Plant and Soil 68, 271–278 (1982). 0032-079X/82/0642-0273$01.20. Ms. 4936
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Interaction of phosphorus and molybdenum and the availability of zinc, copper, manganese, molybdenum and phosphorus in waterlogged rice soil

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Received 27 November 1981. Revised April 1982

Key words Copper Manganese Molybdenum Phosphorus Rice Waterlogging Zinc

Summary Laboratory incubation experiments were conducted with low-land rice soil to study the effect of applying three different levels of molybdenum (0, 2.5 and 5.0 ppm) and phosphorus (0, 100 and 200 ppm), in all possible combinations, on the changes in available Mo, P, Mn, Zn and Cu in soil. The results showed that application of Mo at both the levels increased the content of extractable Mo and P but decreased those of Cu and Mo in soil whereas application of Mo at higher level only increased the content of extractable Zn in soil. Application of P at both the levels decreased the content of extractable Mo, Mn and Cu but increased that of P whereas it showed an inconsistent effect on the extractable Zn content in soil. The P × Mo interaction effect was found to be beneficial for the content of P, Mo and Zn only. During the initial period of incubation all elements except Cu recorded an increase but with the progress of incubation period the content of all the elements except Mn gradually declined.

Introduction

Gupta and Mehla[4] observed a significant decrease in Cu content in soils with Mo application. They also indicated an antagonism between Mn and Mo in soil. Jones[5] called attention to the analogy between the reaction of Mo and P in respect of their effects on micronutrient element in acid soils. Gupta and Cutcliffe[3], however, reported that application of P to soil even at high rates did not reduce the concentration of exchangeable Mo in the soil. Most of the informations so far available on P × Mo interaction relates to upland soils and informations on the effect of P and Mo application on the availability of Mo, P, Mn, Zn and Cu in waterlogged rice soils are very much lacking. Keeping the above aspects in view, it was considered worthwhile to study the influence of P and Mo application on the availability of Mo, P, Mn, Zn and Cu in a waterlogged rice soil.

Materials and methods

Soil sample was collected from the surface (0–15 cm) of a representative low-land rice field in the University farm at Mohanpur situated in the Gangetic alluvial region of West Bengal, India. The sample was air-dried, ground in wooden mortar and sieved through a nylon sieve. The physico-chemical properties of the soil are as follows: pH (1 : 2 ratio) 6.50; Org. C 0.48%; Total N 0.08%; C.E.C.

16.90 meq/100 g of soil; Av. P 2.50 ppm; Av. Mo Trace; DTPA-ext. Mn, Zn and Cu 33.00, 1.18 and 9.60 ppm respectively. Ten g portion of the soil samples thus prepared were taken in each of a number of wide (3 cm diameter) test tubes made of corning glass of 50 ml capacity, treated with three levels of P (0, 100 and 200 ppm) and of Mo (0, 2.5 and 5.0 ppm) in all possible combinations and waterlogged, puddled with de-ionised water and incubated in the laboratory at room temperature, the level of standing water being maintained constant (5 ± 0.5 cm) by periodic addition of de-ionised water. Phosphorus and molybdenum were applied in the form of KH_2PO_4 (A.R.) and $(NH_4)_6Mo_7O_{24}$, $4H_2O$ (A.R.). The samples were periodically analysed for DTPA extractable Mn, Cu and Zn with the help of Atomic Absorption Spectrophotometer[7] and available Mo by modified acid ammonium oxalate extraction method of Grigg *et al.*[2] For determination of the changes in the available P (Bray No. 1), 5 g portion of the soil samples were incubated as described above with all treatment combinations, extracted periodically with Bray's No. 1 solution and the P in the extract was estimated colorimetrically by the molybdenum blue method, using a Klett Summerson Photoelectric Colorimeter. There were, in fact, three separate series of test tubes – one for estimation of DTPA extractable Mn, Cu and Zn, the second for Av. Mo and the third for Av. P. The concentration of the respective extracting solution as described in the respective methods, were suitably adjusted taking into account the amount of water present in the tubes of the respective sets.

Results and discussion

Available molybdenum

The results (Table 1) showed that application of Mo at both the levels increased the extractable Mo in soil throughout the period of incubation, the extent of increase being 3.4 and 5.4 times of that in the control at 2.5 and 5.0 ppm level of Mo application respectively during the initial 7 days of incubation followed by a gradual and rapid increase at the later period of incubation. Recovery of added Mo by Grigg's method was found to be 13.6 and 10.8 per cent at 7 days of incubation and 6.4 and 7.4 per cent at 42 days of incubation respectively at the above two levels of applied Mo. Application of P, on the other hand, decreased the extractable Mo content in soil almost throughout the period of incubation. Similar depressing effect of P on available Mo content in soil was also reported by Gupta and Cutcliffe[3]. The combined application of P and Mo was found to be beneficial for the availability of Mo in soil. The results suggest that in Mo-deficient soil, phosphate fertilization should be accompanied with Mo application. The results showed that with the progress of incubation period the content of available Mo in soil gradually declined. Similar decrease in available Mo content in soil with progress of incubation was also reported by Singh *et al.*[9]

DTPA-extractable manganese

Application of Mo at highest level decreased the content of extractable Mn in soil throughout the period of incubation. Similar depression was also recorded at lower level of applied Mo with exception at 14 and 28 days of incubation where it showed an increase. This reduced content of Mn in soil due to Mo application may be attributed to the formation of Mn-molybdate of low solubility. The

Table 1. Effect of P and Mo application on available Mo content (ppm) in soil

	Days after incubation																							
	7				14				21				28				35				42			
	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean
P_0	0.10	0.36	0.55	0.34	0.10	0.31	0.51	0.31	0.07	0.29	0.53	0.29	0.03	0.27	0.51	0.27	Trace	0.23	0.48	0.23	Trace	0.22	0.43	0.22
P_1	0.10	0.34	0.55	0.33	0.09	0.32	0.54	0.32	0.07	0.28	0.49	0.28	0.07	0.25	0.56	0.29	0.05	0.20	0.44	0.23	Trace	0.13	0.31	0.15
P_2	0.09	0.31	0.51	0.30	0.08	0.31	0.51	0.30	0.07	0.27	0.49	0.27	0.07	0.30	0.49	0.29	Trace	0.16	0.34	0.17	Trace	0.11	0.36	0.16
Mean	0.10	0.34	0.54		0.09	0.32	0.52		0.07	0.28	0.50		0.06	0.27	0.52		0.01	0.19	0.42		Trace	0.16	0.37	

Table 2. Effect of P and Mo application on DTPA-extractable Mn content (ppm) in soil

	Days after incubation																							
	7				14				21				28				35				42			
	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean
P_0	60.0	56.0	65.0	60.33	44.0	55.0	40.0	46.33	57.0	54.0	53.0	54.67	50.0	40.0	42.0	44.00	60.0	58.0	58.0	58.67	60.0	56.0	55.0	57.00
P_1	58.0	48.0	50.0	52.00	38.0	52.0	40.0	43.33	52.0	53.0	57.0	54.00	36.0	55.0	34.0	41.67	48.0	50.0	48.0	48.67	55.0	52.0	55.0	54.00
P_2	53.0	52.0	52.0	52.33	49.0	42.0	36.0	42.33	53.0	50.0	50.0	51.00	50.0	47.0	34.0	43.67	50.0	48.0	46.0	48.00	50.0	46.0	46.0	47.33
Mean	57.00	52.00	55.67		43.67	49.67	38.67		54.00	52.33	53.33		45.33	47.33	36.67		52.67	52.00	50.67		55.00	51.00	52.00	

results clearly suggest ion antagonism between Mo and Mn in soil. Similar Mo–Mn antagonism was the observation of Gupta and Mehla[4].

Application of P at both the levels decreased the extractable Mn in soil throughout the period of incubation, the magnitude of decrease being more at higher level of P application. This depressive effect may be attributed to the possible formation of insoluble Mn-phosphate in soil. Similar depressive effect of P on extractable Mn content in soil was reported by some workers[1,8]. The decrease in the content of extractable Mn in soil was greatest when P was applied along with Mo at their highest levels.

The content of extractable Mn in soil during the initial 28 day period of incubation recorded inconsistent changes though the values were always higher than the initial value. This was followed by a slow but constant increase throughout the period of incubation. This increase in the content of extractable Mn in soil due to waterlogging may be associated with both microbial and chemical reduction of higher oxides of Mn *e.g.* MnO_2, Mn_2O_3 and Mn_3O_4[6].

DTPA-extractable zinc

The results (Table 3) showed that application of Mo at lower level did not practically bring about any change in Zn content during the initial 21 days period of incubation, but thereafter it caused a rapid decrease during the later period of incubation. Application of Mo at higher level, on the other hand, resulted in a slow but steady increase over that in the control throughout the period of incubation. Further studies are required to explain this inconsistent effect of Mo application on extractable Zn content in soil.

The effect of applied P on extractable Zn content showed an inconsistent result. Application of P at the level of 100 ppm decreased the extractable Zn during the initial 14 days of incubation followed by an increase during the later period. Application of P at higher level resulted in an increase in extractable Zn content in soil throughout the period of incubation excepting at 35 days when it showed a decrease.

The results showed that when Mo was applied at a higher rate along with P it resulted in a greater increase in the content of extractable Zn in soil and this trend was found to be same almost throughout the period of incubation.

During the initial 14 days period of incubation the extractable Zn content in soil recorded a gradual increase, followed by a slight decrease at the later period of incubation.

DTPA-extractable copper

Application of Mo at both the levels recorded a decrease in the content of extractable Cu almost throughout the period of incubation. Similar increase was also recorded at higher level of Mo application during the initial 7 days period of incubation. Application of P at both the levels decreased the extractable Cu content in soil, which may be attributed to the possible formation of $Cu_3(PO_4)_2$

Table 3. Effect of P and Mo application on DTPA-extractable Zn content (ppm) in soil

	Days after incubation																							
	7				14				21				28				35				42			
	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean
P_0	2.00	2.00	1.84	1.95	2.04	1.76	2.88	2.23	1.76	1.84	1.72	1.77	1.58	1.72	2.32	1.87	1.58	1.14	1.58	1.43	0.72	0.96	0.94	0.87
P_1	1.84	1.84	2.12	1.93	2.08	1.92	2.20	2.07	1.86	1.70	1.90	1.82	2.24	1.88	2.08	2.07	1.86	1.12	1.84	1.61	1.00	0.74	1.30	1.01
P_2	1.88	1.96	2.10	1.98	2.02	2.54	2.16	2.24	1.78	1.88	2.06	1.91	2.08	1.26	2.32	1.89	0.94	0.86	0.98	0.93	0.96	0.76	1.02	0.91
Mean	1.91	1.93	2.02		2.05	2.07	2.41		1.80	1.81	1.89		1.97	1.62	2.24		1.46	1.04	1.47		0.89	0.82	1.09	

Table 4. Effect of P and Mo application on DTPA-extractable Cu content (ppm) in soil

	Days after incubation																							
	7				14				21				28				35				42			
	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean
P_0	8.0	11.0	12.6	10.53	5.2	6.0	5.2	5.47	6.0	4.0	5.0	5.00	1.6	2.0	4.4	2.67	1.2	1.4	1.2	1.27	1.4	1.2	1.2	1.27
P_1	7.2	6.4	8.4	7.33	4.4	5.0	4.4	4.60	4.8	4.6	4.0	4.47	1.6	2.6	1.6	1.93	1.2	1.0	0.8	1.00	1.0	0.6	0.8	0.80
P_2	11.8	8.8	11.6	10.73	5.2	3.6	4.4	4.40	4.6	4.6	3.4	4.20	2.8	2.8	2.4	2.67	1.0	0.8	0.6	0.80	1.0	0.4	0.2	0.53
Mean	9.00	8.73	10.87		4.93	4.87	4.67		5.13	4.40	4.13		2.00	2.47	2.80		1.13	1.07	0.87		1.13	0.73	0.73	

Table 5. Effect of P and Mo application on available P content (ppm) in soil

	Days after incubation																							
	7				14				21				28				35				42			
	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean	M_0	M_1	M_2	Mean
P_0	7.5	7.5	9.9	8.3	3.5	4.0	4.7	4.1	3.5	4.0	4.2	3.9	3.0	3.5	4.0	3.5	3.0	3.5	4.0	3.5	2.5	3.0	3.5	3.0
P_1	46.0	51.0	50.5	49.2	31.2	37.5	38.5	35.7	36.0	36.4	36.4	36.3	36.4	37.5	37.5	37.1	33.6	35.0	36.0	34.9	33.6	35.2	35.2	34.7
P_2	92.5	96.0	97.5	95.5	78.5	83.8	86.0	82.8	80.0	88.0	87.5	85.2	77.0	80.0	82.5	79.8	75.0	78.0	80.0	77.7	72.5	76.5	75.0	74.7
Mean	48.7	51.5	52.8		37.7	41.8	43.1		39.8	42.8	42.7		38.8	40.3	41.3		37.2	38.8	40.0		36.2	38.2	37.9	

of lower solubility[8]. The combined application of P and Mo, on an average, recorded no beneficial effect on the content of extractable Cu in soil.

The extractable Cu content of soil recorded a continuous decrease throughout the period of incubation. The decrease in extractable Cu content due to waterlogging may be attributed to microbial immobilization of available Cu in soil or to ionic interaction between Cu and Mn, the solubility of which (Mn) increased due to waterlogging[8].

Available phosphorus

Application of Mo at both the levels increased (Table 5) at varying degrees the available P content in soil throughout the period of incubation, the increase being more at higher level of Mo application. This increase in available P content in soil may be due to the release of phosphate (PO_4^{-3}) by molybdate (MoO_4^{-2}) ion from the soil colloidal complex through anion exchange phenomena. The results, therefore, indicate synergistic effect of Mo on available P content in soil.

The application of P at both the levels, as expected, increased the available P content in soil throughout the period of incubation, the magnitude of increase being more over control when P was applied at the higher level. The recovery of added P by Bray No. 1 extractant was on an average about 40 per cent indicating that a large portion of added P was transformed to some forms not extractable by Bray No. 1 extractant. The recovery of added P was, however, more when it was applied in combination with Mo, than when it was applied alone.

The results of the present investigation indicates that in P/Zn deficient soil, it is always advisable to add P/Zn along with Mo. The present investigation also finds its way to establish the fact that in adequate nutrition of lowland rice, what is more important is not the mere application of a blanket dose of a particular nutrient, especially a micronutrient, but its judicious combination with other nutrients which are most likely to affect and modify its own effect.

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