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RESPONSE OF RICE TO ZINC AND COPPER IN THE FIELD*

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Response of Basmati-370 rice to Zn and Cu on 9 soils deficient in Zn and Cu was studied in the field. Grain yield response to Zn or Cu application was obtained though it was irregular.

Zinc concentration in plants generally decreased towards maturity and showed little correlation with Zn applied to the soils. Copper concentration did not change with the age of plants. Efforts made to delineate Zn and Cu deficient soils on the basis of Zn or Cu extractable by DTPA, HCl and NH_4OAc and the yield response met little success.

Deficiency of Zn and Cu in Basmati-370 and some other varieties of rice has been reported [15–18] following the introduction of high yielding IRRI varieties of rice and an increasing use of N^9 and P^{13} fertilizers it was expected that deficiency of Zn and Cu in the rice growing areas would become a more serious problem.

Some experiments were, therefore, conducted to examine the response of rice to Zn and Cu in the field. In these experiments three chemical soil tests were used to estimate available Zn and Cu in the rice soils before the application of fertilizers.

MATERIALS AND METHODS

A number of field trials, using different rates of Zn and Cu applications, were conducted on Basmati-370 rice in summer, 1975. Some physicochemical properties of dry surface (0 – 15 cm depth) soils sampled before the start of the experiment are given in Table 1. The clay contents of soils were determined with Bouycous hydrometer, organic matter by Walkely and Black $K_2Cr_2O_7-H_2SO_4$ oxidation using $FeSO_4-$ diphenylamine titration, available P with Olsen's 0.5*M* $NaHCO_3$ extraction using $SnCl_2$ as a colour developing agent and pH on a Corning-EEL model 12 pH meter using a glass-electrode in suspensions having 1:5, soil – water ratios as explained by Jackson [7] and the $CaCO_3$ contents by Puri's method as given by Piper [10]. Dry and wet soils (collected at the time of transplanting before the addition of any fertilizers) were analysed for Zn and Cu concentrations to be determined in 0.005*M* DTPA, 0.1M HCl and 1*N* NH_4OAc soil extractions, as used by Stewart and Tahir [14], by atomic absorption spectrophotometry.

Nitrogen at 100 kg/ha as urea and P at 60 kg P_2O_5/ha in the form of superphosphate were uniformly broadcast on the soil before transplanting of rice. Zinc at 10, 20, 50 and 100 kg and Cu at 5, 10, 20 and 50 kg/ha as their sulphates were applied to all except the control plots which measured 3 x 10 m each. The treatments were replicated four times in a randomized block design. A month old rice seedlings were transplanted at a row to row and plant to plant distance of 22.5 cm.

Plant leaf samples, collected at panicle initiation, flowering and grain formation stages of growth, were washed with deionized water and, after drying at 65^o in an oven, ground to a fine powder and were digested in a HNO_3-HClO_4 mixture. Zinc and Cu concentrations in the digests were determined by atomic absorption spectrophotometry.

RESULTS AND DISCUSSION

Grain yield. Zinc applications increased the dry weights of grain somewhat at five out of a total number of eight sites grown to rice (in the rice growing areas) in the region (Table 2). The highest response in grain yields with increasing applications of Zn to 20–50 kg/ha was obtained at four sites: grain yields between treatments did not, however, significantly differ. There was little correlation between the yield response to Zn (weights of grain) and any of the soil characteristics studied viz. pH, organic matter, clay contents or available phosphorus. In other studies on rice, response of plants to Zn has been correlated to soil pH [5] and organic matter [3]. In the present experiment, optimum grain yields were obtained at values of pH, clay contents and organic matter that varied greatly among themselves and could not thus be related to the plant response.

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Table 1. Some physicochemical characteristics of 9 rice soils of the Punjab.

Soil sites	Soil characteristics						
	pH	Clay (%)	Organic matter (%)	$CaCO_3$ (%)	Available contents (ppm)		
					P	Zn	Cu
Nankana	8.30	39.88	1.04	0.72	8.50	0.72	3.08
Kala Shah Kaku	8.10	30.16	0.92	0.35	12.70	0.72	2.66
Joyanwala	8.20	14.16	0.41	2.21	14.50	0.36	1.40
Gakhar	8.20	18.88	0.38	0.88	2.10	0.40	0.98
Verpal	7.98	18.16	0.60	0.30	5.20	0.36	1.40
Raiwind	8.50	19.20	0.51	0.74	9.50	0.36	1.68
Chuhrkana	8.30	26.88	0.42	0.40	5.00	0.40	1.82
Khankadogran	8.40	13.60	0.37	3.06	8.00	0.30	1.68
Sadhoke	8.40	26.88	0.70	0.78	6.50	0.42	2.73

Table 2. Range and average grain yield values of rice as affected by different Zn or Cu applications.

Zn/Cu applied (kg/ha)	Grain yield (kg/ha)	
	Ranges	Averages
Control	2578–4188	3608
Zn applied		
10	2950–4423	3753
20	2630–5094	3815
50	3236–4845	3999
100	2925–4570	3831
Cu applied		
5	2773–4994	3732
10	2737–4949	3594
20	2809–4514	3806
50	2861–5309	3954

In most cases, however, increasing applications of Zn above 50 kg/ha caused reduction in grain yields. Although no attempt was made to examine factors other than those discussed, i.e. the growth data and the lack of correlation between the dose applied and the plant ionic contents at most stages of plant growth, the importance of interactions of other soil factors (electrochemical changes associated with the submerged conditions of the rice soil) need not be over emphasized [11] in so far as the plant response to Zn on these soils is concerned.

Application of 5 kg Cu/ha to the rice soils gave response similar to that of Zn (Table 2). Increasing application of Cu to 10 kg/ha had either further little effect or depressed the grain yield substantially on most soils. Response of plants to further applications of Cu was, however, variable and erratic. The yields were higher than those in controls on most soils but were not much different from those obtained at 5 kg Cu/ha. Elsewhere, Cu applied at rates equivalent to 20 kg/ha to corn on a soil with similar characteristics substantially decreased the vegetative growth without affecting concentrations of Cu in plant tops [12].

Leaf Concentrations. Zinc: Concentrations of Zn in plant leaves in the present experiment showed no correlation with the dose of Zn applied to these soils (Table 3). The results obtained in the present work paralleled some others in the literature showing few correlations between plant Zn content and soil solution Zn concentrations [4]. Conversely, Gangwar and Chandra [3] showed plant Zn contents and the dose of Zn application in rice to be highly correlated. Zinc concentrations in plant parts in the present experiment decreased generally with the physiological stages subsequent to panicle initiation (Table 3.) Panicle initiation was thus the only stage in the growth of rice which corresponded, in general, to the stage of maximum Zn concentration in rice. However, the absence of data at seedling stage renders any conclusion about the stage of maximum concentration of Zn in plants invalid. Elsewhere seedling stage has been shown to be the stage of maximum Zn concentration in rice [4]. Cherian *et al.* [1] reported total plant analyses at 5 weeks growth and showed less concentrations of Zn while Obermueller and Mikkelsen [8] presented total Zn data for mature plants that were much higher than plant Zn contents recorded in the present study and elsewhere [2]. Results of Zn levels in plants presented in this study, however, approximate the levels of Zn reported from IRRI [6].

Notwithstanding the differences among values in relation to growth stages, the concentration of Zn in leaves of plants receiving $ZnSO_4$ in the present experiment did not quite differ from those grown in the control, which could well be a reason for not obtaining significant responses.

Copper: With the application of Cu, the concentrations of Cu in the uppermost leaves of rice plants at the stage of

Table 3. Zn and Cu contents at various growth stages in rice plant.

Soil sites	Zn applied, (kg/ha) 0	Zn applied 10			Cu applied (kg/ha) 0	Cu applied 10	
	PI	PI	FI	GF	PI	FI	GF
	Zn content (ppm)				Cu contents (ppm)		
Nankana	23.5	25.1	19.4	16.4	10.0	11.4	9.6
Kala Shah Kaku	20.1	25.9	22.2	32.2	7.5	8.8	8.4
Joyanwala	19.3	24.0	19.4	18.6	6.2	8.4	9.0
Gakhar	28.5	23.8	*	18.8	8.0	10.2	8.2
Verpal	27.5	26.2	21.8	20.1	5.0	7.6	6.4
Raiwind	25.0	27.0	20.1	17.1	8.0	6.7	6.7
Chuhrkana	26.5	23.8	*	16.7	8.0	6.7	6.9
Khankadogran	22.5	24.1	19.0	15.8	7.5	8.4	7.8
Sadhoke	25.0	23.4	17.2	17.5	7.5	7.7	8.4

PI panicle initiation, FI flowering, GF grain formation, *Plant samples spoiled.

Table 4. Zinc and cu contents in soils extracted with various extractants

Soil sites	State of soils	Extractant DTPA	HCl	NH_4OAc	DTPA	HCl	NH_4OAc
		Zn content (ppm)			Cu content (ppm)		
Nankana	D	0.72	4.0	0.72	5.32	7.0	0.98
	W	0.84	8.8	0.84	1.75	4.9	0.42
Kala Shah Kaku	D	0.90	7.2	0.90	2.66	6.6	0.70
	W	1.74	16.0	2.34	2.24	9.8	1.12
Joyanwala	D	0.54	5.6	0.96	1.68	2.8	0.56
	W	0.66	6.2	1.32	1.54	4.2	1.40
Gakhar	D	0.72	3.8	0.66	1.12	2.8	0.28
	W			Sampling missed —		—	—
Verpal	D	0.60	3.6	0.60	1.54	4.2	0.28
	W			Sampling missed —		—	—
Raiwind	D	0.72	4.6	0.96	1.68	4.2	0.42
	W	0.72	8.4	1.44	1.54	6.3	0.70
Chuhrkana	D	0.64	3.4	0.66	1.82	3.5	0.42
	W	1.20	5.2	1.08	1.54	2.4	0.28
Khankadorgan	D	0.64	4.0	1.20	1.96	1.0	0.84
	W	1.02	1.6	1.92	1.68	0.7	1.26
Sadhoke	D	0.76	4.4	0.96	2.80	4.9	0.70
	W	0.96	5.4	0.84	1.40	2.8	0.42

*D dry soil, W wet soil.

flower formation did not much differ from those at panicle initiation in the control (Table 3), though (grain) yield in a number of cases (at 5 sites out of 8) was much higher (Table 2). Copper concentration in leaves at grain formation stage of plants also did not materially differ from that in leaves at the panicle initiation growth stage. Although leaf and straw data are not at hand, dilution due to increased dry weights may be thought to have occurred thus resulting in the lack of difference in Cu concentrations. However, in the absence of data for Cu contents at panicle intiation stage of the plants receiving copper, definition of a stage of maximum uptake would be rather speculative. Data from similar work, however, suggest panicle initiation stage in other varieties of rice to be the stage of maximum Cu uptake [4].

Soil Concentration. Zinc and Copper: Zinc extracted by DTPA, HCl and NH_4OAc extractants from all soils (Table 4) illustrated Zn deficiency according to the established critical range of Zn concentrations [2]. Correlations between Zn extractable by these extractants and the Zn applied were not determined in the present experiment. An assessment of the availability of Zn from soils following the application of Zn fertilizer and the relation of extractable Zn to Zn contents in plants is, thus, lacking. Elsewhere, Zn extractable with DTPA extractant from deficient soils has been shown to correlate with Zn applied to the soil [5]. The situation in respect of Cu was also similar. However, response data could not be used to support data on soil solution concentrations which show all sites to be deficient. Attempt to delineate soils deficient in Zn or Cu in the present experiments, therefore, remains inconclusive.

Conclusion

Response of rice to the application of Zn and Cu in the present experiments was erratic. Concentrations of Zn or Cu in leaves of fertilized plants at the stage of panicle initiation and the others subsequent to it did not exceed the concentrations in the leaves of that in the control, thus pointing out further difficulties associated with the attempt to delineate Zn and Cu deficient soils in the reigon.

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