains per cob were significantly enhanced by soil application of Zn. Other studies conducted by Shaaban, (2001) and Kassab, (2005) also found that Zn application increased number of grains per ear.

Thousand grains weight

Data concerning thousand grains weight are presented in Fig. 5. The results exhibited that thousands grain weight was significantly affected by Zn application. Highest value of thousand grains weight was noted in Zn treatments (5.0 soil + 0.5 foliar) whilst lowest value was recorded from control. Zn applied by soil application gave greater value for thousand grain weight as compared to foliar. The maximum thousand grain weight found was due to increase in Zn fertilizer because Zn stimulates metabolic processes in seed (Umar *et al.,* 2005).

These results are similar with the findings of Ziaeryan and Rajaie, (2009) that thousand grain weight in maize was increased by Zn application via soil. Same reports were also reported by Yilmaz *et al.,* (1997) Zn application increased thousand grain weight in wheat plant.

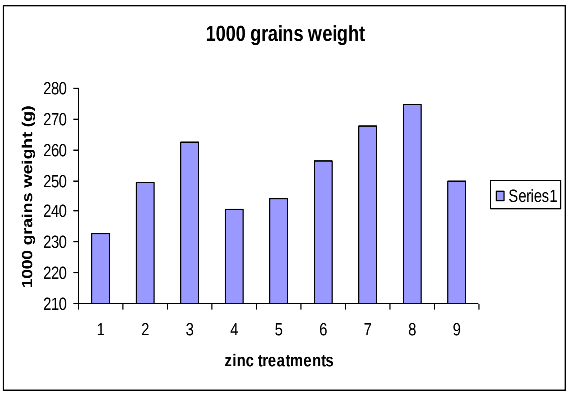

Fig. 4. Effect of different methods and levels of Zn application on 1000 grains weight.

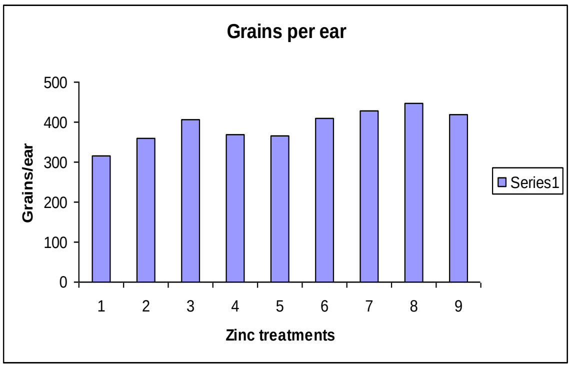

Fig. 5. Effect of different methods and levels of Zn application on grains per ear.

Biological yield

Biological yield of maize as shown in Fig. 6. The data exhibited that methods of Zn application significantly affected biological yield. The treatment interaction 5.0 soil + 0.5 foliar resulted in maximum biological yield 10330 kg ha-1. While lowest biological yield was obtained from control. Data showed that all the treatment means were significantly varied from each other. Furthermore Zn application via soil resulted in greater biological yield as compared to foliar application. Similar findings are reported by Wisal *et al.,* (1990) that Zn applied by soil application significantly enhanced biological yield in wheat and rice than control respectively.

Grain yield

The grain yield of maize as presented in Fig. 7 showed that grain yield was significantly affected by Zn application methods. The maximum grain yield was obtained from treatment interaction 5.0 soil + 0.5 foliar whereas minimum grain yield was noticed in control (1753 kg ha^{-1}). These results are in accordance with Yilmaz *et al.,* (1997) who observed that Zn application via soil was better fertilization technique than applied through foliar. Similar results were reported by Shah *et al.,* (1985) and Rehman and Barnard, (1988) who obtained maximum yield in lentil and maize by application of Zn 5 kg ha^{-1} as compared to control. Moreover the nutrient quantity and plant production depend on quantity and the association between zinc and boron which effect positively on crop yield (Aref, 2007).

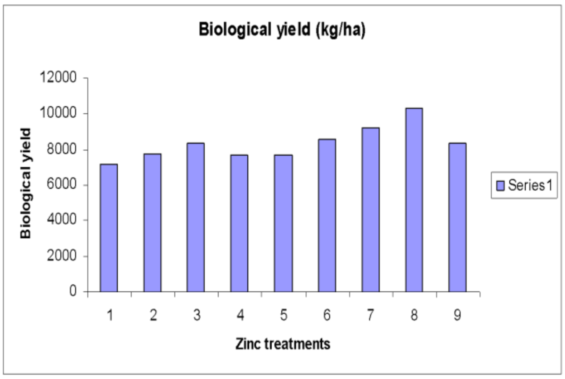

Fig. 6. Effect of different methods and levels of Zn application on biological yield.

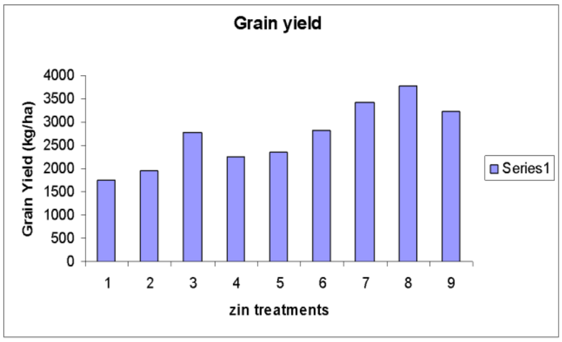

Fig. 7. Effect of different methods and levels of Zn application on grain yield.

Zinc concentration in plant

The results regarding Zn concentration in crop is presented in Fig. 8. The consequences showed that Zn application via soil and foliar treatment did not significantly affected Zn accumulation in plant. The interaction of soil and foliar treatments also non-significant to Zn Concentration in plant.

The highest accumulation of Zn 27.033 µg g^{-1} was recorded in T_7 (2.5 soil + 1.0 foliar) and lowest was noted in T_4 25.76 µg g^{-1} while 27.207 µg g^{-1} was observed in control. Zhang *et al.* (2013) found that during experiment there was a great variation of Zn content in shoot. The new studies carried out by Harris *et al.,* (2007) and Hossain *et al.,* (2008) reported that Zn concentration in plants can increased by Zn application either by soil or seed priming method. Zn is not being hyper accumulated by maize might be due to poor ability of maize roots to take up Zn from high Zn concentration (Zhang *et al.,* 2013). Due to poor mobility of inorganic Zn fertilizers in soil and response of maize root to Zn it was supposed that this variation of Zn accumulation occurred in all treatments. The root surface area and availability of Zn in soil are important for Zn uptake by plants (Genc *et al.,* 2007; Lindsay and Norvell, 1978).

Zinc uptake by plant

The results for Zn uptake by plants (Fig. 9) showed that all the treatments found to be non-significantly different at 5 % level of probability. The highest uptake of Zn 0.698 g ha^{-1} was noticed in T_3 (5.0 Kg soil Zn ha^{-1}) whereas lowest Zn uptake 0.260 g ha^{-1} was recorded in control.

Therefore application of Zn in soil layer 0-30 cm or 0-15 cm by foliar spray or broadcasting method and then incorporating into plow layer through field preparation may improve distribution to roots as a result Zn uptake by roots increased and thus enhanced its accumulation in shoots (Zhang *et al.,* 2013). These findings are in accordance with Zhang *et al.,* (2013) reported that Zn application can increased Zn uptake by plants. These results are also confirm by Harris *et al.,* (2007) and Hossain *et al.,* (2008) that Zn application through soil can increases Zn uptake by plants as compared to control. In wheat crop Zn application caused to increased Zn uptake (Cakmak, 2008).

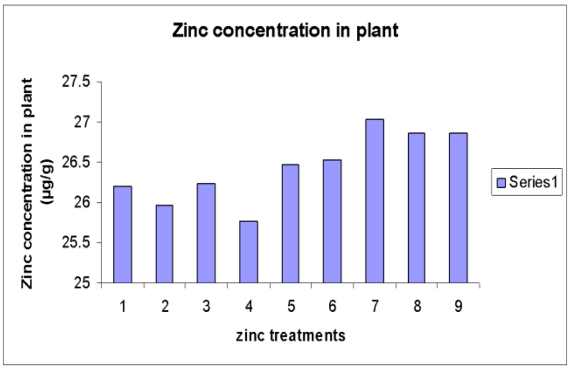

Fig. 8. Effect of different methods and levels of Zn application on zinc concentration on plant.

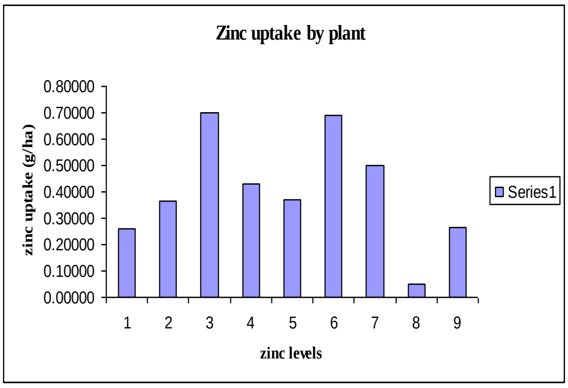

Fig. 9. Effect of different methods and levels of Zn application on zinc uptake by plant.

Zn concentration in surface soil

The outcomes of Zn accumulation and allocation in surface soil as presented in Table 3 showed a significant effect at the depth of 0-15 cm during post-harvest stage.

All the treatment indicated that there was increased Zn concentration at surface soil. The highest value of Zn concentration 0.7230 mg kg^{-1} was observed in treatment interaction 5.0 soil + 1.0 foliar kg Zn ha^{-1} while lowest value was noticed in control. This might be due the fact that maize roots are mostly spread throughout the topsoil layers. About 90 % of maize roots were recuperated in topsoil layers (Dwyer *et al.,* 1996). Approximately half of the maize roots recuperated from soil layers of 0-15 cm (Peng *et al.,* 2010).

Zn concentration in subsurface soil

The accumulation of Zn in subsoil surface showed a significant effect on Zn application. The maximum accumulation 0.847 mg kg^{-1} was noted in T_5 (1.0 Kg Zn ha^{-1}) whereas minimum accumulation was detected in T_3 (5.0 Kg Zn ha^{-1}). Application of zinc sulfate fertilizers in soil increased soil exchangeable Zn (Sims, 1986).

Furthermore 58 to 60 % Zn application to soil in the form of zinc sulfate converted into carbonate form of Zn (Yasrebi *et al.,* 1994). The variation in different treatments was due to application of larger quantity of Zn which increases Zn concentration in soil as compared to control (Aref, 2007). The increased in Zn content in soil was due to availability of total Zn which was released by roots in the form of available Zn (Sarkar and Deb, 1985).

Table 3. Effect of different methods and levels of Zn application on soil Zn concentration.

Treatments (Zn kg ha^{-1})	Soil Zn concentration in upper surface (mg kg^{-1})	Soil Zn concentration in sub surface (mg kg^{-1})
T_1 Control	0.2170	0.663
T_2 (2.5 Soil)	0.3170	0.567
T_3 (5.0 Soil)	0.6870	0.460
T_4 (0.5 Foliar)	0.3970	0.610
T_5 (1.0 Foliar)	0.4800	0.847
T_6 (2.5 Soil+0.5 Foliar)	0.5370	0.710
T_7 (2.5 Soil+1.0 Foliar)	0.6030	0.743
T_8 (5.0 Soil+0.5 Foliar)	0.6900	0.493
T_9 (5.0 Soil+1.0 Foliar)	0.7230	0.570
CV %	6.70	34.78
LSD value	0.0316	NS

Conclusions

By keeping in mind the data on yield this can be concluded that combined application of Zn (soil + foliar) is much better than their alone application. Furthermore biological yield, grain yield, ear length, ear weight, 1000 grains weight and grains ear^{-1} were significantly affected by treatment combination of (5.0 soil + 0.5 foliar kg ha^{-1}) Zn in Peshawar Pakistan.

However Zn concentration and uptake were nonsignificantly affected by the application of Zn. Thus there is need to further study about Zn application in maize in sub-humid and rain fed Zn deficient soils. Hence Zn application by soil and or foliar way not only significant for vegetative growth but also improves grain value for human needs.

Recommendations

From this study it is recommended that combine application soil and foliar 5.0 and 0.5 kg Zn ha^{-1} respectively may be better for increasing yield of maize at prevailing conditions. Further research trails should be made to confirm these applications of Zn in different areas of Pakistan.

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