Forage Res., **37** (4) : pp. 221-225 (2012)

PHYTOAVAILABILITY OF NUTRIENTS IN Ni AND Cd SPIKED SOILS AS AFFECTED BY PHOSPHORUS APPLICATION IN INDIAN MUSTARD

MOHINDER SINGH, RAJESH KUMAR AND B. S. PANWAR

Department of Soil Science
CCS Haryana Agricultural University,
Hisar-125 004 (Haryana), India

SUMMARY

A screen house experiment in pots was carried out to study the effect of P application on forage yield, elemental composition and to determine the critical limits of available P in Ni and Cd spiked soils. Fifteen levels of P ranging from zero to 300 mg P/kg soil were applied. The application of P significantly increased the dry forage yield up to 80 and 100 mg P/kg soil in Ni and Cd spiked soils, respectively. The concentration of N and uptake of N, P, Zn, Fe, Cu, Ni, Cd and Cr increased significantly up to 80 mg P/kg soil application. The concentration of P was lowest in control and increased significantly and subsequently with the application of the P at all levels. The concentration of Zn, Fe, Cu, Ni, Cd and Cr was the highest in control and then significantly decreased with the increasing levels of P. In general, the forage yield, nutrient concentration and their uptakes were lower in Cd spiked soil over Ni spiked soil as there was a significant interaction between soil and P levels. Olsen's soil test was the best for determining the available P for Indian mustard crop owing to higher correlations with dry forage yield and P uptake in Ni (r=0.92* and 0.91**) and Cd (r=0.93* and 0.92**) spiked soils. The critical limits of available P by Olsen's soil test methods were 19.5 and 30.5 kg P/ha, for Ni and Cd spiked soil, respectively.

Key words : Ni, Cd, phosphorus, Indian mustard

Some of the non-essential heavy metals such as Ni, Cd, Cr and Pb, etc. get accumulated into the cultivated soils due to disposal of sewage sludge and factory effluents with rapid advancement of industrialization and urbanization. The phosphorus interacts with heavy metals by forming insoluble or sparingly soluble metal phosphates resulting in reduced availability of phosphorus to plants. Under such situation, it is expected that higher levels of P might be required to ameliorate the adverse effect of heavy metals on plant growth. The information on the effect of P application in heavy metals polluted soils is very scarce. Therefore, the present study was carried out to investigate the effect of P application on forage yield and uptake of nutrients by Indian mustard in Ni and Cd spiked soils.

MATERIALS AND METHODS

To study the effect of phosphorus application on forage yield and nutrients uptake by Indian mustard, a screen house experiment in pots was conducted on Ni and Cd spiked coarse loamy soil (Typic Haplustept). The bulk surface soil sample was processed to pass through 2 mm stainless steel. The physico-chemical properties of the experimental soil were : pH (1 : 2) 8.25, electrical conductivity (1 : 2) 0.25 dS/m, organic carbon 0.31 per cent, free calcium carbonate 1.25 per cent, cation exchange capacity 7.2 c mol (p+)/kg, available N 56 mg/kg, Olsen's P 3.00 mg/kg and DTPA extractable Cd, Ni, Cr, Fe, Cu and Zn were 0.08, 0.07, 0.003, 26.0, 5.84 and 0.20 mg/kg soil, respectively. Fifteen levels of P viz., 0, 2, 4, 6, 8, 10, 12, 15, 20, 40, 80, 100, 150, 200 and 300 mg P/kg soil replicated thrice were applied through AR grade ammonium dihydrogen phosphate along with 50 mg Ni/kg soil through $NiCl_2$ solution to the processed soil for preparing Ni spiked soil. Similarly, the Cd spiked soil was prepared by applying 50 mg Cd/kg soil along with above mentioned 15 levels of phosphorus and incubated at room temperature and at field capacity for three weeks. A 200 g of soil was drawn from each treatment after incubation of Ni and Cd spiked soils and analysed for available P by five soil tests viz., Olsen's (Olsen *et al.*, 1954), Bray's P_1 and Bray's P_2 (Bray and Kurtz, 1945), ammonium bicarbonate-EDTA (Soltanpour and Schwap, 1977) and ammonium bicarbonate-DTPA (Soltanpour and Schwap, 1977).

Indian mustard (cv. RH-30) plants were raised in each pot with 5 kg soil by following standard screen house technique. The basal doses of N, K, S and Zn were also applied at the rate of 150, 65, 30 and 10 mg/kg soil in each pot through AR grade urea, potassium chloride, potassium sulphate and zinc chloride, respectively. After germination, four plants per pot were raised. The crop was harvested after 11 weeks of germination. The plant samples were dried in oven at 70°C till constant weight and dry forage yield was recorded. The plant samples were digested in 4 : 1 acid mixture (H_2SO_4 : $HClO_4$) and analyzed for total N (Lindnar, 1944) and P (Koeing and Johnson, 1942). For the determination of Zn, Fe, Cu, Ni, Cd and Cr (by atomic absorption spectrophotometer), the plant samples were digested in 4 : 1 acid mixture (HNO_3 : $HClO_4$). The correlation coefficients were worked out between available P and yield parameters. The critical limit of available P was established by Waugh *et al*. (1973) linear response plateaus method for both the types of soils.

RESULTS AND DISCUSSION

Effect on Forage Yield

The application of P significantly increased the forage yield of Indian mustard up to 80 and 100 mg P/kg soil in Ni and Cd spiked soil, respectively. The forage yield was 3.94 g/pot in control which increased by about 1.3, 1.4, 1.7, 2.1, 3.3, 4.6, 5.6, 6.7 and 7.1 times with the application of 2, 4, 6, 8, 10, 12, 15, 20, 40 and 80 mg P/kg soil, respectively, in comparison to the control in Ni spiked soil. Thereafter, the forage yield significantly decreased (from 27.80 g/pot with 80 mg P/kg soil application) with the application of 100, 150, 200 and 300 mg P/kg soil over lower levels. The high magnitude of increase in forage yield with P application might be due to lower available P status of soil, whereas decrease it higher levels of applied P might be due to imbalanced nutrition. Singh and Khin (2009) also reported similar results of increase in dry matter yield of maize with 60 mg P/kg soil application with 60 mg Ni/kg soil.

The forage yield of Indian mustard was 2.16 g/pot in control which significantly increased with the increasing levels of applied P up to 100 mg P/kg soil. The highest optimum yield (23.56 g/pot) at 100 mg P/kg soil application was about 10.9 times over control. Further increase in P levels to 150, 200 and 300 mg P/kg soil resulted in significant decrease in yield due to adverse effect of higher P levels. Gupta *et al.* (1994) also reported that the maize dry matter yield was significantly increased with the application of 80 mg P/kg soil in Cd polluted soil. A perusal of data in Table 1 clearly depicts that the dry matter yield of Indian mustard in Cd spiked soil at each respective level of applied P was significantly lower than Ni spiked soil. The results reported earlier by Singh *et al*. (2009) have shown that the forage yield of Indian mustard with each respective levels of applied P in normal soil was high than the yield obtained in Ni and Cd spiked soil. These results clearly demonstrate that the Ni and Cd both had adverse effect on dry matter yield of the crop which has been ameliorated to some extent with higher levels of applied P. Gupta *et al*. (1994) and Panwar *et al*. (1999) also reported that the P application alleviated the toxic effect of Cd on cowpea, moongbean and maize crops.

Effect of P on Concentration of Elements

The application of P significantly increased the concentration of N up to 80 mg P/kg soil by about 35 and 41 per cent over control in Ni and Cd spiked soils, respectively (Table 1). The concentration of P significantly increased from 0.16 per cent in control to 0.31 per cent (94% over control) at 300 mg P/kg soil application in Ni spiked soil. The concentration of P significantly increased by about 93 per cent over control with the application of highest level of P. The increase in P concentration with its application was due to low available P in the soil.

The concentration of Zn was the highest in control which subsequently and significantly decreased with increasing levels of applied P up to 300 mg P/kg soil with mean value of 67.9 and 52.5 mg Zn/kg soil in Ni and Cd spiked soil, respectively.

A perusal of the concentration of Zn, Fe, Cu, Ni, Cd and Cr in the forage of Indian mustard clearly reveals that their concentration was the highest in control pots which significantly decreased with the application of P up to 300 mg P/kg in both the soils. The content of Zn, Fe, Cu, Ni, Cd and Cr decreased to about 52, 57, 45, 41, 55 and 10 per cent of the control, respectively, with 300 mg P/kg soil application in Ni spiked soil. Similarly, the application of 300 mg P/kg soil significantly depressed the content of Zn, Fe, Cu, Ni, Cd and Cr by about 51, 58, 40, 57, 35 and 48 per cent of control, respectively,

TABLE 1
Effect of phosphorus application on forage yield and elemental composition of Indian mustard in nickel and cadmium spiked soils

P levels (mg/kg)	Fodder yield (g/pot)	Elemental composition							
		N	P	Zn	Fe	Cu	Ni	Cd	Cr
		----------(%)----------		----------(mg/kg)----------					
					Ni spiked Soil				
0	3.94	0.46	0.16	92.9	322	10.13	40.2	4.90	4.94
2	5.01	0.46	0.16	89.0	299	1014	40.2	4.80	4.75
4	5.48	0.47	0.17	83.6	288	9.24	36.7	4.80	4.60
6	6.52	0.50	0.18	78.6	282	9.19	33.1	4.70	4.45
8	8.20	0.52	0.18	78.6	276	9.07	31.8	4.60	3.89
10	10.00	0.54	0.19	70.3	270	8.89	30.4	4.60	3.83
12	13.00	0.56	0.20	68.6	264	8.88	29.1	4.50	3.25
15	18.00	0.57	0.22	66.6	256	8.49	27.2	4.10	3.08
20	22.00	0.59	0.23	65.3	245	7.47	24.6	3.97	2.35
40	26.24	0.60	0.24	65.0	238	7.60	23.5	3.80	2.29
80	27.80	0.62	0.26	60.3	219	6.72	22.7	3.70	1.78
100	26.00	0.58	0.28	51.6	211	6.67	19.8	3.50	1.47
150	25.00	0.52	0.29	50.3	201	5.87	18.4	3.20	0.81
200	24.05	0.48	0.30	50.3	192	5.60	17.1	3.00	0.61
300	23.15	0.46	0.31	48.0	183	4.52	16.5	2.70	0.49
Mean	16.25	0.53	0.23	67.9	250	7.91	27.4	4.01	2.85
					Cd spiked soil				
0	2.16	0.41	0.14	85.3	261	8.72	3.70	44.0	0.46
2	2.38	0.41	0.14	83.7	242	8.15	3.57	41.3	0.45
4	2.78	0.42	0.15	76.5	234	7.47	3.50	35.8	0.44
6	2.94	0.42	0.15	73.6	228	7.29	3.50	34.3	0.43
8	3.12	0.45	0.15	72.0	228	7.06	3.40	32.7	0.43
10	3.25	0.47	0.16	67.0	223	6.75	3.30	31.6	0.41
12	3.98	0.49	0.17	62.0	218	6.30	3.30	29.3	0.41
15	4.76	0.50	0.18	62.0	211	6.06	3.20	27.6	0.40
20	7.85	0.52	0.20	60.2	203	6.06	3.00	26.3	0.38
40	14.00	0.56	0.22	58.5	197	5.84	2.80	23.3	0.36
80	22.00	0.58	0.24	57.0	190	5.60	2.60	20.7	0.34
100	23.56	0.51	0.24	49.0	177	5.49	2.50	19.3	0.31
150	21.13	0.49	0.25	43.6	169	5.14	2.47	18.7	0.29
200	20.00	0.45	0.26	43.6	161	3.73	2.20	17.3	0.26
300	19.47	0.42	0.27	43.0	151	3.47	2.10	15.3	0.22
Mean	10.23	0.47	0.20	52.5	206	6.20	3.01	27.8	0.37
C. D. (P=0.05) : P	0.47	0.01	0.01	3.0	7.3	0.31	0.29	0.30	0.07
Soil	0.23	0.01	0.01	1.5	3.7	0.16	0.15	0.15	0.04
P x Soil	0.93	NS	NS	6.1	14.6	0.62	0.58	0.60	0.14

NS–Non-significant.

in Cd spiked soil. The decrease in the concentration of these heavy metals in the plants might be due to the formation of insoluble metal phosphates which resulted in their decreased availability to the plants. The decrease in the contents of heavy metals in crops with higher levels of applied P was also reported by Santillan and Jurinak (1975), Street *et al*. (1978) and Singh and Khin (2009).

Effect of P on Uptake of Elements

The application of P significantly increased the uptake of N, P, Zn, Fe, Cu, Ni, Cd and Cr by the Indian mustard fodder (Table 2). The uptake of N, P and Ni was the lowest in control which significantly and subsequently increased with the increase in level of P application up to 80 mg P/kg soil by about 9.5, 11.3 and

3.9 times, respectively, in comparison to control, in Ni spiked soil. Similarly, the uptake of Zn, Fe, Cu, Cd and Ni increased significantly with applied P up to 40 mg P/ kg soil by about 4.4, 4.9. 4.6, 5.2 and 5.2 times, respectively, than the uptake in control. The increase in the uptake of these elements by crop up to 80 or 40 mg P/kg soil application was due to increase in forage yield. The higher levels of applied P decreased the uptake of different elements mainly because of decrease in their concentration in plants.

The uptake of N, P, Zn, Fe, Cu, Ni, Cd and Cr was the lowest in control pots which significantly increased with the application of P in Cd spiked soil (Table 2). The uptake of N and P had significantly and enormously increased by about 14.4 and 17.5 times with the application of 80 mg P/kg soil due to tremendous

TABLE 2
Effect of phosphorus application on uptake of some nutrients and heavy metals in nickel and cadmium spiked soils

P levels (mg/kg)	Uptake							
	N	P	Zn	Fe	Cu	Ni	Cd	Cr
	----------(mg/pot)----------		----------(µg/pot)----------					
				Ni spiked Soil				
0	18.1	6.30	383	1270	40.5	158	19.3	1.85
2	23.0	8.01	445	1503	50.7	198	24.0	2.35
4	25.7	9.30	457	1580	51.2	201	26.3	2.52
6	32.3	11.93	513	1838	59.9	215	30.6	2.99
8	42.6	15.03	646	2266	74.4	216	37.7	3.68
10	52.2	18.70	679	2614	86.0	293	44.1	4.25
12	70.9	26.20	870	3343	112.4	369	57.0	5.44
15	102.6	39.59	1200	4610	152.8	490	73.7	7.38
20	129.7	51.32	1435	5408	164.3	534	87.3	8.57
40	154.4	62.96	1705	6254	185.2	618	99.7	9.71
80	172.3	71.39	1715	6093	190.1	631	100.9	9.45
100	150.8	72.78	1348	5508	173.4	515	90.9	8.57
150	130.1	72.61	1261	5048	146.9	467	77.6	7.50
200	119.9	72.43	1210	4629	134.8	412	72.2	6.56
300	108.8	71.78	1111	4254	106.8	382	62.5	5.55
Mean	88.9	40.69	999	3747	115.3	383	60.3	6.20
				Cd spiked soil				
0	8.87	3.02	184	565	18.8	8.01	95.3	0.99
2	9.83	3.35	199	577	19.4	8.49	985	1.07
4	11.80	4.10	213	619	20.7	9.66	99.6	1.17
6	12.34	4.27	216	643	21.4	10.3	106.6	1.25
8	13.88	5.00	228	700	21.6	10.41	108.3	1.34
10	14.07	5.02	235	709	21.8	10.43	114.0	1.35
12	19.61	6.63	246	869	25.0	12.97	120.2	1.62
15	23.84	8.38	294	1006	25.1	15.20	131.6	1.90
20	41.07	14.91	473	1601	47.5	24.18	206.4	2.98
40	78.38	28.02	820	2758	81.7	39.22	322.9	5.04
80	127.6	52.80	1254	4194	123.2	57.02	456.2	7.48
100	119.95	53.37	1154	4184	129.3	58.87	455.4	7.64
150	104.17	49.95	923	3568	108.9	52.15	392.9	6.14
200	90.04	49.34	872	3139	74.4	44.01	346.6	5.19
300	81.84	48.67	845	2947	67.5	40.27	298.5	4.34
Mean	50.83	22.15	548	1874	54.1	26.89	225.0	3.39
C. D. (P=0.05) : P	3.58	1.94	45.1	139	5.80	5.00	6.08	0.64
Soil	1.85	1.00	23.3	71.8	3.0	2.58	3.14	0.32
P x Soil	7.16	3.88	NS	NS	NS	10.0	12.2	1.28

NS–Non-significant.

increase in yield and higher concentration of N and P in plants. The uptake Zn, Fe, Ni, Cd and Cr had significantly increased up to 80 mg P/kg soil application by about 6.8, 7.4, 7.1, 4.8 and 7.5 than control which was mainly due to improvement in the fodder yield of the Indian mustard in Cd spiked level. However, the uptake of Cu had significantly increased up to 100 mg P/kg soil application. The data (Tables 1 and 2) clearly revealed that the concentration and uptakes of different elements was the lowest in Cd spiked soil than Ni spiked soil thereby indicating that Cd had more harmful effect on crop growth and elements removal by the crop. However, the concentration of Ni and its uptake in Ni spiked soil and Cd and its uptake in Cd spiked soils were higher due to higher addition in soils. Dahlon *et al*. (1998) also reported that the application of P increased the concentration but decreased the concentration of K and other heavy metals like Pb, Zn and Mn in lucean plants.

Evaluation of Soil Tests of Available P and Critical Limits

The available P with its application (0 to 300 mg P/kg soil) was determined by soil tests (Olsen's, Bray's P_1, Bray's P_2, ammonium bicarbonate, DTPA and ammonium carbonate DTPA methods) and correlated with the forage yield and P uptake by the Indian mustard crop. The correlation coefficient between contents Olsen P and forage yield and P uptake were higher (0.92 and 0.91 in Ni spiked soil; and 0.93 and 0.92 for Cd spiked soil). The other methods were inferior to Olsen's soil test and thus it was considered to be the best for determining critical limits of available P for Indian mustard crop. The linear response plateau model (Waugh *et al*., 1973) was employed for establishing the critical limit of available P. The critical limits of available P were found to be 19.5 and 30.5 kg P/ha by Olsen's soil test for Indian mustard crop for Ni and Cd spiked soils, respectively. These critical limits of available P were higher than 13.5 kg P/ha earlier reported by Singh *et al.* (2009) in normal soil for Indian mustard crop.

The present study indicated that the application of P resulted in significant increase in forage yield and uptake of elements in Ni and Cd spiked soils to varying magnitude. Higher levels of P application might be required in heavy metals polluted soil than normal soil to get optimum yield. The critical limits by Olsen soil tests were 19.5 and 30.5 kg P/ha for Ni and Cd spiked soil, respectively.

REFERENCES

Bray, R. H., and L.T. Kurtz, 1945 : *Soil Sci.*, **59** : 39-45.

Dahlon, M. S. A., S. E. Demerdashe, M. S. A. Foda, and E. L. Kassas, 1998 : *Egyptian J. Soil Sci.*, **36** : 245-256.

Gupta, V. K., S. P. Gupta, Ram Kala, B. S. Potalia, and R. D. Kaushik, 1994 : *Res. Bull.*, Deptt. of Soil Sci., CCSHAU, Hisar, Hayana.

Koeing, R. A. and C. R. Johnson, 1942 : *Engg. Chem. Analyst. Edn.*, **14** : 155-156.

Lindnar, R. C. 1944 : *Plant Physiol.*, **19** : 76-89.

Olsen, S. R., C.V. Cole, F. S. Watanabe, and L. A. Dean, 1954 : U. S. D. A. Circ. **939**.

Panwar, B. S., J. P. Singh, and R. D. Laura, 1999 : *Water, Air and Soil Pollution* **112** : 163-169.

Santillan, M. J., and J. J. Jurinak, 1975 : *Proc. Soil Sci. Soc. Am.*, **39** : 851-856.

Soltanpour, P. N., and A. A. Schwab, 1977 : *Commun. Soil Sci. Plant Anal.*, **8** : 195-207.

Singh, Mohinder, and May May Khin, 2009 : *Forage Res.*, **35** : 96-100.

Singh, Mohinder, Rajesh Kumar, and B. S. Panwar, 2009 : *Forage Res.*, **35** : 23-26.

Street, J. J., B. R. Sabey, and W. L. Lindsay, 1978 : *Environ. Qual.*, **7** : 286-290.

Waugh, D. L., R. B. Jr. Cate, and L. A. Nelson, 1973 : *Tech. Bulletin No. 7.* ISFEL Soils, North Carolina State Univ., Releigh, W. C.