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Effect of copper on growth, yield and concentration of Fe, Mn, Zn and Cu in wheat plants (*Triticum aestivum* L.)

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Abstract: *A pot experiment was conducted at six graded levels of copper (Cu) viz., 0, 0.5, 1.0, 1.5, 2.0 and 2.5 mg kg^{-1} to test the response of wheat plants grown in a copper-responsive alluvial soil (entisol) under glass house conditions. The growth attributes like plant height, fresh and dry matter yield, percent dry matter enhanced with increasing Cu levels and was maximum at 1.5 mg kg^{-1} Cu while the number of tillers was minimum at this level. The grain yield at 1.5 mg kg^{-1} Cu was enhanced by 62.9% from the control. The increase in weight of 1000 grains ranged from 33.93 to 41.35 g in comparison to control (32.58 g). Harvest index (%) also increased and ranged from 39.42 to 47.73 in different treatments in comparison to control (35.92). Both 1000 grain weight and harvest index were maximum in the plants at 1.5 mg kg^{-1} copper. Cu concentrations in leaves, grain and straw enhanced with increasing levels of Cu application. The Fe concentration in leaves was significantly reduced by Cu application and the reduction was 10.3% at 2.5 mg kg^{-1} Cu and was not influenced in by Cu application in grain and straw. The Mn concentration was not affected by Cu application in any of the plant part studied. However, Zn concentration decreased significantly at higher levels of Cu (2.0 and 2.5 mg kg^{-1}) in leaves and remained unaffected in the grain and straw.*

Key words: *Cu, Fe, Mn, Zn, Growth, Grain, Straw yield*
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Introduction

Micronutrient deficiency has become a major constraint for crop productivity in many Indian soils. The deficiency of micronutrients may either be primary, due to their low total contents or secondary, caused by soil factors that reduce their availability to plants (Sharma and Chaudhary, 2007). Copper as an essential micronutrient for normal growth and metabolism of plants is well documented (Sharma and Agarwal, 2005; Singh *et al.,* 2007). Deficiency of Cu in soils has been observed only in certain pockets of Uttar Pradesh (Tiwari and Tiwari, 1993) and therefore responses of crops to Cu were assessed only at a few locations (Sakal, 2001). Although the reported available soil Cu content in alluvial soils of U.P. is not indicative of Cu deficiency but plant response to Cu application is known for such soils (Katyal and Agarwala, 1982; Mehrotra, 1993). It is also known for agricultural species that soil analysis does not always discriminate between responsive and non-responsive sites (Robson and Reuter, 1981). Moreover, level of Cu in soil decreases with increasing pH due to stronger adsorption of Cu to soil particles (Lindsay, 1972). Hence, high pH soils may also possess problem of low Cu availability.

A nutrient imbalance may also arise by the presence of an excessive amount of a nutrient element that hinders another nutrient in performing its normal metabolic functions (Malewar, 2005; Zengin and Kirbag, 2007). Furthermore, the knowledge of the plant parts which accumulate the highest concentration of any nutrient should prove to be useful criterion in delineating the deficiency levels of nutrients from sufficiency and toxicity levels. The concentration of micronutrient cations (Cu, Fe, Mn and Zn) often does not vary greatly within plant parts, however, application of nutrient(s) in question may alter the concentration of other micronutrients to some extent which may influence their critical level in plant parts (Sharma and Bapat, 2000). Wheat is an important cereal crop of India which is highly susceptible to low level of Cu (Patel and Singh, 1995). Despite the application of recommended quantities of the major plant nutrients, the increase in productivity of wheat crop is not encouraging. This indicates that in addition to major plant nutrients, there is a need to apply those micronutrients which are deficient or low in the soil in a balanced manner. Many interactions among these micronutrients may also occur. Studies have shown that Cu and Zn interact with each other due to antagonistic relationship as Cu –Zn antagonism has been suggested by many workers (Dangarwala, 2001). Hence, the present study was undertaken to evaluate the effect of soil application of Cu on the growth, yield and concentration of Fe, Mn, Zn and Cu in various parts of wheat plant in soil- pot culture with a Cu-responsive alkaline alluvial soil.

Materials and Methods

A pot culture experiment was conducted with wheat (*Triticum aestivum* L. cv. HD 2285) in Gomti – upland alluvial soil (entisol). Some physico-chemical characteristics of the soil were: texture– sandy loam, pH (1:2.5 soil water extract) 8.6, EC_2 0.20 dSm^{-1}, organic matter 0.67%, $CaCO_3$ 0.80%, diethylene triamine penta acetic acid (DTPA) extractable Cu, Fe, Mn and Zn were 1.1, 8.4, 7.8 and 1.7 $\mu g\ g^{-1}$ soil, respectively. Soil analysis for calcium carbonate was done by rapid titration method (Jackson, 1958), organic matter by Walkley and Black's titrimetric method and available Cu, Fe, Mn

Table - 1: Effect of graded levels of copper application on growth parameters of wheat at 80 days

Cu applied (mg kg^{-1})	Plant height (cm)	Number of tillers $plant^{-1}$	Shoot fresh matter yield (g pot^{-1})	Shoot dry matter yield (g pot^{-1})	Percent dry matter
0	37.4	2.7*	22.40	5.40	24.1
0.5	42.9	2.5	24.52	6.24	25.4
1.0	44.8*	1.8	24.76	6.44	26.0*
1.5	46.0*	1.3	28.08*	7.52*	26.8*
2.0	44.5*	1.6	27.40	6.64	24.2
2.5	44.0*	1.5	27.24	6.72	24.7
SE (difference) ±	2.9	0.6	2.43	0.80	0.8
Critical difference (p=0.05)	6.2	1.3	5.10	1.68	1.8

*Significant at p=0.05 (5% level of probability)

Table - 2: Effect of graded levels of copper application on the grain yield attributes, straw yield and harvest index of wheat

Cu applied (mg kg^{-1})	Length of main ear (cm)	No. of ears $plant^{-1}$	No. of grains ear^{-1}	Grain yield (g pot^{-1})	Straw yield (g pot^{-1})	1000 grains wt. (g)	Harvest index (%)
0	6.6	2.1	12.7	3.88	6.92	32.58	35.92
0.5	7.7	1.9	16.7	4.48	6.64	35.02	40.29
1.0	8.5*	2.3	12.9	4.64	6.68	38.62*	40.99*
1.5	9.5*	1.9	20.0*	6.32*	6.92	41.35*	47.73*
2.0	7.8	1.7	18.5*	4.44	6.44	35.85*	40.81
2.5	7.1	1.6	17.3	3.80	5.84	33.93	39.42
SE (d) ±	0.9	-	2.6	0.98	-	1.54	2.39
CD (p=0.05)	1.9	NS	5.5	2.06	NS	3.24	5.03

*Significant at p = 0.05, NS: non-significant

and Zn in DTPA extract (Lindsay and Norvell , 1978). A basal treatment of 200 mg kg^{-1} soil as Ca (NO_3), 100 mg kg^{-1} soil as KH_2PO_4 and 100 mg kg^{-1} soil as $MgSO_4$ was applied to all the pots. The different micronutrients, like Fe, Mn, Zn, B and Mo were applied @ 10, 10, 1,1 and 0.5 mg kg^{-1}, respectively through their AR grade salt solutions, $FeSO_4.7H_2O$, $MnSO_4.4H_2O$, $ZnSO_4.7H_2O$, $Na_2B_4O_7.10H_2O$ and $(NH_4)_6Mo_7O_{24}.4H_2O$, respectively.

The experiment was conducted in completely randomized design. There were six treatments comprising 6 levels of Cu (0, 0.5, 1.0, 1.5, 2.0 and 2.5 mg Cu kg^{-1} soil). Cu treatments were given through addition of varying amounts of AR grade salt solutions of $CuSO_4.5H_2O$. The solutions were prepared in distilled water using required amount of copper sulphate. The fertilized soil was filled in 10" undrained polyethylene (plastic) pots (8 kg soil pot^{-1}). Four plants of wheat were grown in each pot and each treatment had four replications. Pots were randomized in an evaporatively cooled glass house and irrigated with deionised water throughout the experiment.

Data pertaining to growth parameters were recorded as plant height, tillering, fresh and dry matter yield. Various grain yields attributes were also recorded at harvest. Samples of leaves at flowering stage, grain and straw at maturity were taken for chemical anlaysis. The plant samples were oven dried at 70°C for 48 hours and powdered. For analysis of micronutrients like Fe, Mn, Zn and Cu, 1 g dried sample was wet digested in nitric-perchloric acid (10:1 v/v) mixture (Piper, 1942). The concentrations of Fe, Mn, Zn and Cu were determined by using an atomic absorption spectrophotometer (Techtron AA120).

The data have been analyzed for its statistical significance at p=0.05 (5% level of probability) by analysis of variance in completely randomized design.

Results and Discussion

Plant growth, fresh and dry matter yield: The increase in plant height was maximum (23%) at 1.5 mg kg^{-1} Cu application in comparison to control plants . The number of tillers was maximum in control plants which decreased to a minimum in the plants at 1.5 mg kg^{-1} Cu level (Table 1). However, all the tillers of control plants were not of effective type. Thus the plants at low copper had decreased height and profuse tillering which could be attributed to the loss of apical dominance of the main stem. Similar effects of low Cu have also been described in different plants (Agarwala and Sharma, 1976; Agarwala and Sharma, 1979; Marschner, 1995).

Shoot fresh and dry matter yield and percent dry matter were minimum in the control plants and increased with an increase in Cu application rate to a maximum at 1.5 mg kg^{-1} Cu at 80 days of growth (Table 1). At levels higher than 1.5 mg kg^{-1} Cu, the shoot dry matter yield decreased slightly in agreement with the reports of Kumar *et al.* (1990) in wheat plants.

Grain yield attributes and straw yield: The length of the main ear was significantly increased in plants applied with 1.0 mg kg^{-1} and 1.5 mg kg^{-1} Cu while the number of ears per plant was not significantly affected by Cu application. The number of grains per ear was significantly increased in plants at 1.5 and 2.0 mg kg^{-1} Cu levels. The

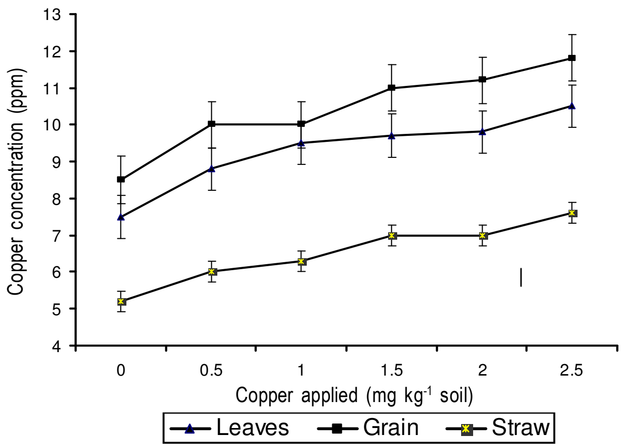

Fig. 1: Effect of copper application on copper concentrations in different plant parts of wheat (Bars represent standard error)
[Critical difference (p=0.05) Leaves - 1.21, Grain - 1.32, Straw - 0.59]

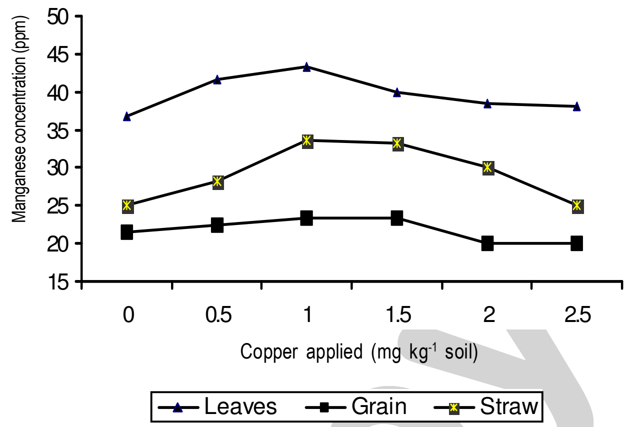

Fig. 3: Effect of copper application on manganese concentrations in different plant parts of wheat (Bars represent standard error)
[Critical difference (p=0.05) Leaves - NS, Grain - NS, Straw - NS]

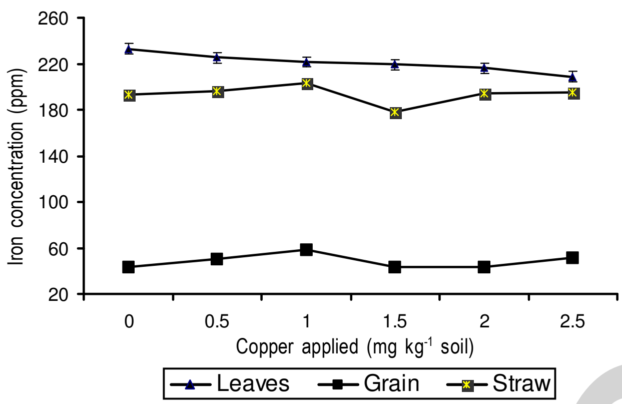

Fig. 2: Effect of copper application on iron concentrations in different plant parts of wheat (Bars represent standard error)
[Critical difference (p=0.05) Leaves - 9.46, Grain - NS, Straw - NS]

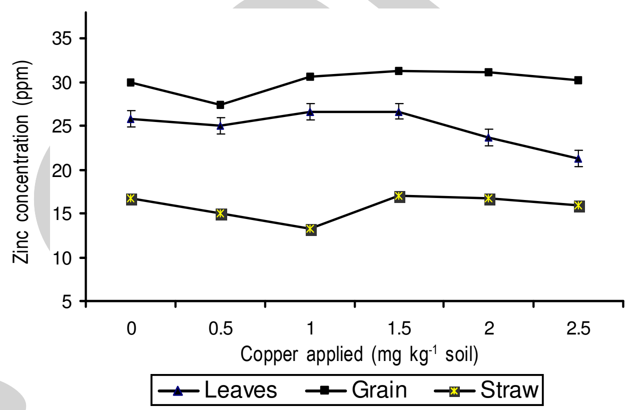

Fig. 4: Effect of copper application on zinc concentrations in different plant parts of wheat (Bars represent standard error)
[Critical difference (p=0.05) Leaves - 1.94, Grain - NS, Straw - NS]

grain yield was maximum in the plants at 1.5 mg kg^{-1} Cu level and it was 62.9% higher than the control plants. However, the grain yield was reduced by further addition of Cu at 2.0 mg kg^{-1} and 2.5 mg kg^{-1}. The weight of 1000 grains and harvest index were also increased significantly in plants at 1.5 mg kg^{-1} Cu (Table 2).

The grain yield enhancement at 1.5 mg kg^{-1} Cu was mainly due to increase in the length of ear, grain number per ear, grain weight and harvest index. The results are in accord with the earlier reports that plants grown in alluvial soils of Uttar Pradesh respond to Cu application even if the soil is not deficient in available Cu (Katyal and Agarwala, 1982; Mehrotra, 1993; Tiwari and Tiwari, 1993). Reduced grain yield in low Cu plants is in accordance with the reports of Nambiar (1976) and Agarwala and Sharma (1979). This is due to the reduction in the number of effective tillers, disturbed setting of grains and the production of rudimentary and blind ears in such plants. The reduction in grain yield at 2.0 and 2.5 mg kg^{-1} Cu levels may be due to excess of Cu and its interaction with other micronutrients like Fe and Zn (Dangarwala, 2001).

The straw yield of wheat was not significantly influenced by Cu application (Table 2). This might be due to excessive tillering in low Cu plants as a result of loss of apical dominance of the main stem (Marschner, 1995).

Tissue concentrations of Cu, Fe, Mn and Zn: The Cu concentrations in leaves, grain and straw increased significantly with an increase in the level of applied Cu and was maximum at 2.5 mg kg^{-1} Cu (Fig. 1). This is in accordance with the reports of Loneragan *et al.* (1980) and Kumar *et al.* (1990). The percent increase in Cu concentration at 2.5 mg kg^{-1} Cu was 40.0, 38.8 and 46.1 respectively in leaves, grain and straw.

The application of Cu significantly reduced the Fe content in the leaves and the magnitude of reduction was 10.3% with the application of 2.5 mg kg^{-1} Cu over control (Fig. 2). The results are in agreement with those of Brar and Sekhon (1978) who observed that excess Cu antagonistically affect the translocation of Fe from stem to the leaves. However, no such effect was seen in the Fe content of grains and straw which showed only slight variation with the increasing Cu levels (Fig. 2).

The concentration of Mn in leaves, grain and straw was higher at lower levels of Cu and insignificantly decreased at higher levels of Cu (Fig. 3). Hulagur and Dangarwala (1982) have reported a decrease in Mn uptake on Cu application in maize plants grown in a loamy sand soil.

The application of Cu did not affect the concentration of Zn in the leaves of wheat plants at lower levels of Cu but at higher levels of Cu (2.0 and 2.5 mg kg^{-1}), the Zn concentration decreased significantly (Fig. 4). The antagonistic effect of Cu and Zn on plant growth has been well documented (Arora and Sekhon, 1982; Dangarwala, 2001). However, no such effect was observed in Zn concentrations of grain and straw of wheat plants.

The present findings thus suggest that Cu fluxes and it's interactions with other micronutrients (Fe, Mn and Zn) affect the growth and yield of wheat plants. Application of Cu in excess amount may induce the deficiency of other micronutrients and adversely affect the yield. Hence, judicious and adequate amendment of Cu can contribute to a great deal in enhancing the yield of wheat crop, especially in Cu-responsive alkaline alluvial soils of India.

References

Agarwala, S.C. and C.P. Sharma: Plant nutrients – their functions and uptake. *In*: Soil Fertility – Theory and Practice (*Ed.*: J.S. Kanwar). I.C.A.R., New Delhi. pp. 7-64 (1976).

Agarwala, S.C. and C.P. Sharma: Recognizing Micronutrient Disorders of Crop Plants on the Basis of Visible Symptoms and Plant Analysis. Botany Department, Lucknow University, Lucknow (1979).

Arora C.L. and G.S. Sekhon: The effect of soil characteristics in the zinc-copper interaction in the nutrition of wheat. *J. Agric. Sci.*, **99**, 185-189 (1982).

Brar, M.S. and G.S. Sekhon: Effect of zinc and copper application on the yield and micronutrient content of wheat. *J. Ind. Soc. Soil Sci.,* **26**, 84-86 (1978).

Dangarwala, R.T.: Need for sustaining balanced supply of micronutrients in soil rather than their correction. *J. Ind. Soc. Soil Sci.*, **49**,647-652 (2001).

Hulagur, B.F. and R.T. Dangarwala: Effect of zinc, copper and phosphorus fertilization on the uptake of iron, manganese and molybdenum by hybrid maize. *Madras Agric. J.*, **69**, 11-16 (1982).

Jackson , M.L.: Soil Chemical Analysis. Constable and Co. Ltd., London (1958).

Katyal, J.C. and S.C. Agarwala: Micronutrient research in India. *Fertil. News*, **27**, 66-86 (1982).

Kumar, V., D.V. Yadav and D.S. Yadav: Effect of nitrogen sources and copper levels on yield, nitrogen and copper contents of wheat. *Plant Soil*, **126**, 79-83 (1990).

Lindsay, W.L.: Inorganic phase equilibria of micronutrients in soils. *In*: Micronutrients in agriculture. Soil Sci. Soc. Am., Madison, W.I. pp. 41-57 (1972).

Lindsay, W.L. and W.A. Norvell: Development of a DTPA soil test for zinc, iron, manganese and copper. *Soil Sci. Soc. Am. J.*, **42**, 421-428 (1978).

Loneragan, J.F., K. Snowball and A.D. Robson: Copper supply in relation to content and redistribution of copper among organs of the wheat plant. *Ann. Bot.,* **45**, 621-632 (1980).

Malevar, G.U.: Micronutrient stresses in soils and crops: Serious sickness and clinical approaches for sustainable agriculture. *J. Ind. Soc. Soil Sci.*, **53**, 484-499 (2005).

Marschner, H.: Mineral Nutrition of Higher Plants. Academic Press, London (1995).

Mehrotra, N.K.: Productivity constraints of U.P. soils : Nutritional aspects – an overview. *In*: Management of productivity constrained U.P. soils (*Eds*.: N.K. Mehrotra and V.K. Garg). Proc. Seminar 1992, Lucknow Chapter, Indian Society of Soil Science, Lucknow. pp. 9-19 (1993).

Nambiar, E.K.S.: Genetic differences in the copper nutrition of cereals. I. Differential responses of genotypes to copper. *Aust. J. Agric. Res.,* **27**, 453-463 (1976).

Patel, K.P. and M.V. Singh: Copper research and agricultural production. *In*: Micronutrient research and agricultural production *(Ed.*: H.L.S. Tandon). Fertiliser Development and Consultation Organisation, New Delhi. pp. 38-56 (1995).

Piper, C.S.: Soil and Plant Analysis. Monograph, Waite Agric. Res. Inst., The Univ. Adelaide, Adelaide (1942).

Robson, A.D. and D.J. Reuter: Diagnosis of copper deficiency and toxicity. *In*: Copper in soils and plants (*Eds.*: J.F. Loneragan, A.D. Robson and R.D. Graham). Academic Press, Sydney, Australia. pp. 287-312 (1981).

Sakal, R.: Efficient management of micronutrients for sustainable crop production. *J. Ind. Soc. Soil Sci.*, **49**, 593-608 (2001).

Sharma, B.L. and P.N. Bapat: Levels of micronutrients cations in various plant parts of wheat as influenced by zinc and phosphorus application. *J. Ind. Soc. Soil Sci.*, **48**, 130-134 (2000).

Sharma, J.C. and S.K. Chaudhary: Vertical distribution of micronutrient cations in relation to soil characteristics in lower shivaliks of Solan district in North-West Himalayas. *J. Ind. Soc. Soil Sci.*, **55**, 40-44 (2007).

Sharma, R.K. and M. Agarwal: Biological effects of heavy metals: An overview. *J. Environ. Biol.,* **26,** 301-313 (2005).

Singh, Dharam, Kamlesh Nath and Yogesh Kumar Sharma: Response of wheat seed germination and seedling growth under copper stress. *J. Environ. Biol.*, **28**, 409-414 (2007).

Tiwari, K.N. and S. Tiwari: Management of mineral stress in soils of Uttar Pradesh. *In*: Management of productivity constrained U.P. soils (*Eds.*: N.K. Mehrotra and V.K. Garg). Proc. Seminar 1992, Lucknow Chapter, Indian Society of Soil Science, Lucknow. pp. 84-93 (1993).

Zengin, Fikriye Kirbag and Sevda Kirbag: Effects of copper on chlorophyll, proline, protein and abscisic acid level of sunflower (*Helianthus annuus* L.) seedlings. *J. Environ. Biol.,* **28**, 561-566 (2007).