

Toxic Effect of copper on growth, yield, Photosynthetic Pigments and Mineral composition of wheat plants (*Triticum aestivum* L.)

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ABSTRACT

A pot experiment was conducted with six different concentrations of copper (Cu) viz., 0, 10, 20, 30, 40 and 50 (ppm) to determine the response of wheat plants grown in earthen pots lined with polythene bags under glass house conditions. The growth attributes like plant height, fresh and dry weight yield, percent dry matter enhanced with increasing Cu concentrations and was maximum at 30 (ppm) Cu while the number of tillers was minimum at this level. The grain yield at 30 (ppm) Cu was enhanced by 65.2% from the control. The increase in weight of 1000 grains ranged from 45.95 to 48.49 g in comparison to control (3205 g). Harvest index (%) also increased and ranged from 42.49 to 49.50 in different treatments in comparison to control (39.99). Both 1000 grain weight and harvest index were maximum in the plants at 30 (ppm) 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 11.5% at 50 (ppm) 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 (40 and 50 ppm) in leaves and remained unaffected in the grain and straw.

Keywords: Growth, Yield, Photosynthetic Pigments, Mineral Composition, Wheat, Cu, Toxicity

1. INTRODUCTION

Micronutrient deficiency has become a major constraint for crop productivity in many Pakistani 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 parts of punjab (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 Pakistan, 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). The present study was conducted to examine the effect of different exogenously applied concentrations of Cu on the growth, yield, photosynthetic pigments and mineral composition in various parts of wheat in pot culture.

2. EXPERIMENTAL

A pot experiment was conducted with wheat (*Triticum aestivum* Faisalabad 2008) in the botanical garden, department of biological sciences university of Sargodha. Some physicochemical characteristics of the soil were: texture- sandy loam, pH (1:50 soil water extract) 8.6, EC₂ 0.20 dSm⁻¹, organic matter 0.67%, CaCO₃ 0.80%, diethylene triamine penta acetic acid (DTPA) extractable Cu, Fe, Mn and Zn were 1.1, 8.4, 7.8 and 1.7Dg 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 and Zn in DTPA extract (Lindsay and Norvell, 1978). A basal treatment of 200 ppm soil as Ca (NO₃), 100 mg kg⁻¹ soil as KH₂PO and 100 mg kg⁻¹ soil as MgSO₄ was applied to all the pots. The different micronutrients, like Fe, Mn, Zn, B and Mo were applied @ 10, 10, 1,1 and 10 ppm, respectively

through their AR grade salt solutions, $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, $\text{MnSO}_4 \cdot 4\text{H}_2\text{O}$, $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$, $\text{NaBO}_3 \cdot 10\text{H}_2\text{O}$ and $(\text{NH})_2\text{MoO}_4 \cdot 4\text{H}_2\text{O}$, respectively. The experiment was conducted in completely randomized design. There were six treatments comprising 6 levels of Cu (0, 10, 20, 30, 40 and 50 mg Cu kg^{-1} soil). Cu treatments were given through addition of varying amounts of AR grade salt solutions of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$. 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 analysis. 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.

3. RESULTS AND DISCUSSIONS

Plant growth, fresh and dry matter yield: The increase in plant height was maximum (23%) at 30 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 30 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 30 mg kg^{-1} Cu at 80 days of growth (Table 1). At levels higher than 30 ppm Cu, the shoot dry matter yield decreased slightly in agreement with the reports of Kumar et al. (1990) in wheat plants.

Table-1: Toxic Effect of different increasing concentrations of copper on growth parameters of wheat at seedling stage

Cu applied Ppm	Plant Height (cm)	Number of tillers /plant	Shoot fresh weight (g/pot)	Shoot dry weight (g/pot)	Percent dry weight %
0	1.09	0.21	1.29	0.28	5.68
10	1.03	0.18	1.23	0.29	5.63
20	1.16	0.21	1.39	0.32	5.60
30	1.02	0.19	1.26	0.26	5.45
40	1.01	0.15	1.19	0.24	5.38
50	1.00	0.13	1.17	0.21	5.18
SE (difference)					

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

Table-2: Toxic Effect of different increasing concentrations of copper on the grain yield attributes, straw yield and harvest index of wheat

Cu applied Ppm	Length of main ear (cm)	Number of ears/plant	Number of grains /ear	Grain yield (g/pot)	Straw yield (g/pot)	1000 grains weight.(g)	Harvest index (%)
0	7.7	1.9	11.6	4.99	8.88	33.68	36.96
10	8.8	1.8	15.8	5.48	7.77	36.07	42.39
20	9.5	1.3	13.7	5.46	6.66	39.52	43.99
30	10.5	1.7	18.00	7.42	4.90	42.75	46.76
40	8.8	1.6	16.5	5.55	0.96	34.75	41.81
50	8.2	1.5	17.1	3.90	5.48	34.94	40.52
SE (difference)							
CD ($p=0.05$)							

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

Table-3: Toxic Effect of different increasing concentrations of copper on Photosynthetic pigments

Cu applied	Chlorophyll a	Chlorophyll b	Chlorophyll a+b	Carotenoids	Chlorophyll a/b
0	1.09	0.21	1.29	0.28	5.68
10	1.03	0.18	1.23	0.29	5.63
20	1.16	0.21	1.39	0.32	5.60
30	1.02	0.19	1.26	0.26	5.45
40	1.01	0.15	1.19	0.24	5.38
50	1.00	0.13	1.17	0.21	5.18
SE (difference)					

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

Grain yield attributes and straw yield: The length of the main ear was significantly increased in plants applied with 20 ppm and 30 ppm 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 30 and 40 ppm Cu levels. The grain yield was maximum in the plants at 30 ppm Cu level and it was 62.9% higher than the control plants. However, the grain yield was reduced by further addition of Cu at 40 mg kg⁻¹ and 50 mg kg⁻¹. The weight of 1000 grains and harvest index were also increased significantly in plants at 30 ppm Cu (Table-2).

The grain yield enhancement at 30 ppm 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 40 and 50 ppm 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 Mineral composition The Cu concentrations in leaves, grain and straw increased significantly with an increase in the level of applied Cu and was maximum at 50 mg kg⁻¹ Cu. This is in accordance with the reports of Loneragan et al. (1980) and Kumar et al. (1990). The percent increase in Cu concentration at 50 ppm 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 50 ppm Cu over control. 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.

The concentration of Mn in leaves, grain and straw was higher at lower levels of Cu and insignificantly decreased at higher levels of Cu. 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 (40 and 50 ppm), the Zn concentration decreased significantly. 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 its 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, in Pakistan.

4. REFERENCES

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