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Comparison of chelated zinc vs mineral zinc on the yield of rice applied through soil and foliar application

Ifra Saleem*, Shahid Javid, Shabana Ehsan, Fareeha Habib and Tahir Majeed

Institute of Soil Chemistry & Environmental Sciences, Ayub Agricultural Research Institute, Faisalabad

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Abstract

Zinc is essential for plants, animals and humans. Zinc deficiency persists in our soils which creates problem in many physiological processes of plants. Presently many chelated Zn compounds are available in the market for foliar application with the claim that these compounds perform better than mineral Zn application. To test this claim a field experiment was conducted for three consecutive years (2009-2011) at Soil Chemistry Section, ISCES, Ayub Agricultural Research Institute Faisalabad on a permanent lay out to compare the efficiency of chelated vs. mineral zinc applied through soil and foliar application. The experiment was laid out according to randomized complete block design with three replications. Three levels of mineral Zn viz. 2.5, 5.0 and 7.5 kg/ha were applied at the time of soil preparation. The foliar application of zinc sulphate and cheated Zn was made @ 0.1, 0.2 and 0.3% solutions at transplanting and at 30 days after transplanting. A control was also kept where no Zn fertilizer was applied. Basal dose of NPK was applied @ 150-90-60 kg/ha. The results showed that rice crop significantly respond to Zn application as expected. The three year pooled data revealed that foliar application of mineral Zn and chelated Zn @ 0.3 %gave statistically similar paddy yields (4.67 and 4.50 t/ha, respectively). The plant analysis at panicle initiation stage showed that Zn concentration in plant significantly improved by foliar application of chelated Zn @ 0.3%. Cost benefit ratio showed that foliar application of 0.3% mineral Zn gave maximum return by spending minimum, however the grain yield was also at par with the foliar application of cheated Zn @ 0.3% and soil application of mineral Zn @ 7.5 kg/ha. It is concluded from the study that 0.3% chelated zinc and 0.3% mineral zinc application produced similar yield but the use of chelated zinc is not economically friendly.

* **Corresponding Author:** Ifra Saleem ✉ ifra_saleem@yahoo.com

Introduction

The Food and Agriculture Organization (FAO) has determined that zinc is the most commonly deficient micronutrient in agricultural soils, with deficiency occurring in one out of every two cases. Zinc is known to have an important role either as a metal component of enzymes or as a functional, structural or regulatory cofactor of a large number of enzymes (Grotz and Guerinot, 2006). Potarzycki and Grzebisz (2009) reported that zinc exerts a great influence on basic plant life processes, such as (i) nitrogen metabolism– uptake of nitrogen and protein quality; (ii) photosynthesis– chlorophyll synthesis, carbon anhydrase activity.

In Pakistan rice is a 2nd major food crop after wheat and zinc deficiency is the most common nutrient constraining the productivity (Rashid, 1996). Rice has been reported more prone to Zn deficiency than upland crops like wheat (Kausar et al., 1976) because flooded soil conditions for the cultivation of rice are usually not favourable for availability of zinc and hence the disorder accentuates (Rahmatullah et al., 1976, Bhatti and Rashid, 1985). . Zinc is an essential nutrient required for proper growth of plants (Hemantharanjan, 1996) and its deficiency is a major micronutrient disorder in alkaline calcareous soils of the Pakistan (Anonymous, 1998) because of availability and high Zn fixation. The concentration of zinc in high pH soils is several times lower than the required range, and it further decreases one hundred times for each increase in the pH value. The exceedingly low zinc concentration resulted in restricted diffusion of zinc to the root surface thereby limiting zinc supply to crops (Chand et al., 1981). Application of high water soluble Zn fertilizers to soils is the most satisfactory way to cure Zn deficiency (Amrani et al., 1997 and 1999). Due to alkaline and calcareous nature of soils in Pakistan, fertilizer zinc is mainly adsorbed by soil and very little is available and recovered by plants (Tahir et al., 1991). Zinc sulphate has traditionally been the "reliable" source of Zn fertilizer but other sources of Zn are also available. True chelates are compounds containing ligands that can combine with a single metal ion (e.g. Zn^{+2}) to form a well defined, relatively stable cyclic structure called a chelation complex (Mortvedt et al., 1999). Some products are called “organic chelates” but are actually organically complexed Zn sources. Organic complexes, sometimes called “organic chelates”, are formed by reacting metallic salts with various organic, industrial by-products (e.g byproducts of the wood pulp industry). The degree of Zn availability in Zn sources made from the various by-products is related to the manufacturing process, the source of complexing or chelating agents (organic sources), and the original product used as the Zn source. Many claims are made regarding relative efficiency of organic vs. inorganic Zn sources. Mortvedt et al. (1999) reported that these products may be less stable in the soil than true chelates and have greater Zn availability than inorganic Zn salts and require lower application rates to satisfy plant needs. Widespread use of such chelates for improving zinc nutrition of field crops, however, has been restricted on account of the economic consideration (Chand et al., 1981).

Foliar application of nutrients has become an efficient way to increase yield and quality of crops (Romemheld and El-Fouly, 1999). In semiarid regions, foliar application of nutrients is a more suitable option compared with soil fertilization as it gives quick compensation of nutrient deficiency.

This study was planned to compare the efficiency of chelated zinc (foliar application) with the mineral Zn fertilizer ($ZnSO_4$) which is commonly used to correct the zinc deficiencies and to compare the economics of both products.

Material and methods

A study was conducted as Randomized Complete Block Design (RCBD) with three replications at research area of Soil Chemistry Section, Institute of Soil Chemistry and Environmental Sciences, Ayub agricultural Research Institute Faisalabad for three consecutive year i. e. 2009, 2010 and 2011. To compare chelated Zn with mineral Zinc, the following treatments were tested.

1. No zinc fertilizer
2. 2.5 kg/ha mineral Zn (soil application, SA)
3. 5.0 kg/ha mineral Zn (soil application, SA)

4. 7.5 kg/ha mineral Zn (soil application, SA)
5. 0.1% mineral Zn (foliar application, FA)
6. 0.2% mineral Zn (foliar application, FA)
7. 0.3% mineral Zn (foliar application, FA)
8. 0.1% chelated Zn (foliar application, FA)
9. 0.2% chelated Zn (foliar application, FA)
10. 0.3% chelated Zn (foliar application, FA)

Soil application was done at the time of soil preparation and foliar application of mineral and chelated Zn at transplanting and at 30 days after transplanting. NPK were applied at 150-90-60 kg ha^{-1} using urea, SSP and MOP as source, respectively. Full dose of P, K and ½ N was applied as basal dose while ½ N was applied at panicle initiation stage. Before transplanting of each rice crop a composite soil sample was collected and analyzed for EC (Mclean, 1982), pH (Mclean, 1982), organic matter (Nelson and Sommers, 1982), phosphorus (Rowell 1994), potassium (Sheldrich and wang, 1993), zinc (Lindsay and Norvell, 1978) and textural class (Sheldrich and wang, 1993). The pooled soil analysis data of the field is given in Table 1. The soil analysis showed that soil was free from all salinity and sodicity hazards. The soil was low in organic matter content having sandy clay loam texture. Phosphorus and potassium analysis indicated that soil had sufficient P and potassium content. After harvesting, at maturity, the paddy yield data were recorded. At panicle initiation stage leaves samples were collected and dried at 70°C till constant weight in an oven and ground in a Wiley micro mill, so to pass through 2mm sieve. The dried ground material (0.5 g) was digested in sulphuric acid, nitric acid and perchloric acid (Rashid, 1986). The digested samples were run on Atomic Absorption Spectrophotometer. A graded series of standards (ranging from 0.5-2.0 ppm) of Zn were prepared and computed Zn value. Statistical analysis was done by using the M-State computer program (Steel and Torrie, 1984). Cost benefit ratio of different treatments was calculated (CIMMYT, 1998).

Table 1. Average fertility status of field used for study

Soil depth (cm)	pH_s	EC_e (dsm^{-1})	O.M (%)	Available P (ppm)	Extractable K (ppm)	Extractable Zn	Textural class
0-15	8.24	1.73	0.83	12.9	233	1.37	Sandy clay loam
SD	0.17	0.57	0.045	1.26	11.55	0.07	

Results and Discussion

Effects of chelated and mineral Zn on the paddy yield of rice (t/ha)

The three year pooled paddy yield data are presented in Figure 1. The results revealed that there is significant increase in grain yield by soil application of mineral Zn fertilizer and foliar application of both chelated and mineral zinc over control. Although the highest paddy yield of 4.67 t/ha was recorded in treatment receiving 0.3% foliar spray of mineral zinc ($ZnSO_4$)but it did not significantly differ from the treatment receiving 0.3% foliar spray of chelated Zn (4.50 t/ha). Minimum paddy yield of 3.13 t/ha was recorded in control which might be due to the non availability of zinc to rice crops. The higher pH value and lower organic matter as well as lower native Zn content might be the reasons of non availability of Zn while the higher paddy yield due to zinc application might be due to combined effect of many yield components. Tisdale et al. (1993), Singh et al. (1996), Maqsood et al. (1999), Rahman et al. (2001), Mehla et al. (2006) also reported similar results.

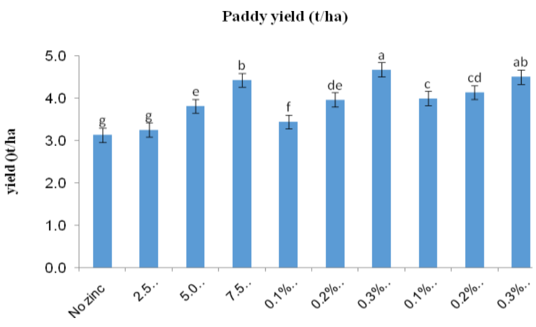

Fig. 1. Effects of chelated and mineral Zn on the paddy yield of rice (t/ha)

Effects of chelated and mineral Zn on the straw yield of rice (t/ha)

The pooled straw yield data is presented in Figure 2. The data showed that the application of zinc fertilizers (chelated and mineral) increased significantly the straw yield over control. The maximum straw yield (12.83 t/ha) was found in treatment receiving soil application of mineral Zn @ 7.5 kg/ha and minimum straw yield (9.63 t/ha) was recorded in control (no zinc). When we compare foliar application of mineral and chelated zinc it was found that foliar application of mineral zinc fertilizer (@ 0.3%) increased the straw yield (12.05 t/ha) more than the treatment receiving chelated zinc at same rate. This increase in straw yield is 25.1% over control with the application of 0.3 % foliar mineral zinc fertilizer while it is 23% over control where we apply chelated Zn @ 0.3%. Application of zinc may influence the favorable effect on the root proliferation and thereby increasing the uptake of plant nutrients and ultimately enhancing the vegetative growth of plants. These results are in agreement with that of Reyes and Brinkman (1983). Srivastava et al. (1999) also obtained similar results.

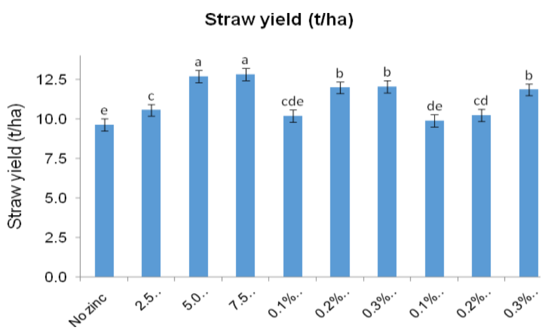

Fig. 2. Effects of chelated and mineral Zn on the straw yield of rice (t/ha)

Effects of chelated and mineral zinc on the Zn concentration of rice leave (ppm)

The three years pooled data regarding the concentration of zinc in rice leaves at panicle initiation stage as influenced by application of Zn (mineral and chelated) and by its of method of application (soil and foliar) is presented in Figure 3. Zinc concentration of leaves was significantly affected by application of Zn over control. The maximum zinc concentration (103.5 ppm) was found in treatment where 0.3% chelated zinc (foliar spray) was applied followed by treatment receiving foliar spray 0.3% mineral zinc (95.8 ppm). The minimum zinc content (42.7 ppm) was found in case of control. Comparing all the treatments receiving zinc it was found that low Zn concentration was found in treatments receiving soil application of Zn fertilizer comparing with the foliar application. The foliar application of chelated Zn compared with the foliar application of mineral Zn revealed that although the concentration of solutions were same but more zinc concentration was found in treatments receiving chelated Zn. Jhonson-Beebout (2008) reported that in rice growing flooded soils zinc fertilizers applied become unavailable so to load grains with zinc, fertilizer application practice changed from soil to foliar application. High pH, low organic matter and rapid adsorption by clay decreased the mobility of zinc so foliar application of fertilizers improved the zinc status of leaves irrespective of these factors (Alloway, 2004, Cakmak, 2008). These vegetative parts than effectively be utilized for remobilization of Zn utilized for deposition of zinc into grains (Kutman et al., 2010). It is reported that there are reduction in leaf size and Zn concentration in leaf due to zinc deficiency (Wutscher, 1979). The foliar application of zinc raised the zinc content of the leaves (Kanwar et al., 1963).

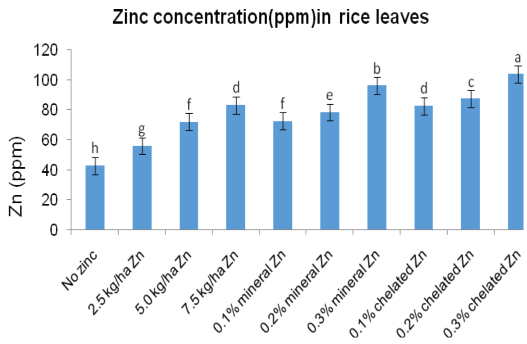

Fig. 3. Effects of chelated and mineral zinc on the Zn concentration of rice leave (ppm)

Cost Benefit Ratio

The performance of all treatments was evaluated through economic analysis. The cost benefit ratio is presented is presented in Table 2. The analysis showed that the highest net price was obtained from foliar spray of 0.3% mineral Zn (48125 rupees) and the lowest one (3750 rupees) was from the soil application of Zn (2.5 kg Zn/ha). The cost benefit ratio indicates that foliar application of 0.3% mineral zinc gave maximum return and also the paddy yield were significantly higher than 0.3% foliar application of chelated Zn. Chand et al. (1981) reported that zinc chelates are quite effective in modifying zinc solubility relationships but widespread use of these chelates for improving zinc nutrition of field crops was not economic friendly. The soil application of mineral Zn @ 7.5 kg/ha not only improved the CBR but also gave statistically more paddy yield than 0.1 and 0.2% foliar application of chelated zinc and statistically similar yield to treatment receiving 0.3% foliar application of chelated zinc.

Table 2. Cost Benefit Ratio.

Treatments	Cost of Zn/ha (Rs.)	Yield (t/ha)	Paddy price (Rs.)	Net price (Rs.)	CBR
No zinc	0	3.13	97812	-	-
2.5 kg/ha Zn	1071	3.25	101562	3750	3.5
5.0 kg/ha Zn	2142	3.81	119062	21250	9.9
7.5 kg/ha Zn	3213	4.42	138125	40313	12.5
0.1% mineral Zn	203	3.44	107500	9688	47.7
0.2% mineral Zn	405	3.96	123750	25938	64.0
0.3% mineral Zn	612	4.67	145937	48125	78.6
0.1% chelated Zn	8740	3.99	124687	26875	1.5
0.2% chelated Zn	17480	4.13	129062	31250	3.6
0.3% chelated Zn	26312	4.50	140625	42813	1.6

Conclusion

The results indicate that there is need for zinc application (soil or foliar) for better paddy yield either as chelated form or as mineral $ZnSO_4$. The foliar application of chelated zinc increased the Zn concentration in leaves as well as paddy yield but not economic friendly as these are very costly. The soil application mineral Zn improved the CBR but its foliar application @ 0.3% gave maximum increase in yield over control as well as maximum net return.

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