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EFFECT OF PHOSPHORUS AND ZINC ON THE GROWTH AND PHOSPHORUS, ZINC, COPPER, IRON AND MANGANESE NUTRITION OF RICE

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KEY WORDS

Rice Zinc-phosphorus interaction

SUMMARY

A greenhouse experiment was conducted to study the effect of phosphorus and zinc application, in three lowland alluvial rice soils (Haplustalf) on the growth of rice and the concentration of phosphorus, zinc, copper, iron and manganese in shoots and roots. The results showed that application of phosphorus and zinc significantly increased the dry matter yield of shoots, grains and roots. Application of phosphorus caused a decrease in the concentration of zinc, copper, iron and manganese both in shoots and roots. Application of zinc also similarly lowered the concentration of phosphorus, copper and iron, but increased that of manganese in shoots and roots. The decrease in the concentration of the elements in the shoots was not due to dilution effect or to the reduced rate of translocation of the elements from the roots to tops. This has been attributed more to the changes in the availability of the elements in soil resulting from the application of phosphorus and zinc.

INTRODUCTION

Application of phosphorus has been reported in some cases to cause a decrease in the total uptake of zinc in plants[10,19], while in others it has shown either to have no effect or increased the uptake[9,12,24]. Results on uptake of zinc and phosphorus in plants as influenced by the application of phosphorus and zinc respectively, therefore, still remain controversial[13]. According to Ward *et al.*[22], other factors like pH, organic matter *etc.* may have some role in influencing the zinc-phosphorus interaction in plants. Wallace *et al.*[21] showed in a solution culture experiment that at high pH increasing solution phosphorus decreased the concentration of zinc, copper and manganese in soybean leaf, stem and root whereas at low pH it resulted in an increase in their concentration.

Most of the investigations so far conducted on zinc-phosphorus interaction are related to upland crops. Giordano and Mortvedt[5] investigated the response of rice to applied zinc in flooded and nonflooded soils and observed that zinc

Plant and Soil 59, 415–425 (1981). 0032-079X/81/0593-0415$01.65.

concentration in the tissue decreased at high phosphorus rate on moist soil but not on flooded soil. Giordano *et al.*[6] studied the absorption of zinc by 14-day-old intact rice seedlings in short term uptake experiments in solution culture. They suggested that high solution concentrations of reduced iron and manganese which develop in paddy culture might be related to zinc nutrition of rice. Information regarding zinc-phosphorus interaction in respect of rice grown in flooded soil, therefore, seems to be inadequate.

A green house experiment was, therefore, conducted with three typical paddy soils (Haplustalf) to study the effects of phosphorus and zinc application on (i) growth of rice plant, (ii) tissue concentration of phosphorus, zinc, copper, iron and manganese and (iii) the relative rate of translocation of the elements from roots to shoots. It was thought that the results would be helpful in understanding whether the changes in absorption of the elements by rice plant as influenced by P and Zn application is related to purely physiological factors or reactions in soil are also responsible for such changes.

MATERIALS AND METHODS

The soil samples used in the investigation were collected from the surface layer (0–15 cm) of lowland paddy fields located in three different places in the alluvial soil tract of West Bengal, (India). The soils were clay loam in texture (clay, 32–43%), poor in organic matter (org. C, 0.86–1.15%) and available P (6.1–8.4 ppm) and slightly alkaline in reaction (pH, 7.70–8.00) and have been classified as Haplustalf according to soil taxonomy. The soils after collection were air dried, powdered and sieved through plastic mesh and potted (4 kg) in polythene pots (5 liter capacity). The treatments consisted of all possible combinations of three levels of P (0, 50 and 100 ppm) as KH_2PO_4 and three levels of Zn (0, 5 and 10 ppm) as $ZnSO_4$, each being replicated three times in a randomised complete block design. A basal application of N and K at the rate of 60 kg/ha as $(NH_4)_2SO_4$ and KCl respectively was provided to each pot. The soils were mixed thoroughly with the treatment materials, puddled with deionised water and kept under waterlogged condition for one week. Two 25-day old rice seedlings (Var. IR-579) were thereafter transplanted in each of the pots. The plants were allowed to grow in green house under natural light during January-April, 1978. The pots were irrigated daily with appropriate amount of deionised water so as to maintain the level of standing water at a height of 5 ± 0.5 cm during the growth period of the plants. The plants were harvested after their maturity, washed several times in running tap water, followed by dilute acid (0.01 *N* HCl) and deionised water and finally by double glass distilled water, separated into roots, shoots and grains, dried first in air and then in oven at 70°C and weighed. The samples were ground in a stainless steel grinder and digested in tri-acid mixture[8]. Zn, Cu, Fe and Mn in the digest were estimated with the help of Atomic Absorption Spectrophotometer (207, Hitachi Model). Phosphorus was determined by vanadomolybdo-phosphoric yellow colour method[8] using a Klett Summerson Photo-electric Colorimeter.

Table 1. Mean effect of P and Zn application on the shoot, grain and root yield (gm/pot) of rice

	Shoot				Grain				Root			
	Zn_0	Zn_1	Zn_2	Mean	Zn_0	Zn_1	Zn_2	Mean	Zn_0	Zn_1	Zn_2	Mean
P_0	10.43	12.81	13.51	12.25	15.74	18.22	18.62	17.53	1.70	2.15	2.16	2.00
P_1	11.89	13.45	13.93	13.09	17.25	19.22	19.59	18.69	2.14	2.31	2.33	2.26
P_2	11.62	13.22	14.07	12.97	16.55	18.70	19.72	18.32	2.09	2.26	2.36	2.24
Mean	11.31	13.16	13.84		16.51	18.71	19.31		1.98	2.24	2.28	
CD at 5%												
P & Zn		0.3296		0.0238								
P × Zn		0.7509		0.1344								

RESULTS AND DISCUSSION

Dry matter yield of shoots, roots and grains

Application of P and Zn at all the levels significantly increased the dry matter yield of shoots, roots and grains (Table 1). The increase was highest when both P and Zn were combined with each other at their respective highest levels, the mean increase of shoots, roots and grains in the P_2Zn_2 treatments being 35, 39 and 25 per cent respectively over that in the control (P_0Zn_0). The increase in the dry matter yield resulting from combined application of P and Zn might be due to their beneficial effect on metabolism of plants[15].

Nutrient concentration in shoots and roots

The mean of the results in respect of the three soils of the effect of P and Zn application on the concentration of Zn, Cu, Fe, Mn and P in shoots and roots of rice are presented in Table 2 and 3. The data show that Zn concentration both in shoots and roots increased with increasing levels of Zn application when no phosphorus was applied, the magnitude of increase being about 100 per cent over that in the control both in shoots and roots when Zn was applied at the rate of 10 ppm. Application of P, on the other hand, progressively depressed the Zn concentration both in shoots and roots at all the levels of Zn application, the mean magnitude of decrease when P was applied at the rate of 100 ppm irrespective of the level of Zn application being about 50 per cent below that in the no phosphorus control. It may be noted that although the absolute values of Zn concentration in roots was much higher than that in the shoots, the relative

Table 2. Mean effect of P and Zn application on Zn, Cu, Fe, Mn and P content (ppm) of shoot

	Zn				Cu				Fe			
	Zn_0	Zn_1	Zn_2	Mean	Zn_0	Zn_1	Zn_2	Mean	Zn_0	Zn_1	Zn_2	Mean
P_0	14.05	29.58	35.77	26.47	7.32	6.30	5.96	6.53	240.13	200.10	189.27	209.83
P_1	10.22	17.42	20.20	15.95	6.60	5.59	5.30	5.83	223.63	183.77	161.43	189.61
P_2	8.95	15.34	17.43	13.91	6.40	5.44	5.08	5.64	200.00	167.20	154.50	173.90
Mean	11.07	20.78	24.47		6.77	5.78	5.45		221.25	183.69	168.40	

	Mn				P			
	Zn_0	Zn_1	Zn_2	Mean	Zn_0	Zn_1	Zn_2	Mean
P_0	397.77	415.43	431.40	414.87	668.23	610.53	592.57	623.78
P_1	370.87	381.20	396.73	382.93	706.33	676.50	665.23	682.69
P_2	359.00	366.57	381.70	383.63	734.57	687.80	685.70	702.69
Mean	375.88	387.73	403.28		703.04	658.28	647.83	

CD at 5%	Zn	Cu	Fe	Mn	P
P & Zn	0.0479	0.0479	0.2536	0.2786	0.1943
P × Zn	0.0831	0.0831	0.4393	0.4826	0.3365

Table 3. Mean effect of P and Zn application on Zn, Cu, Fe, Mn and P content (ppm) of root

	Zn				Cu				Fe			
	Zn_0	Zn_1	Zn_2	Mean	Zn_0	Zn_1	Zn_2	Mean	Zn_0	Zn_1	Zn_2	Mean
P_0	36.67	76.50	89.53	67.57	5.89	4.44	4.28	4.87	1037.5	847.8	809.9	898.4
P_1	28.40	42.43	48.83	39.89	5.04	4.14	3.94	4.37	886.1	794.1	705.8	795.3
P_2	27.07	37.73	39.63	34.81	4.52	4.00	3.83	4.12	742.1	726.4	689.0	719.1
Mean	30.71	52.22	59.33		5.15	4.19	4.02		888.5	789.4	734.9	

	Mn				P			
	Zn_0	Zn_1	Zn_2	Mean	Zn_0	Zn_1	Zn_2	Mean
P_0	527.0	530.8	541.2	533.0	657.8	647.7	641.6	649.0
P_1	478.4	495.6	513.2	495.7	668.5	657.8	651.5	659.2
P_2	456.4	477.4	496.3	476.7	672.6	665.4	654.2	664.0
Mean	487.2	501.2	516.9		666.3	656.9	649.1	

decrease in the concentration of the element due to P application was similar both in roots and shoots.

Copper concentration in shoots as well as roots decreased with increasing levels of P or Zn application, the effect of Zn being more prominent as compared to that of P. Application of Zn at the rate of 10 ppm irrespective of the level of P application decreased the Cu concentration in shoots and roots to the extent of about 20 and 22 per cent respectively below that in the no Zn control whereas similar decrease in Cu concentration due to application of P at the rate of 100 ppm was only 13.6 and 15.4 per cent in shoots and roots respectively. Here also the proportionate decrease of Cu concentration in shoots and roots was of similar magnitude. The decrease in concentration became most pronounced when P and Zn were applied in combination at their highest levels, the magnitude of decrease being 30.6 and 35 per cent in shoots and roots respectively as compared to P_0Zn_0 control. Shukla and Singh[17] also observed decreased concentration of Cu in wheat grain and straw in the presence of high P level. They suggested that since the soil pH was high, the decreased availability of Cu in soil due to the formation of $Cu_3(PO_4)_2$ might be one of the reasons for the decreased concentration of Cu in grain and straw. They further suggested that besides the probable decreased Cu availability in soil the interaction at absorption sites and during translocation from root to shoot could also be the reasons.

Iron concentration in shoots and roots decreased progressively with the increase in the level of P or Zn application, the depressing effect of Zn being more prominent in respect of shoot concentration. In respect of concentration in the root the effect of both P and Zn was, however, similar in magnitude. Application of Zn at the rate of 10 ppm and of P at the rate of 100 ppm decreased the iron concentration in the shoot to the extent of about 24 per cent as compared to only 17 per cent below that in the no Zn and no P treatments respectively. The decrease in concentration became largest when P and Zn were applied in combination at their respective highest levels, the magnitude of decrease being 35.6 and 33.5 per cent in shoots and roots respectively as compared to P_0Zn_0 control. Chavan and Banerjee[4], however, could not find any depressing effect of Zn application upto 10 ppm level on iron concentration in rice plant. They rather observed a significant increase in the dry matter yield of rice as well as iron uptake when Zn was applied at 5 ppm level as compared to no Zn treatment. Ajakaiye[2] observed in solution culture experiments a decrease in the concentration of iron in shoot and root of millet and sorghum with increasing levels of P. Using radioactive iron it was shown that the translocation of Fe from root to shoot was affected at high P level due to P/Fe interaction.

Manganese concentration both in shoots and roots increased with the increase in the level of Zn application. The magnitude of increase was, however, very small being only about 6 per cent at 10 ppm level as compared to no Zn treatment. Application of P on the other hand, decreased the Mn concentration in shoots as well as in roots, the magnitude of decrease was, however, comparatively small. This indicates that Mn absorption by rice plant is little affected by P or Zn application in soil. Singh and Låg[18] observed similar increase in Mn concentration in barley plant as a result of Zn application. Ajakaiye[2] reported that manganese in shoots and roots of sorghum tended to increase with increasing levels of P.

Phosphorus concentration in shoot tended to decrease with the increase in the level of Zn application, whereas the same in root remained almost unaltered.

The results presented above clearly show that there is significant interaction of P and Zn among themselves as well as with Cu, Fe and Mn in influencing their concentration in the plant parts. Similar effects in crops like wheat, corn and maize have been reported by other workers[1,7,14]. The changes in concentration of the elements in the plant parts might be due to the changes in their absorption from the soil resulting from change in availability and/or to dilution effect due to increased growth of plants and/or to the changes in the translocation of the elements from roots to tops.

In order to examine critically whether the decrease in the concentration of the elements in shoots and roots was due to any dilution effect, the total uptake of the elements by shoots and roots have been calculated and presented in Table 4 and

Table 4. Mean effect of P and Zn application on the uptake (μ gm/pot) of Zn, Cu, Fe, Mn and P in shoot

	Zn				Cu				Fe			
	Zn_0	Zn_1	Zn_2	Mean	Zn_0	Zn_1	Zn_2	Mean	Zn_0	Zn_1	Zn_2	Mean
P_0	146.5	378.9	483.2	336.2	76.3	80.7	80.5	79.1	2504.5	2563.2	2557.0	2541.5
P_1	121.5	234.3	281.3	212.3	78.4	75.1	73.8	75.7	2658.9	2471.7	2248.7	2459.7
P_2	104.0	202.7	245.2	183.9	74.3	71.9	71.4	72.5	2324.0	2210.3	2173.8	2236.0
Mean	124.0	271.9	336.5		76.3	75.9	75.2		2495.8	2415.0	2326.5	

	Mn				P			
	Zn_0	Zn_1	Zn_2	Mean	Zn_0	Zn_1	Zn_2	Mean
P_0	4148.7	5321.6	5828.2	5099.5	6969.6	7820.8	8005.6	7598.6
P_1	4409.6	5127.1	5526.4	5021.0	8398.2	9098.9	9266.6	8921.2
P_2	4171.5	4846.0	5370.5	4796.0	8535.7	9092.7	9647.8	9092.0
Mean	4243.2	5098.2	5575.0		7967.8	8670.8	8973.3	

Table 5. Mean effect of P and Zn application on the uptake (μ gm/pot) of Zn, Cu, Fe, Mn and P in root

	Zn				Cu				Fe			
	Zn_0	Zn_1	Zn_2	Mean	Zn_0	Zn_1	Zn_2	Mean	Zn_0	Zn_1	Zn_2	Mean
P_0	62.34	164.48	193.38	140.07	10.01	9.55	9.24	9.60	1763.7	1822.7	1749.3	1778.5
P_1	60.78	98.01	113.77	90.85	10.79	9.56	9.18	9.84	1896.2	1834.3	1644.5	1791.6
P_2	56.58	85.27	93.53	78.46	9.45	9.04	9.04	9.18	1550.9	1641.6	1626.0	1606.1
Mean	59.90	115.92	133.56		10.08	9.38	9.15		1736.9	1766.2	1673.2	

	Mn				P			
	Zn_0	Zn_1	Zn_2	Mean	Zn_0	Zn_1	Zn_2	Mean
P_0	895.9	1141.2	1168.9	1068.6	1118.2	1392.5	1385.8	1298.8
P_1	1023.7	1144.8	1195.7	1121.4	1430.5	1519.5	1518.0	1489.3
P_2	953.8	1078.9	1171.2	1067.9	1405.7	1503.8	1543.9	1484.4
Mean	957.8	1121.6	1178.6		1318.1	1471.9	1482.5	

5. The data show that although application of P increased the dry matter yield of shoots and roots, the total uptake of Zn, Cu, Fe and Mn by shoots as well as by roots showed a declining trend. Similarly, application of Zn increased the dry matter yield of shoots and roots but the uptake of the elements excepting that of Mn either showed a declining trend or remained more or less unchanged. This leads to suggest that the decrease in the concentration of some of the elements in shoots and roots was not due to any dilution effect.

With a view to examine whether the decrease in the concentration of the elements in the shoots was due to any decrease in the rate of translocation of the elements from roots to tops, the ratios of the concentration of an element in shoots and roots were calculated and presented in Table 6. The data clearly indicate that the ratios in respect of Zn, Cu, Fe and Mn remained more or less unchanged due to P application. Similarly the ratios in respect of Cu, Fe, Mn and P also did not change much due to Zn application. This rules out the hypothesis that the decrease in the concentration of the elements in shoots might be due to the reduced rate of translocation of the elements from roots to tops. Sharma *et al.*[16] reported a decrease in the concentration of Zn in the tops of the corn plants due to P fertilization and attributed this to the physiological inhibition of translocation of Zn from roots to tops. Burleson and Page[3] and Warnock[23] also suggested that P interacts with Zn and reduces its mobility within the plant. Van der Vorm and van Diest[20], while studing the aspects of Fe and Mn nutrition of

Table 6. Mean effect of P and Zn application on the changes in the ratios of distribution of Zn, Cu, Fe, Mn and P in shoots and roots of rice plant

	Zn				Cu				Fe			
	Zn_0	Zn_1	Zn_2	Mean	Zn_0	Zn_1	Zn_2	Mean	Zn_0	Zn_1	Zn_2	Mean
P_0	0.38	0.38	0.39	0.38	1.24	1.41	1.39	1.35	0.23	0.23	0.23	0.23
P_1	0.35	0.41	0.41	0.39	1.31	1.35	1.36	1.34	0.25	0.23	0.22	0.23
P_2	0.33	0.40	0.43	0.39	1.41	1.36	1.32	1.36	0.26	0.23	0.22	0.24
Mean	0.35	0.40	0.41		1.32	1.37	1.36		0.25	0.23	0.22	

	Mn				P			
	Zn_0	Zn_1	Zn_2	Mean	Zn_0	Zn_1	Zn_2	Mean
P_0	0.75	0.78	0.79	0.77	1.01	0.94	0.92	0.96
P_1	0.77	0.76	0.77	0.76	1.05	1.02	1.02	1.03
P_2	0.78	0.76	0.76	0.77	1.09	1.03	1.04	1.05
Mean	0.77	0.77	0.77		1.05	0.99	0.99	

rice plants on the other hand, concluded that low contents of Mn in rice plants grown under acid anaerobic conditions were likely to result from low levels of available soil manganese, rather than from high levels of available Fe, exerting a competitive influence on the absorption of Mn.

Mandal and Haldar[11] in one of their earlier work have shown that application of P decreased the DTPA extractable Zn, Cu, Fe and Mn content in soil. Similarly application of Zn decreased the content of P, Cu and Fe but increased that of Mn. So decrease or increase in absorption of the elements owing to a change in their availability in soil resulting from P or Zn application can not be ruled out as one of the possible causes of the changes in the concentration of the elements in rice plant parts. A close examination of this possibility may be made by comparing the mean effects of two contrasting treatment combinations *viz* P_0Zn_0 ans P_2Zn_2 on the percentage changes of the extractable content of the concerned element in soil, its concentration in shoot and uptake (Table 7). The magnitude of the effect on these different parameters was found to be of similar order. The changes in concentration of P/Zn, Cu, Fe and Mn in rice plant due to Zn/P application are likely to be due to the changes in absorption of the elements resulting from the changes in their availability in soil. The interaction of P and Zn with each other and with Cu, Fe and Mn in soils rather than in plants seem to be more important in influencing the concentration of these elements in rice plants.

Received 7 May 1980. Revised October 1980.

Table 7. Relative change in the contents of Zn, Cu, Fe, Mn and P in two contrasting treatment combinations. (Results are expressed as change in % of the content over that in the adverse combination)

	Extractable Zn content in soil			Zn content in plant			Zn uptake by plant		
	P_0Zn_2	P_2Zn_0	D (%)	P_0Zn_2	P_2Zn_0	D (%)	P_0Zn_2	P_2Zn_0	D (%)
S_1	13.24	2.88	78.2	34.85	8.32	76.1	533.90	102.00	80.8
S_2	13.16	4.32	67.1	35.88	9.82	72.6	469.31	117.74	74.9
S_3	10.70	4.94	53.8	36.58	8.70	76.2	443.34	92.39	79.1
	Extractable Cu content in soil			**Cu content in plant**			**Cu uptake by plant**		
	P_0Zn_0	P_2Zn_2	D (%)	P_0Zn_0	P_2Zn_2	D (%)	P_0Zn_0	P_2Zn_2	D (%)
S_1	2.35	1.68	28.5	8.25	5.24	36.4	72.40	82.89	10.2
S_2	3.44	2.79	18.8	7.40	5.35	27.7	77.10	74.79	2.9
S_3	3.12	2.60	16.6	6.32	4.64	26.5	61.05	57.62	5.6
	Extractable Fe content in soil			**Fe content in plant**			**Fe uptake by plant**		
	P_0Zn_0	P_2Zn_2	D (%)	P_0Zn_0	P_2Zn_2	D (%)	P_0Zn_0	P_2Zn_2	D (%)
S_1	583	513	12.0	300.1	181.6	39.4	3361.12	2872.91	14.5
S_2	526	441	16.1	176.8	131.4	25.6	1842.25	1836.97	0.28
S_3	640	544	15.0	243.5	150.5	38.1	2352.21	1869.21	20.5
	Extractable Mn content in soil			**Mn content in plant**			**Mn uptake by plant**		
	P_0Zn_2	P_2Zn_0	D (%)	P_0Zn_2	P_2Zn_0	D (%)	P_0Zn_2	P_2Zn_0	D (%)
S_1	358	294	17.8	478.3	401.6	16.0	7327.55	4923.61	32.8
S_2	313	229	26.8	380.9	312.9	17.8	4982.17	3751.67	24.6
S_3	198	139	29.7	435.0	362.5	16.6	5272.20	3849.75	26.9
	Available P content in soil			**P content in plant**			**P uptake by plant**		
	P_2Zn_0	P_0Zn_2	D (%)	P_2Zn_0	P_0Zn_2	D (%)	P_2Zn_0	P_0Zn_2	D (%)
S_1	215.3	82.2	61.8	960.2	725.8	24.4	11772.05	11119.25	5.5
S_2	195.6	69.7	64.3	545.0	420.1	22.9	6534.55	5494.90	15.9
S_3	195.1	62.2	68.1	698.5	631.8	9.5	7418.07	7657.41	3.2 (I%)

D = Decrease; I = Increase.

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