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THE EXTENT AND SEVERITY OF Zn AND Cu DEFICIENCY AND THEIR MUTUAL INTERACTION IN MAIZE ON SOILS OF THE PUNJAB

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Abstract. The effect of Zn and Cu fertilizers on yield and their uptake by maize was studied in a pot experiment on 23 calcareous soils collected from major maize growing tracts of the Punjab. Ten ppm Zn applications increased dry matter yields quite appreciably, while 10 ppm Cu decrease it on most of the soils. Zinc uptake by plants rose on Zn treated soils. Its applications generally depressed Cu concentration in in plants without exhibiting any adverse effect on plant growth. Copper application enhanced Cu uptake but aggravated Zn deficiency in plants resulting in marked reductions in dry matter yield on many soils.

Zinc fertilization depressed P concentration in plants on most of the soils. The respone of maize to Zn addition was found to have little relevance to P/Zn ratio of maize tissue.

Introduction

The soil and climatic conditons of Pakistan appear to be quite conducive to micronutrient deficiencies in plants.[1] Their wide-spread deficiencies have been reported for many crops in various regions of country.[1-3]

Maize is an important cereal crop of Pakistan. Its N, P and K requirements are now reasonably understood. Little is known, however, about the micronutrient disorders of this crop. Maize is highly susceptible to Zn deficiency[4, 5] and may show Zn deficiency even on areas where other crops grow well.[6] The disorder usually gets serious as higher maize production is planned.[7]

The maize growing soils of the Punjab are alkaline and calcareous. Such types of soils are especially conducive to Zn deficiency.[4,5,8] They contain low organic matter contents and receive heavy doses of N fertilizers for higher crop yields. N fertilizers have been reported to aggravate Zn deficiency in plants.[4] The situation may get more serious by the adoption of high yielding varieties of maize coupled with a heavy demand for soil nutrients.[9]

Copper is more likely to be problem on peat and muck soils. However, its deficiency may also occur on alkaline and calcareous soils.[10] Heavy applications of N[4] and P[4, 11] are known to aggravate the problem. Zinc induced Cu deficiency in cereal crops is a well-known antagonism.[3, 12, 13] This may operate under field situations of the Punjab where widespread deficiency of Cu along with Zn occurs in wheat on many soils.[1]

Little information is available on micronutrient nutrition of maize under local soil and climatic conditions. The present studies were, therefore, conducted on 23 soils of major maize growing tracts of the Punjab to investigate the possible Zn and Cu nutritional problem of maize.

Materials and Methods

Twenty-three surface soils (0-15 cm) were collected from the major maize growing areas of the Punjab. The soils were air-dried, crushed to pass through a 2 mm plastic sieve, and analyzed for various physico-chemical properties (Table 1).

Sub-samples of 4.5 kg soil were filled in polythene lined plastic pots. The basal fertilizer dressing consisted of 75 ppm N as urea and 20 ppm P as KH_2PO_4. Zinc and Cu as SO_4 were applied to the soils at 0 and 10 ppm. The treatments were imposed in triplicate. All the fertilizers used were of the analytical reagent grade and applied in their aqueous solutions before planting. Ten seeds of maize (*Zea mays* L. cv. Neelam) were sown in each pot and the stand thinned to 4 seedlings 10 days later. Soil moisture in all the pots was maintained at field capacity by daily addition of deionized water throughout the plant growth period.

The plants were harvested 35 days after sowing and rinsed thoroughly in deionized water. Plant tops were dried at 70° for 48 hr. in a stainless steel oven and ground to a 40-mesh powder in a Wiley mill fitted with stainless steel blades and other interior parts of the cutting chamber. One g portions of ground plant material were digested with 25 ml of diacid mixture (redistilled HNO_3 and $HClO_4$ at 4:1). Zn and Cu in the diluted digest were determined by atomic absorption spectroscopy[14] and P by spectrocolorimetry after development of metavanadate yellow colour.[15]

TABLE 1. SOME PHYSICO-CHEMICAL PROPERTIES OF THE SOILS

Soil No.	Soil Location	Clay %	Textural class	pH	ECe $\times 10^3$	O.M.	$CaCO_3$ equiv.	$NaHCO_3$ extractable P	DTPA extractable* Zn	Cu	Fe	Mn
						——%	——		——ppm	——		
1.	Govern. Agr. Farm, Jhang	14.8	Loam	8.15	2.22	0.62	7.1	5.06	0.70	1.74	2.6	7.5
2.	Chimranwali, Jhang	9.6	Sandy loam	8.25	1.55	0.52	6.3	5.20	0.28	0.68	1.9	5.5
3.	Thikriwala, Faisalabad	13.8	Sandy loam	8.20	2.20	0.67	4.1	6.51	0.46	1.08	3.2	9.5
4.	Seed Farm, Gojra	17.6	Sandy clay loam	8.25	3.60	0.66	6.1	9.22	0.46	1.70	3.8	10.0
5.	Alhar Pind, T. T. Singh	17.8	Sandy clay loam	8.05	1.67	0.84	5.7	4.17	0.42	1.40	3.8	7.5
6.	Saraba, T. T. Singh	15.6	Sandy clay loam	8.02	5.00	1.09	6.5	8.85	0.50	1.84	3.8	16.7
7.	Chak 285/JB, Rejana	8.8	Sandy loam	8.70	1.55	0.46	6.5	6.34	0.32	0.64	1.9	7.1
8.	Mauza Chaddar, Kamalia	26.6	Loamy clay	8.15	2.62	1.31	4.6	6.56	0.62	2.86	9.0	7.5
9.	Chak 17/11-L, Chichawatni	8.8	Sandy loam	8.40	1.75	0.47	6.5	8.23	0.42	0.74	2.6	11.2
10.	Chak 521/EB, Vehari	12.8	Loam	8.50	2.42	0.57	9.2	5.12	0.17	1.18	5.1	5.5
11.	Chab Chauki, Kacha Khuh	9.6	Loamy sand	8.00	3.35	0.24	4.6	4.84	0.36	0.54	3.2	6.0
12.	Burewala Textile Mills	18.8	Clay loam	8.20	2.50	0.76	9.8	8.79	0.46	5.1	5.1	7.5
13.	Muhammad Nagar Farm, Arifwala	10.6	Sandy loam	8.10	1.85	0.94	8.2	6.79	0.38	1.12	2.6	5.5
14.	Chak 7/11-L, Sahiwal	16.8	Sandy clay loam	8.00	2.00	0.93	7.3	12.57	0.28	1.18	3.8	10.7
15.	Qadirpur Rawan, Multan	15.6	Clay loam	7.80	4.60	0.93	3.4	14.02	0.56	1.94	5.8	8.2
16.	Chak 133/16-L, Mian Channu	9.6	Sandy loam	8.05	3.40	0.62	7.5	3.11	0.36	0.68	1.9	11.0
17.	Chak 187/9-L, Harapa	10.8	Sandy loam	8.20	3.20	0.54	5.9	4.45	0.42	1.08	2.6	8.2
18.	Chak 118/9-L, Arifwala	14.8	Loam	8.30	1.93	1.08	2.4	4.78	0.46	2.08	5.1	6.0
19.	Maize Farm, Yousafwala	20.8	Clay loam	8.05	2.85	1.13	4.8	12.52	0.46	2.18	7.7	19.5
20.	Iqbal Nagar, Mian Channu	16.8	Sandy clay loam	8.20	1.42	1.04	5.4	9.01	0.52	1.36	3.8	8.0
21.	Chah Din Muhammad Wala, Kabirwala	22.8	Clay loam	7.80	6.25	0.84	4.8	5.34	0.50	1.84	3.8	8.2
22.	Chak 84/10-R, Khanewal	12.3	Sandy loam	8.25	2.12	0.94	6.2	5.12	0.62	0.92	3.2	8.1
23.	Nawab Iftikhar Farm, Jhang City	9.6	Sandy loam	8.20	1.46	0.83	7.1	9.40	1.66	2.16	3.8	6.0

*Determined according to the method of Lindsay and Norvell.[22]

TABLE 2. EFFECT OF Zn AND Cu FERTILIZERS ON DRY MATTER YIELD OF MAIZE TOPS

Soil No.	Fertilizer treatments		
	Check	10 ppm Zn	10 ppm Cu
	Dry matter, g/pot		
1	8.99	7.99	8.08
2	4.43	8.84	5.44
3	2.98	4.97	3.74
4	5.80	5.63	5.25
5	5.31	5.78	5.73
6	6.34	5.91	5.85
7	3.65	4.75	2.79
8	6.11	8.68	7.16
9	7.85	9.14	7.50
10	4.11	7.19	2.39
11	3.52	5.72	2.11
12	7.46	9.14	5.31
13	6.24	6.93	5.07
14	7.12	8.94	8.55
15	8.31	12.17	8.57
16	6.42	7.06	6.58
17	4.13	6.51	4.76
18	4.65	6.04	3.68
19	7.23	8.57	6.68
20	9.84	12.15	10.28
21	5.97	5.57	4.16
22	6.32	5.84	4.91
23	6.84	8.70	5.57
Mean	6.07	7.49**	5.66*

Treatment LSD (0.05) = 0.32
Treatment LSD (0.01) = 0.42

The data were processed by standard statistical procedures.

Results and Discussion

(*a*) *Effect of Zn and Cu fertilizers on dry matter yield of maize tops.* Maize plants on most of the soils with no-Zn treatment exhibited severe Zn deficiency in maize have been reported by earlier researchers.[6, 16] Zn concentrations of plant tissue from most of the control soils (Table 3) were lower than the critical Zn concentration suggested for maize, which is 20 ppm according to Jones,[17] Chapman[18] and Mehta *et al.*[19] and 15 ppm according to Melsted *et al.*[20].

Dry matter yields were affected markedly with Zn application ($P<0.01$, Table 2). Zinc fertilization increased the yields on 75% of the soils studied. The 0.005 *M* DTPA (diethylenetriaminepentaacetic acid) extractable Zn contents of these soils (Table 1) were lower than 0.8 ppm, the critical Zn concentration in calcareous soils for maize growth.[21, 22] These results substantiate the recent findings in the Indian Punjab where Zn has recently been found to generally increase yields of maize and "bajra" crops.[13]

Zinc fertilization resulted in lower yields on four soils (soil nos. 1, 6, 21 and 22) and had little effect on two soils (soil nos. 4 and 5). The reasons are unknown.

Several researchers have reported alkaline calcareous soils[4, 5, 8], soils with low organic matter [4, 16] and light in texture[16, 23] to be low in Zn availability. Heavy applications of N and P fertilizers[4] and adoption of higher yielding varieties[9] are known to aggravate the problem. The soils under study, representing most of the maize growing areas of the

TABLE 3. EFFECT OF Zn AND Cu FERTILIZERS ON THE CONCENTRATION AND TOTAL CONTENTS OF Zn IN MAIZE TOPS

Soil No.	Fertilizer treatments					
	Check	10 ppm Zn	10 ppm Cu	Check	10 ppm Zn	10 ppm Cu
	Plant Zn concentration			Total Zn contents in plants		
	ppm			ug/pot		
1	21.33	46.33	16.00	191.76	370.18	129.28
2	13.00	38.67	10.67	57.59	341.84	58.04
3	13.00	37.00	12.00	38.74	183.89	44.88
4	13.83	37.67	11.00	80.21	212.08	57.75
5	15.50	32.67	13.67	82.31	188.83	78.33
6	15.33	42.33	11.17	97.19	250.17	65.34
7	12.00	34.17	7.83	43.80	162.31	21.85
8	14.67	33.00	10.67	89.63	220.44	76.40
9	14.67	36.00	11.00	115.16	329.04	82.50
10	13.83	38.17	9.50	56.84	274.44	22.71
11	11.17	35.50	—	39.32	203.06	—
12	13.17	35.00	11.17	98.25	319.90	59.31
13	13.17	47.67	12.17	82.18	330.35	61.70
14	15.50	34.83	12.33	110.36	311.38	105.42
15	15.33	26.33	12.83	127.39	320.44	109.95
16	13.00	49.50	11.67	83.46	349.47	100.13
17	16.17	47.17	10.83	66.78	307.08	51.55
18	13.83	43.50	—	64.31	262.74	—
19	13.67	27.33	11.83	98.83	234.22	79.02
20	14.67	33.00	10.00	144.35	400.95	102.80
21	12.17	54.00	12.17	72.65	300.78	50.63
22	13.83	38.83	15.50	87.41	226.77	76.11
23	28.83	34.83	27.83	197.20	198.53	155.01
Mean	14.86	38.41**	12.49**	92.25	281.09**	70.94**

Treatment LSD (0.05) = 1.28
Treatment LSD (0.01) = 1.68

Treatment LSD (0.05) = 11.36
Treatment LSD (0.01) = 14.93

Punjab, were alkaline calcareous containing low organic matter and available Zn contents (Table 1). High yielding varieties of maize and other major crops have also been widely adopted. Liberal doses of fertilizers, particularly of N, are applied. The problem of Zn deficiency which has appeared on several soils is feared to be more severe in future. It needs special attention. Maize is to be more carefully tackled due to its higher susceptibility to Zn deficiency than several other crops.[6]

Copper fertilization also affected dry matter yields significantly ($P<0.05$, Table 2). Its additions generally reduced plant growth (on 56% soils). Only on a few soils (22% soils) has it enhanced yields. Since Cu deficiency has been reported to occur generally on organic soils,[8] the disorder was less likely to prevail on the current low organic matter soils. Furthermore, maize crop is known only to be moderately sensitive to Cu deficiency.[4, 24] The Punjab soils thus appear to be generally optimum in Cu supplies for maize growth.

(*b*) *Effect of Zn and Cu application on their uptake by maize.* Without Zn application, its concentration in maize tissue on most of the soils was in the deficient range.[17, 20] Zn fertilization increased its concentration in plants quite markedly on all the soils ($P<0.01$, Table 3). Total Zn contents also markedly increased. Thus on the current alkaline calcareous soils, soil applied Zn is fairly available to plants. Its soil application can, therefore, be safely adopted. These results contradict several earlier findings indicating little availability of soil applied Zn fertilizers from calcareous soils.

TABLE 4. EFFECT OF Zn AND Cu FERTILIZERS ON THE CONCENTRATION AND TOTAL CONTENTS OF Cu IN MAIZE TOPS

Soil No.	Fertilizer treatments					
	Check	10 ppm Zn	10 ppm Cu	Check	10 ppm Zn	10 ppm Cu
	Plant Cu concentration			Total Cu contents in plants		
	ppm			ug/pot		
1	9.00	8.33	8.50	80.91	66.56	68.68
2	8.33	6.50	10.50	36.90	57.46	57.12
3	9.17	6.67	11.50	27.33	33.15	43.01
4	10.00	8.33	11.33	58.00	46.90	59.48
5	8.33	8.00	9.67	44.23	46.24	55.41
6	11.33	8.00	10.50	71.83	47.28	61.43
7	8.67	6.83	9.50	31.65	32.44	26.51
8	14.00	7.67	14.17	85.54	66.58	101.46
9	9.50	6.33	9.25	74.58	57.86	69.38
10	14.17	7.67	14.67	58.24	55.15	35.06
11	8.83	8.00	9.50	31.08	45.76	20.05
12	10.00	8.33	10.50	74.60	76.14	55.76
13	9.00	6.00	7.67	56.16	41.58	38.89
14	12.50	8.00	11.50	89.00	71.52	98.33
15	12.00	6.83	13.33	99.72	83.12	114.24
16	9.50	7.33	9.67	60.99	44.49	82.97
17	9.50	8.83	10.00	39.24	57.48	47.60
18	10.00	8.33	10.00	46.50	50.31	36.80
19	8.83	7.67	9.67	63.84	65.73	64.60
20	8.67	6.83	9.17	85.31	82.98	94.27
21	9.50	8.33	11.33	56.72	46.40	47.13
22	6.83	7.33	8.83	43.17	42.81	43.36
23	6.83	7.67	8.83	46.72	66.73	49.18
Mean	9.73	7.56**	10.40**	58.79	56.30NS	58.70NS

Treatment LSD (0.05) = 0.38
Treatment LSD (0.01) = 0.50

Treatment LSD (0.05) = 3.88
Treatment LSD (0.01) = 5.10

Cu application, on the other hand, exhibited antagonistic effect on Zn nutrition of crop. It severely reduced concentration and total Zn contents on most of the soils ($P<0.01$, Table 3). Since most soils were already deficient in available Zn[21, 22] Cu application proved quite detrimental reducing plant yields in several cases. Chaudhry and Loneragan[12] had similarly reported $CuSO_4$ to aggravate Zn deficiency in wheat. They postulated that Cu depressed Zn concentrations in plants primarily by depressing Zn absorption.

Copper concentration in maize plants was higher than its critical value on most of the soils[18] (Table 4). Its application generally increased its concentration in plants ($P<0.01$). Total contents increased only on some soils. In most of the cases it decreased with Cu application. This depression appears to have occurred from yield reduction resulting from Cu-Zn antagonism.

Zn fertilization also significantly affected Cu concentration in plants ($P<0.01$, Table 4). It depressed Cu concentrations on most of the soils, probably due to dilution effect since it has little effect on total Cu contents of the plants.

(c) *Effect of Zn fertilization on P uptake by maize.* Interaction between P and Zn in plant nutrition is well documented.[25, 27, 29] Zn fertilization even in these studies affected P concentration and P contents of maize tissue significantly ($P<0.01$ and 0.05 respectively, Table 5). Thus 10 ppm Zn reduced P concentration in plant tissue on most of the soils (73.5% soils). The exact nature of the mechanism cannot be deduced from these studies. Two factors seem to be predominately responsible. Dilution

TABLE 5. EFFECT OF Zn FERTILIZATION ON THE CONCENTRATION AND TOTAL CONTENTS OF P IN MAIZE TOPS

Soil No.	Zn application			
	Check	10 ppm Zn	Check	10 ppm Zn
	Plant P concentration		Total P contents in plants	
	ppm × 1000		mg/pot	
1	1.23	1.11	11.06	8.85
2	1.12	1.01	4.95	8.93
3	0.75	1.03	2.23	5.12
4	0.95	0.98	5.49	5.50
5	0.97	0.98	5.17	5.68
6	1.18	1.06	7.48	6.25
7	1.40	1.11	5.10	5.26
8	1.39	1.02	8.49	8.88
9	1.33	1.06	10.46	9.69
10	1.25	0.93	5.13	6.71
11	1.09	1.05	3.83	6.01
12	1.00	1.01	7.46	9.20
13	1.27	1.14	7.94	7.90
14	1.80	1.17	12.80	10.43
15	1.81	1.62	15.04	19.72
16	1.35	1.13	8.65	7.98
17	1.08	1.05	4.46	6.82
18	1.98	0.81	4.54	4.91
19	1.19	1.15	8.63	9.83
20	1.22	1.06	12.03	12.92
21	0.84	0.94	5.03	5.22
22	1.12	0.99	7.06	5.78
23	1.01	1.12	6.89	9.74
Mean	1.19	1.07**	7.41	8.10*

Treatment LSD (0.05) = 0.03
Treatment LSD (0.01) = 0.04

Treatment LSD (0.05) = 0.55
Treatment LSD (0.01) = 0.73

effect caused by increased plant growth since only P concentration in plants decreased on most of the soils while total P contents were either not affected or increased.

Thus Zn application enhanced P contents on 43.5% soils and had little effect on 26% soils. It also depressed total P contents on 30.5% soils, indicating most probably an antagonistic effect of Zn on P uptake.

Some earlier workers have related crop growth condition with the P/Zn ratio of concentration in plant tissue. A P/Zn ratio of 150 was indicated to exhibit normal growth of maize and a ratio of greater than 300[28] depressed growth due to Zn deficiency. The P/Zn ratios in the maize tissue of the present studies were quite low, ranging from 35.1 to 118.1 on non-Zn treated soils and from 17.4 to 61.5 on Zn treated soils showing normal growth (data not shown). The current studies thus contradict the earlier findings with critical P/Zn ratio in plants.[28] These indicate that P/Zn ratios in maize tissue had no relevance with maize response to Zn fertilization under local soil conditions. Giordano and Mortvedt[29] and Stukenholtz *et al.*[27] reported similar results. They indicated that yield depressions could not be predicted from P/Zn ratios in maize tissue since it strongly varied with small variation in soil, climate and varietal factors.

Conclusions

The results of the present pot culture studies have indicated that most of the soils were Zn deficient for the optimum growth of maize and Zn application fairly increased the yields on most of the soils. Since the disorder has appeared quite serious in these pot studies, it is suggested that these findings may be verified by extensive field trials in various regions of the province to properly assess the extent and severity of the problem. The DTPA extractable Zn contents of most soils were lower than 0.8 ppm. This may therefore be taken as the critical level in local calcareous soils for maize growth.[21, 22]

Cu application had a little positive effect on maize growth; rather, it proved detrimental by accentuating Zn deficiency. This antagonistic effect of Cu on Zn uptake suggests careful application of a micronutrient to crops on a new region, particularly on soils deficient or marginal in other trace elements, since due to mutual antagonism, it may depress plant growth or have only limited beneficial effect.

Zn application adversely affected P nutrition of plants on most of the soils. As our soils are already deficient in P supplies,[26] due attention must be paid to the P status of the soil while applying Zn fertilizers to Zn responsive soils.

The study also indicated that the P/Zn ratio in the maize tissue had no relevance with maize response to Zn fertilization under local soil conditions.

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