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EFFECT OF GYPSUM, IRON AND COPPER ON THE AVAILABILITY OF ZINC IN SALINE-SODIC SOIL

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Salinity and sodicity level of a clayey soil was raised to EC_e 13×10^3, pH 9.28 and exchangeable sodium percentage 48.69 by adding sodium bicarbonate and sodium hydroxide. Barley (Hordeum vulgare L.) was sown as a test crop. Four levels of gypsum, i.e. 25, 50, 75 and 100 per cent of the total gypsum requirement of the soil were added and three levels each of copper, zinc and iron were applied. The zinc content of plants and soil increased with zinc and iron application while copper had no effect on the zinc content of the plants but decreased available zinc in the soil. A significant increase in zinc content of plants and soil was noticed, which was attributed to the decrease in pH and solubility of insoluble forms of zinc.

INTRODUCTION

Deficiency of zinc usually occurred on soils of pH 6.5 or higher. Camp (1945) reported that zinc was utilized most efficiently in soils which had pH between 6.0 and 6.5 and the availability of zinc declined as the pH of soil increased. Application of calcium carbonate, sodium carbonate and calcium sulphate as soil amendments to increase the pH of acid soil was made by Wear (1956) to study the effect of pH change upon the availability of zinc and he observed that addition of calcium carbonate considerably decreased the zinc content of sorghum crop; this amendment increased the soil pH from 5.7 to 6.6. This change in pH resulted in an increase from 0.78 to 1.09 in the calcium content of plants. Further higher rates of calcium carbonate increased soil pH and so decreased the zinc content of plants to some extent. Sodium carbonate being alkaline in reaction also reduced the zinc uptake as the pH of the soil increased. An application of 2000 lbs. of calcium sulphate per acre did not decrease the zinc content of the plants, because this chemical compound decreased the pH from 5.6 to 4.8 and so, on a percentage basis there was slight increase in the zinc and calcium contents of plants. Melton *et al* (1970) found that liming of the soils induced zinc deficiency as the pH of the soil increased.

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The effect of lime, phosphorus and some fertilizer compounds on zinc availability was studied by Shukla (1972) and he reported that lime addition decreased the zinc availability. Beauchamp (1973) determined the effect of calcium sulphate on the uptake of zinc by soybean leaf tissue and showed that the addition of 0.5 mM $CaSO_4$ increased zinc absorption by the plant leaves. While studying soil properties Tiwari and Kumar (1974) claimed that pH and calcium carbonate correlated negatively and organic matter and cation exchange capacity positively with zinc uptake in case of rice plants. During the process of saline-sodic soils reclamation by the addition of gypsum alone and gypsum followed by leaching and its effect on the absorption of applied zinc by corn plants, Singh and Franklin (1975) concluded that gypsum application followed by leaching with water increased the concentration of zinc compared to gypsum application alone. The results of Lee *et al.* (1970) suggested that iron did not interfere with zinc uptake in flax plants grown in solution culture experiments. Chaudhary *et al.* (1973) conducted a pot experiment in which they observed interaction between copper and zinc and reported that application of copper did not affect the zinc content of plants. Findings of Dolar and Keeney (1974) regarding copper-zinc interaction suggested that complexed copper decreased uptake of zinc. Wu and Antonovices (1975) also worked on the same line and studied the interaction effects between copper and zinc. Their investigations revealed that copper had no effect on zinc uptake by *Agrostis stolonifera* plants. The present study was aimed to further explore this important area of crop nutrition.

MATERIALS AND METHODS

Four levels of gypsum were applied to the soil and three doses of eac4 of copper, zinc and iron were added. The physical and chemical characteristics of the soil used are given below:

Table 1. *Physical and chemical characteristics of the soil after raising salinity and sodicity level.*

$EC_e \times 10^3$	pH	CEC (me/100g)	Soluble Cations (me/100g of soil)				Soluble anions (me/100g of soil)			
			Na	K	Ca	Mg	CO_3	HCO_3	Cl	SO_4
13.00	9.28	30.48	3.04	0.02	0.54	0.09	--	1.18	1.45	1.06

Exchangeable Cations				Available trace elements (ppm)			Total N (%)	Available P (ppm)
Na	K	Ca	Mg	Cu	Zn	Fe		
14.84	1.48	14.37	5.84	1.00	0.65	4.50	0.056	4.58

ESP	$CaCO_3$(%)	Gypsum requirement (tons/acre)
48.69	6.50	3.0978

The full rates of copper and zinc were applied before sowing but the doses of iron were splitted into two equal halves and half of the rate was applied before sowing and the other half when the plants were 2½ months old. Barley (*Hordeum vulgare* L. Var. 5681) was sown and after germination the seedlings were thinned to a total of 10 healthy plants in each pot. The crop was harvested at earing stage. Canal irrigation water was used for irrigation, chemical analysis was done and the various amounts of elements added through irrigation water were also calculated.

The abbreviations used to represent various levels of gypsum and trace elements are as under:

1. *Gypsum:*

   (i) G_0 (No gypsum)
   (ii) G_1 (25% of the total gypsum requirement fulfilled)
   (iii) G_2 (50% of the total gypsum requirement fulfilled)
   (iv) G_3 (75% of the total gypsum requirement fulfilled)
   (v) G_4 (100% of the total gypsum requirement fulfilled)

2. *Iron:*

   (i) Fe_0 (No application of iron)
   (ii) Fe_1 (2.5 lbs/acre as Fe)
   (iii) Fe_2 (5.0 lbs/acre as Fe)
   (iv) Fe_3 (7.5 lbs/acre as Fe)

3. *Copper:*

   (i) Cu_0 (without copper addition)
   (ii) Cu_1 (5.0 lbs/acre as Cu)
   (iii) Cu_2 (10.0 lbs/acre as Cu)
   (iv) Cu_3 (15.0 lbs/acre as Cu)

4. *Zinc:*

   (i) Zn_0 (No zinc was added)
   (ii) Zn_1 (5.0 lbs/acre as Zn)
   (iii) Zn_2 (10.0 lbs/acre as Zn)
   (iv) Zn_3 (15.0 lbs/acre as Zn)

The salts used for application were $FeSO_4.7H_2O$, $CuSO_4.5H_2O$ and $ZnSO_4.7H_2O$.

Plant samples were air dried and then oven dried at 70°C to a constant weight. Plant and soil samples were processed for final analysis. Nitric-perchloric acid was used for digestion of plants and available amounts of zinc iron and copper were extracted by DTPA soil extractant (Lindsay *et al.*, 1969). The concentrations of zinc, iron and copper were estimated by using Atomic Absorption Spectrophotometer model 485. The data were subjected to analysis of variance by factorial design in completely randomized arrangements and individual comparisons between treatments were made according to Duncan's Multiple Range test (1960).

RESULTS AND DISCUSSION

There was no germination in control and in pots where 25 per cent gypsum requirement was satisfied. The analysis of plants from the treatments G_2, G_3 and G_4 indicated that gypsum application increased total zinc content of plants. Among the trace elements Fe and Zn application also increased the zinc content of the plants but copper had no effect. The interaction between G–Fe, G–Cu and G–Zn for the uptake of zinc was non-significant.

Table 2. *Effect of gypsum, iron, copper and zinc on pH of the soil (values are averages of 4 repeats).*

Treatments	Values	Treatments	Values
G_0	9.28	Cu_0	9.28
G_1	8.68	Cu_1	9.24
G_2	8.57	Cu_2	9.22
G_3	8.53	Cu_3	9.20
G_4	8.38		
Fe_0	9.28	Zn_0	9.28
Fe_1	9.26	Zn_1	9.27
Fe_2	9.25	Zn_2	9.25
Fe_3	9.22	Zn_3	9.23

The decrease in pH by the addition of gypsum had a favourable effect upon the zinc content of the plants, the insoluble forms of zinc in the soil were converted to soluble ones and its availability to plants was increased, the plants

Table 3. *Effect of gypsum and iron on zinc content of plants (values are averages of four repeats).*

Treatments	G_0*	G_1*	G_2	G_3	G_4	Iron average
Fe_0	—	—	20.00	24.50	29.50	24.67 b
Fe_1	—	—	20.00	24.60	29.50	24.70 b
Fe_2	—	—	20.10	24.60	30.00	24.89 a
Fe_3	—	—	20.15	24.65	30.00	24.93 a
Gypsum average	—	—	20.06 c	24.59 b	29.75 a	

Table 4. *Effect of gypsum and copper on zinc content of plants (values are average of four repeats).*

Treatments	G_0*	G_1*	G_2	G_3	G_4	Copper average
Cu_0	—	—	20.00	24.50	29.50	
Cu_1	—	—	20.00	24.50	29.25	
Cu_2	—	—	20.00	24.10	29.00	
Cu_3	—	—	20.00	24.00	28.70	
Gypsum average	—	—	20.00 c	24.25 b	29.11 a	

Table 5. *Effect of gypsum and zinc on zinc content of plants (values are average of four repeats).*

Treatments	G_0*	G_1*	G_2	G_3	G_4	Zinc average
Zn_0	—	—	20.00	24.50	29.50	24.67 b
Zn_1	—	—	24.95	28.90	34.35	29.20 c
Zn_2	—	—	30.50	33.40	39.50	34.47 b
Zn_3	—	—	35.20	38.50	44.00	39.23 a
Gypsum average	—	—	27.66 c	31.18 b	36.84 a	

*There was no germination in these Treatments.

Averages followed by the same letters did not differ statistically among themselves at P 0.05.

took more zinc from the soil and thus zinc content of the plants increased. Camp (1945) reported that zinc was utilized most efficiently in soils which had pH between 6.0 and 6.5 and the availability of zinc declined as the pH of soil increased. He stated that zinc like other metals formed hydroxide depending upon the pH of soil liquid environment. The formation of egativelny charged zincate ion was also suggested as it was significant in soils with pH more than 7.85. Wear (1956) stated that an application of 2000 lbs. of calcium sulphate per acre increased the zinc and calcium content of the plants. These results showed that the reduction in zinc uptake by the plants was due to change in pH. Beauchamp (1973) determined the effect of calcium sulphate on the uptake of zinc by soybean leaf tissue and showed that the addition of 0.5 mM $CaSO_4$ increased zinc absorption by the plant leaves. The data presented in Tables 6, 7 and 8 indicate that as the gypsum level increased there was progressive increase in the available zinc concentration of the soil.

Table 6. *Effect of gypsum and iron on available zinc content of soil (ppm) (values are averages of four repeats).*

Treatments	G_0	G_1	G_2	G_3	G_4	Iron average
Fe_0	0.65	1.00	1.25	1.48	1.75	1.2260 c
Fe_1	0.65	1.05	1.25	1.48	1.75	1.2360 b
Fe_2	0.655	1.05	1.25	1.50	1.75	1.2400 b
Fe_3	0.655	1.10	1.25	1.50	1.75	1.2500 a
Gypsum average	0.65 e	1.05 d	1.25 c	1.49 b	1.75 a	

Table 7. *Effect of gypsum and copper on available zinc contents of soil (ppm). (values are averages of four repeats)*

Treatments	G_0	G_1	G_2	G_3	G_4	Copper average
Cu_0	0.65	1.00	1.25	1.48	1.75	1.2260 a
Cu_1	0.65	1.00	1.24	1.48	1.75	1.2240 a
Cu_2	0.63	1.00	1.24	1.47	1.74	1.2160 b
Cu_3	0.62	0.99	1.23	1.46	1.74	1.2080 c
Gypsum average	0.6375 e	0.9975 d	1.2400 c	1.4725 b	1.7450 a	

Table 8. *Effect of gypsum and zinc on available zinc contents of soil (ppm.) (values are averages of four repeats)*

Treatments	G_0	G_1	G_2	G_3	G_4	Zinc average
Zn_0	0.65	1.00	1.25	1.48	1.75	1.2260 d
Zn_1	1.35	1.75	2.15	2.30	2.60	1.9800 c
Zn_2	2.16	2.55	2.75	3.12	3.28	2.7720 b
Zn_3	2.91	3.20	3.50	3.70	4.00	3.4620 a
Gypsum average	1.7675 e	2.1250 d	2.4125 c	2.5875 b	2.9075 a	

Averages followed by the same letters did not differ statistically among themselves at P 0.05.

In comparison to iron, application of copper decreased the available zinc concentration in soil significantly. In pots where zinc application was made, a significant increase in the available zinc content of soil was recorded. The effect of zinc application was positive because there was three times increase in its concentration and thus it quantitatively amounted to 3.4620 ppm in the highest applied zinc rate. Unlike G-Fe the interaction between G-Cu and G-Zn for available soil zinc was non-significant. Increase in availability of zinc like iron and copper with an increase in the level of gypsum was again caused by reduction in pH that resulted with gypsum application. Similar conclusions were suggested by Camp (1945), Wear (1956), Melton *et al.* (1970), Shukla (1972), Beauchamp (1973) and Singh and Franklin (1975). They observed that as the pH of the soil decreased, the available soil zinc content increased. There was a significant increase in available soil zinc content with the application of iron and this increase was due to small reduction in pH brought about by the addition of ferrous sulphate to the soil. There was a decrease in available soil zinc under copper treatments and this was due to antagonistic effect of copper. The results obtained were similar to those reported by Chaudhary *et al.* (1973), Dolar and Keeney (1974) and Wu and Antonorices (1975). Their results showed reduced content of soil zinc with the application of copper to the soil.

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