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COMPARISON OF VARIOUS ZINC APPLICATION METHODS AND THEIR EFFECT ON ZINC UPTAKE AND OTHER NUTRIENT ELEMENTS IN MAIZE PLANTS

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In a glasshouse study, three Zn application methods were tested to correct Zn deficiency in maize. Coating of the maize seed with 1% ZnO of the seed weight and 5 ppm surface applied Zn in solution form proved equally good for 7-week old maize dry matter production. Seed soaking in 5 and 10% $ZnSO_4$ solution for 3 min was the least efficient for growth promotion. Total Zn contents of the plant tissue increased ($P < 0.01$) by all Zn application methods; however, only surface applied Zn increased plant Zn concentration ($P < 0.01$). Applied Zn antagonised Cu uptake and in general reduced Fe, N and P concentrations, while their total contents increased due to growth improvement.

INTRODUCTION

Trace element deficiencies in various field crops have been well documented during the past decade [7, 8]. Among these, Zn deficiency has been reported rather frequently particularly in low land rice [8]. Many researchers have looked into its amelioration [14, 15]. The problem of Zn deficiency in maize have, however, been overshadowed to some extent until Rashid *et al.* [10] reported extensive and severe deficiency in many of the Punjab soils. They observed remarkable response of maize to applied Zn in 17 out of 23 soils collected from various districts. Maize is an important cereal and oilseed crop being cultivated on large areas of the region. As far as these authors are aware no work to alleviate Zn deficiency in maize has so far been done in the country. Zinc fertilizers, especially in developing countries, are expensive commodities, so their economy is highly warranted. A glasshouse study was undertaken to evaluate various Zn application methods to ameliorate its deficiency and their influence on other nutrient elements in maize.

MATERIALS AND METHODS

Bulk soil samples from 0-15 cm were collected from Chimranwali, District Jhang. Some of the soil properties have been given in Table 1. The soil, after crushing and passing through a 2 mm plastic sieve, was packed in polythene lined plastic pots at the rate of 3 kg/pot. Nitrogen and P at the rates of 50 and 40 ppm as urea and KH_2PO_4 were applied as basal dose. Besides control, Zn was applied on the surface at the rate of 5 ppm as $ZnSO_4$ in solution form, by soaking maize seed in 5 and 10% $ZnSO_4$ solution for 3 min and by coating the maize seed with 1 and 4% of the seed weight before sowing. The experiment was replicated thrice. Five seeds of maize (variety-Akbar) in each pot were sown. After a week of germination, the stand was thinned to 4 per pot. Throughout the growth period, moisture in the pots was maintained at field capacity by the daily addition of deionized water. After 7 weeks of growth, plants were harvested, washed thrice with deionized water, and dried at 70° in a stainless steel forced air driven oven. After recording dry matter yield (Table 2), dried plants were ground in a Wiley mill having a stainless steel cutting chamber. Following wet ashing with diacid mixture of HNO_3 and $HClO_4$ (4:1), Zn, Cu and Fe were determined at Atomic Absorption Spectrophotometer (Beckman-485) while N was determined by Micro-Kjeldahl distillation and P on S.P. 600 by developing yellow colour [4]. The data obtained were analysed statistically.

RESULTS AND DISCUSSION

(a) *Dry matter yield.* Plants growing in the control pots (without added Zn) exhibited severe and peculiar Zn deficiency symptoms. Their growth was stunted due to supressed internodes, and leaves were drooping like umbrella with interveinal chlorosis. Where Zn was supplemented, they tended to attain normal appearance. However, plants were still very much stunted in seed soaking (in $ZnSO_4$ solution) treatment and an overall indiscriminate sustained yellowness and papery appearance of leaves in all treatments indicated their hunger for more Zn. Plant dry matter increased remarkably ($P < 0.01$) due to applied

Table 1. Basic properties of the soil used

Property	Unit	Value
Clay	%	9.60
pH --		8.20
Electrical conductivity	mmhos/cm	1.55
Organic matter	%	0.52
$CaCO_3$ equivalent	%	6.30
Olsen's P	ppm	5.20
DTPA ext. Zn.	ppm	0.28

Table 2. Effect of various Zn application methods on the dry matter yield (DMY) of 7 weeks old maize plants

Methods		DMY (g/pot)
1. Control		14.37
2. Surface applied Zn @ 5 ppm as $ZnSO_4$		19.43
3. Seed dip in 5% $ZnSO_4$ for 3 minutes before sowing		15.00
4. Seed dip in 10% $ZnSO_4$ for 3 minutes before sowing		18.83
5. Seed coating with 1% ZnO of the seed weight		20.86
6. Seed coating with 4% ZnO of the seed weight		20.00
LSD	5%	2.35
	1%	3.34

Zn by all methods. Seed coating with 1% ZnO of the seed weight out-yielded the remaining treatments being 5 ppm surface applied Zn insignificantly different followed by seed soaking in $ZnSO_4$ solution. These responses were attributed to very low soil Zn (< critical level, i.e. 0.5 ppm [10] which was apparent from the plant symptoms and confirmed by plant composition.

(b) *Zinc, copper and iron uptake.* Maize plants growing on the control pots (without added Zn) had deficient Zn concentration (10.25 ppm) by any standards (critical level 13 ppm) [5]. That was the reason for significant response to applied Zn. Only 5 ppm surface applied Zn increased plant Zn concentration substantially ($P < 0.01$) but not beyond 20.18 ppm which was still in the marginal range [5]. It might help explain the overall substained yellowness of the plants. However, applied Zn by all methods (with a little exception to seed soaking in 5% $ZnSO_4$ solution) increased its total contents in plants ($P < 0.05$), the surface applied Zn being superior to all. These effects were attributed to growth promotion due to added Zn. In the case of ZnO coating of seed when its rate was increased from 1 to 4% of the seed weight, even then Zn uptake and DMY could not be improved further though plants were having Zn concentration less than the critical limits. One reason could be the probable difficulty encountered in the coating process.

Applied Zn by all methods invariably decreased Cu concentration ($P < 0.01$) as well as total contents (though N.S.) in plants showing an antagonistic effect of Zn on Cu uptake. However, no drastic effect on plant growth associated with as low Cu concentration as 2.75 ppm indicating dominance of dilution effect over Zn-Cu antagonism. But decreased total content of Cu despite remarkable growth promotion due to added Zn indicate the prevelance of Zn-Cu antogonism. This sort of decreased concentration could cause reduction in grain yields.

Research workers have shown Zn-Cu antagonism in short term solution culture studies in upland plant species [3, 11] but their interaction during translocation from roots to shoots did not seem to be operative [2], while other workers reported increased Zn or Cu solubility due to their application by depressing their fixation on soil components and may thus mask their physiological inhibition in absorption by plants [6]. So the net effect of these elements on their uptake by plants grown on soils would, therefore, be governed by two opposing reactions operating simultaneously in soils and plant roots which would also vary with the soil type and plant species. In this study, the physiological inhibition of Cu by Zn seemed to dominate the increased Cu availability in the soil.

Plants contained sufficient Fe in all treatments and in general, applied Zn decreased Fe uptake insignificantly. However, maximum decrease in Fe concentration was noted where Zn concentration increased to maximum (at 5 ppm surface applied Zn) and in fact here the total Fe content also decreased (Table 3). These effects could be attributed to increased plant growth due to applied Zn and to Zn inhibition of Fe. Other workers [13] also reported Zn to inhibit Fe absorption and translocation in the plant.

(c) *Effect of Zn addition on N and P contents.* Applied Zn had little effect on N and P contents of the plants (Table 4). However, small decrease in concentration and increase in the total content of these nutrients could be attributed to growth promition due to applied Zn. But the decreased total content as well as the concentration

Table 3. Effect of various methods of Zn application on the Zn, Cu and Fe contents of the plants

S.No.	Method	Zn		Cu		Fe	
		Conc. (ppm)	Total content (μg/pot)	Conc. (ppm)	Total content (μg/pot)	Conc. (ppm)	Total content (mg/pot)
1.	Control	10.25	134.05	6.73	88.61	168.7	2.172
2.	Zn @ 5 ppm on the surface of the soil	20.18	392.85	3.25	63.05	92.2	1.783
3.	Seed dip (3 min) in 5% $ZnSO_4$	10.03	150.24	5.67	84.10	111.2	1.663
4.	Seed dip (3 min) in 5% $ZnSO_4$	9.40	177.99	3.00	56.27	104.2	2.009
5.	Seed coating with 1% ZnO of the seed weight	9.67	200.84	2.75	57.27	109.5	2.277
6.	Seed coating with 4% ZnO of the seed weight	10.55	211.02	3.17	63.37	130.5	2.610
	LSD 5%	1.20	37.87	1.12	N.S.	N.S.	N.S.
	LSD 1%	1.71	53.87	1.59			

Table 4. Effect of various methods of Zn application on N and P contents of the plants

S.No.	Method	N		P	
		Conc. (mg/g)	Total content (mg/pot)	Conc. (mg/g)	Total content (mg/pot)
1.	Treatment	14.66	180.66	2.60	33.55
2.	Zn @ 5 ppm on the surface of the soil	10.71	207.16	1.58	30.73
3.	Seed dip (3 min) in 5% $ZnSO_4$ soln	12.02	179.20	3.18	46.70
4.	Seed dip (3 min) in 10% $ZnSO_4$ soln	11.18	214.07	1.57	29.04
5.	Seed coating with 1% ZnO of the seed weight	9.59	199.10	2.10	44.16
6.	Seed coating with 4% ZnO of the seed weight	10.15	203.06	1.87	37.38
	LSD 5%	N.S.	N.S.	N.S.	N.S.

of P at the highest Zn absorption at 5 ppm surface applied Zn could be attributed to Zn-P interaction. Other workers [1] have suggested such Zn-P antagonism whenever either element exceeded some threshold value.

CONCLUSIONS

In this study, apart from surface applied Zn, other methods of its application also proved useful for successful maize growth on a Zn deficient soil. In particular, ZnO coating of seed is certainly economical than surface applied Zn. However, this should be further investigated for increasing yield and plant Zn concentration (plants still had Zn less than critical level) by improving the ZnO coating of the seed. Zinc sulphate soaking of seed before sowing also seemed to have potential to alleviate Zn deficiency. This method should also be further explored by increasing the $ZnSO_4$ concentrations and time of seed soaking. To avoid possible Zn-Cu interaction on the soils having marginal and low amounts of Cu, native Cu content must be taken into account.

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