INTERACTIVE EFFECT OF CHROMIUM AND PHOSPHORUS ON GROWTH, DRY MATTER YIELD AND THEIR DISTRIBUTION IN WHEAT SHOOT

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SUMMARY

A pot experiment using sandy soil was conducted in screen house to evaluate the interactive effect of chromium (0, 1, 2, 4 and 8 mg kg^{-1} soil) and phosphorus (0, 15, 30 and 60 mg kg^{-1} soil) on growth and dry matter of shoot in wheat (*Triticum aestivum* L. cv. WH-542), in relation to tissue concentration and uptake of chromium (Cr) and phosphorus (P). Application of Cr to the soil decreased the length and dry matter of shoot significantly irrespective of applied P and the maximum reduction of 39% and 42%, occurred respectively with 8 mg Cr kg^{-1} soil. Phosphorus application, on the other hand, increased the growth and dry matter significantly in all the Cr added soil. Chromium content in shoot and its uptake increased markedly with the increasing doses of Cr in the soil. The magnitude of increase in tissue Cr content was higher in the absence of P than in its presence. Consequently, the level of Cr decreased by 15% and 25% in shoot with application of 30 and 60 mg P kg^{-1} soil, respectively, which ultimately attributed towards the increase in dry matter of the shoot. The content of P in tissue increased and its uptake decreased markedly with increasing levels of Cr in the soil, irrespective of the rates of P applied. It is concluded that added P alleviates the deleterious effect of Cr in the soil and improves the growth and dry matter of shoot in wheat.

***Key words*: Chromium, dry matter, phosphorus, shoot, *Triticum aestivum* L., uptake.**

INTRODUCTION

Heavy metal pollution is a worldwide problem. Heavy metals may be toxic to plants, or, after they enter the food chain, be harmful to animals and humans. Chronic exposure to chromium may lead to liver and kidney damage and appearance of perforation in nasal septum in human being. Besides endangering health, high levels of Cr further jeopardize human welfare by lowering yield potential of different crops. Koenig described phytotoxicity of Cr already in 1910. The negative effect of Cr on growth (Otabbong 1989, Mehta *et al.* 1996), photosynthesis and respiration (Bishnoi *et al.* 1993), and mineral nutrition of plants (Turner and Rust 1971, Barcelo *et al.* 1985, Misra and Jaiswal 1982), alteration of plant water relations causing water stress and wilting (Barcelo *et al.* 1986) and lowering the activity of several hydrolytic enzymes (Dua and Sawhney 1991) have been reported.

The effect of Cr on higher plants is largely concentration dependent. At low concentrations growth stimulating effects have been observed in several studies (Hass and Brussa 1961, Mehta *et al.* 1996). Chromium has also been demonstrated to be beneficial for plants (Huffman and Allaway 1973, Underwood 1981), and growth stimulation by Cr seems to be due to indirect effects on mineral nutrition, phytopathological agents (Pratt 1966), water relationship (Barcelo *et al.* 1986) or

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limited substitution of the chromate for molybdate (Warington 1948). The objective of the present study is to investigate the effects of a range of chromium and phosphorus interaction on growth and dry matter of shoot and their uptake in wheat.

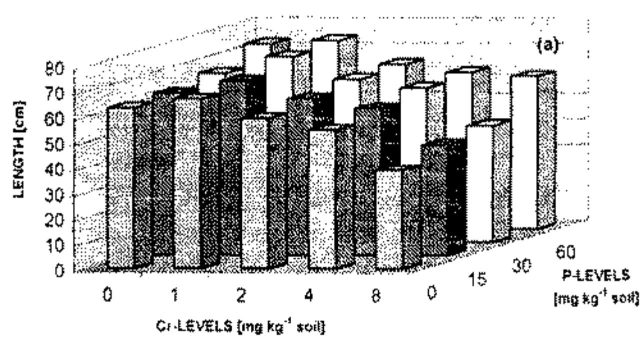
MATERIALS AND METHODS

A pot experiment was conducted using five kg of sandy soil (Typic Ustipsamment) filled in earthen pots lined with polythylene. Some selective characteristics of the soil are as follows : pH (1 : 2, soil to water ratio) 8.6, ECe (soil saturation extract) 0.8 dS m^{-1}, organic carbon 0.06%; CEC 3.2 cmol kg^{-1} soil, DTPA extractable Cr 0.4 mg kg^{-1} soil and Olsen P 4.2 mg kg^{-1} soil. The basal doses of micro and macronutrients were applied at the time of sowing as per recommendations. The treatment consisted of five levels of Cr (VI) (0, 1, 2, 4 and 8 mg kg^{-1} soil as $K_2Cr_2O_7$) and four levels of P (0, 15, 30 and 60 mg kg^{-1} soil as KH_2PO_4) and their all possible combinations. Each treatment was replicated three times in a completely randomized block design. After emergence of seedlings, the number of plants were thinned to three per pot and irrigated with equal quantities of deionized water as and when required. Nutrient solution was given at required intervals. Plant material was harvested at maturity and washed with acidified distilled water and then finally with distilled water. The plant material was first air-dried followed by oven drying at 60°C for 72 h and weighed. One hundred milligram of plant material (ground to > 425 μm in a mill) was digested separately using 10 ml diacid mixture of H_2SO_4 : $HClO_4$ (5 : 1) and then diluted to 50 ml volume with distilled water. The samples were analyzed for phosphorus (Koenig and Johnson 1942) and chromium by atomic absorption spectrophotometer. The results were analyzed statistically by working out least significant difference at 5% probability from three replications under each treatment.

RESULTS AND DISCUSSION

Stimulatory effects of lower dose of Cr (VI) were evident as length and dry matter increased at 1 mg Cr kg^1 soil. Increasing levels of Cr resulted in significant decrease in the growth and dry matter of shoot of wheat at either level of applied P (Fig. 1 a, b). This reduction was 39% and 42%, respectively at 8 mg Cr kg^{-1} soil as compared to control. In the presence of applied P (60 mg P kg^{-1} soil) the corresponding reduction in the length and dry matter were 18% and 38%, respectively. This reduction with increasing levels of Cr has been ascribed to interference with the nutrition of plants, but the views regarding the mechanism are divergent (Turner and Rust 1971, Barcelo *et al.* 1985). However, the magnitude of decrease in length and dry matter with increasing rate of Cr was higher in the absence of P than in its presence. This reflects that P fertilization to some extent mitigated the depressive effect of high doses of Cr. The beneficial effect of P in counteracting the adverse effect of Cr may be attributed to the decreased translocation of Cr in the plants (Table 1).

The concentration of Cr in wheat shoot tissue increased significantly with the increasing levels of Cr in soil (Table 1) but it decreased noticeably with the increasing levels of P in the soil. The accumulation of Cr in the shoot depends upon crop species and the amount of P applied in the soil (Otabbong 1989). The mean decrease in tissue Cr concentrations with the application of 30 and 60 mg P



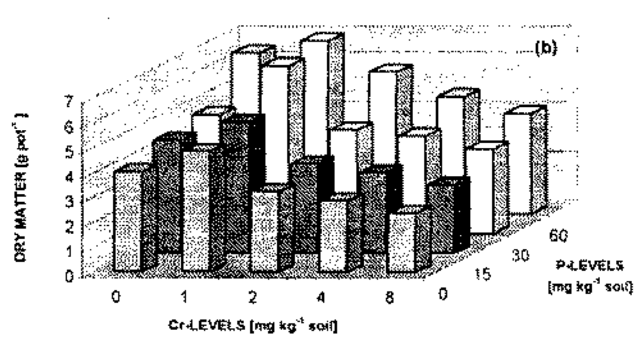


Fig. 1. Effect of Cr and P application on length (a) and dry matter (b) of wheat shoot.
C.D. at 5%: Shoot length: Cr=0.39, P=0.32, CrXP=0.77
C.D. at 5%: Shoot dry matter: Cr=0.14, P=0.12, CrXP=0.29

Table 1. Effect of Cr and P application on tissue Cr content (mg kg^{-1} dry matter) and uptake (µg pot^{-1}) in wheat shoot

Cr-levels (mg kg^{-1} soil)	P-levels (mg kg^{-1} soil)									
	Concentration					Uptake				
	0	15	30	60	Mean	0	15	30	60	Mean
0	0.4	0.4	0.4	0.4	0.4	1.61	1.81	1.91	2.58	1.98
1	1.7	1.6	1.5	1.3	1.5	8.24	8.41	8.74	9.04	8.61
2	3.3	3.0	2.7	2.1	2.8	10.66	10.74	11.26	12.01	11.17
4	3.9	3.6	3.2	2.9	3.4	11.15	11.63	12.53	13.71	12.26
8	4.8	4.4	4.1	3.6	4.2	11.32	12.01	13.94	14.58	13.46
Mean	2.8	2.6	2.3	2.0	-	8.59	8.92	9.68	10.38	
CD at 5%										
Cr	0.27					1.40				
P	0.21					1.08				
Cr x P	0.35					2.96				

Table 2. Effect of Cr and P application on tissue P content (mg kg^{-1} dry matter) and uptake (µg pot^{-1}) in wheat shoot

Cr-levels (mg kg^{-1} soil)	P-levels (mg kg^{-1} soil)									
	Concentration					Uptake				
	0	15	30	60	Mean	0	15	30	60	Mean
0	0.8	1.5	2.6	3.2	2.02	3.22	5.79	12.37	23.90	11.32
1	0.9	1.6	2.6	3.9	2.25	4.37	8.42	17.47	27.14	14.35
2	0.9	1.6	2.7	4.1	2.32	2.91	5.72	11.25	23.45	10.83
4	1.0	1.7	2.8	4.6	2.52	2.86	5.41	11.00	21.75	10.25
8	1.1	1.8	2.8	4.8	2.63	2.60	4.91	9.52	19.44	9.12
Mean	0.9	1.6	2.7	4.1		3.19	6.05	12.32	23.14	-
CD at 5%										
Cr	0.02					0.72				
P	0.02					0.66				
Cr x P	0.03					1.62				

kg^{-1} soil in comparison to plant without P treatment was 18% and 29%, respectively. This reduction in Cr concentration in crop plants is mainly due to growth response to applied P. The uptake of Cr by wheat shoot increased considerably with applied Cr and P in the soil (Table 1). Contradictory results have been reported as to the effect of Cr and P on Cr concentration in different crops because they differ widely in their ability to take up and tolerate Cr. Chromium generally appears to accumulate in plant roots and is poorly translocated to shoot (Shewry and Peterson 1974).

Phosphorus concentration in wheat shoot tissue increased with the Cr addition to soil, irrespective of P rates (Table 2). This increase in tissue P concentration is attributed to reduction in dry matter of crop with the application of Cr in the soil (Fig. 1b). The P uptake in shoot decreased with the addition of Cr in the soil. The magnitude of decrease in P uptake with the addition of Cr to soil was higher in the presence than in the absence of added P. Whereas, in 30 and 60 mg P kg^{-1} soil treatment addition of 8 mg Cr kg^{-1} soil decreased the P uptake by 24% and 19%, respectively. The decrease in P uptake could be due to toxic effects of soil applied Cr on root cells (Shewry and Peterson 1974), which impaired P absorption process, or to decrease availability of P with the addition of Cr in soil. These results reflects competition between P and Cr for absorption by the wheat plants and further confirm that the toxicity induced by Cr depends upon the concentration applied and its uptake which was alleviated to some extent by the addition of P.

REFERENCES

Barcelo, J., Poschenrieder, Ch. and Gunse. B. (1985). Effect of Cr VI on mineral element composition of bush beans. *J. Plant Nutr.* **8:** 211-217.

Barcelo, J., Poschenrieder, Ch. and Gunse. B. (1986). Water relations of chromium VI treated bush bean plants (*Phaseolus vulgaris* L. cv. contender) under both normal and water stress conditions. *J. Exp. Bot.* **37:** 178-187.

Bishnoi, N.R., Chugh, L.K. and Swahney, S.K. (1993). Effect of chromium on photosynthesis, respiration and nitrogen fixation in pea (*Pisum satium* L.). *J. Plant Physiol.* **142:** 25-30.

Dua, A. and Sawhney, S.K. (1991). Effect of chromium on activities of hydrolytic enzymes in germinating pea seeds. *Environ. Exp. Bot.* **31:** 133-139.

Hass, A.R.C., and Brusca, J.N. (1961). Effect of chromium on citrus and avocado grown in nutrient solutions. *California Agric.* **15:** 10-11.

Huffman, E.W.D. and Allaway, W.H. (1973). Growth of plants in solution culture containing low levels of chromium. *Plant Physiol.* **52:** 72-75.

Koenig, P. (1910). Studien uber die stimulierienden und toxischen wirkungen der verscheidenvertigen chromverbindungen auf die pflanzen. *Lanwirt. Jahrb.* **39:** 775-916.

Koenig, R.A. and Johnson, C.R. (1942). Calorimetric determination of phosphorus in biological materials. *Indus Eng. Chem.* (Analytical) **14:** 155-156.

Mehta, R., Gupta, K., Dahiya, D.S. and Kumar, N. (1996). Effect of chromium (VI) on growth, yield and biochemical constituents of sunflower (*Helianthus annus* L.). In : R.K. Bhel, A.P. Gupta, A.L. Khurana and A. Singh (eds.), Resource Management in Fragile Environments, pp. 159-162. CCS HAU, Hisar & MMB, New Delhi.

Misra, S.G. and Jaiswal, P.C. (1982). Absorption of Fe by spinach on chromium VI treated soil. *J. Plant Nutr.* **5:** 755-760.

Otabbong, E. (1989). Chemistry of Cr in some Swedish soils. 3. Assessment of Cr toxicity and Cr x P interaction in rye grass (*Lolium perenne). Acta Agric Scand.* **39:** 19-147.

Pratt, P.F. (1966). Chromium. In: H.D. Chapman (ed.), Diagnostic Criteria for Plants and Soils, pp. 136-141. University of California, Riverside.

Shewry, P.R. and Peterson, P.J. (1974). The uptake of chromium by barley seedlings (*Hordeum vulgare l.). J. Exp. Bot.* **25:** 785-797.

Turner, M.A. and Rust, R.H. (1971). Effects of chromium on growth and mineral nutrition of soybeans. *Soil Sci. Soc. Amer. Proc.* **35:** 755-758.

Underwood, E.J. (1981). The incidence of trace elements deficiency disease. *Philosophical Transactions of the Royal Soc. of London Series B* **294:** 3-8.

Warington, K. (1948). Molybdenum as a factor in the nutrition of lettuce. *Ann. Appl. Biol.* **33:** 249-254.