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# Zinc and copper uptake by plants under two transpiration rates. Part I. Wheat (*Triticum aestivum* L.)

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*Cu and Zn levels normally found in treated wastewater may be beneficial rather than toxic to wheat plants.*

**Abstract**

To evaluate the environmental risk of irrigating crops with treated wastewater, an experiment was conducted using two growth chambers, each offering a different vapour pressure deficit (VPD) for high and low transpiration rates (TR), respectively. One of the two sets of 24 pots planted with 6 week old wheat (*Triticum aestivum* L.), was placed in each growth chamber, and irrigated in triplicates for 20 days with 8 Zn and Cu solutions (0 and 25 mg Zn/L combined with 0, 5, 15 and 30 mg Cu/L). Water losses from planted and non-planted pots served to measure evapo-transpiration and evaporation, respectively. Pots were monitored for Cu and Zn uptake by collecting three plants (shoot and grain)/pots after 0, 10 and 20 days, and roots in each pot after 20 days, and analyzing these plant parts for dry mass, and Cu and Zn levels. Transpiration rate was not affected by any Cu/Zn treatment, but Cu and Zn uptake increase with the time, irrigation solution level and higher TR, with the roots retaining most Cu and Zn, compared to the shoot followed by the grain. For the shoot and grain, Cu had a significant synergetic effect on Zn uptake, when Zn had slight but insignificant antagonistic effects on Cu uptake. For the roots, Cu and Zn had significant synergetic effect on each other. Regression equations obtained from the data indicate that Cu and Zn levels normally found in treated wastewater (0.08 mg/L) are 300 times lower than those used for the most concentrated experimental solutions (30 and 25 mg/L, respectively) and may, on a long term basis, be beneficial rather than toxic to wheat plants and do not acidify soil pH.


*Keywords:* Copper; Zinc; Wheat; Uptake; Transpiration rate

## 1. Introduction

High-yielding cereal varieties and irrigation have significantly contributed to the dramatic rise in world food production over the past 40 years. Since world expansion of cultivated lands has ended, irrigation practices are more important, but have made water shortage a chief physical constraint to crop production. Treated wastewater can play an important role in providing an important source of irrigation water, although it can also contain a significant amount of heavy metals and their plant uptake must be limited (FAO, 1985). There are growing concerns that the consumption of foodstuffs containing unacceptably high levels of heavy metals may lead to chronic toxicity (Wagner, 1993). Copper (Cu) and zinc (Zn) are easily taken-up by plants and transported to different parts,

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posing, through the food chain, a potential health hazard for livestock and humans.

Plant heavy metal uptake depends mostly on soil speciation or that portion of heavy metal dissolved as ions in the soil solution. This portion depends heavily on the soil-binding agents, especially soil organic matter and also hydrous ferric and manganese oxides and carbonate (Sauvé et al., 2000). Therefore, heavy metals applied as sludge are less likely to be mobile than heavy metals applied in irrigation water. Soil pH also influences the solubility of the heavy metal, and therefore their uptake, as Cu for example, binds with $OH^-$ ions at higher pH, to precipitate. Where a multitude of heavy metals are present and available, synergetic effects can arise and affect not only plant uptake but also translocation within the plant (Luo and Rimmer, 1995). Interaction between Zn and Cu has been reported by Beckett and Davis (1978) using barley where Zn and Cu produced a slight antagonistic effect on each other and by Sanders et al. (1987) where Cu had no significant effect on Zn uptake by red beets. Luo and Rimmer (1995) reported that barley growth was mainly regulated by plant available Zn and Cu and, that Cu increased the toxic effect of Zn. Jalil et al. (1994) showed that Zn accumulation in shoots and roots was decreased by adding cadmium (Cd).

The present experiment was designed to investigate Cu and Zn plant uptake and interaction when used to irrigate wheat plants. Uptake of Cu and Zn in the shoot, grain and roots was monitored under two transpiration rates (TR), using irrigation water containing Cu and Zn singly and in combination, to investigate:

(i) the interaction between Zn and Cu in their uptake by wheat;
(ii) which part of the wheat plant absorbs the most heavy metal.

Wheat (*Triticum aestivum* L.) has been selected for this test as it is now produced in Africa and Asia, and its consumption is increasing faster than that of rice (FAO, 1996). Most of the wheat grown in these regions must be irrigated (Khush, 1999).

Table 1
Chemical and physical properties of the experimental sand

| Parameter | Unit | Value |
|---|---|---|
| *Particle size* | | |
| > 1.0 mm | % | 5 |
| 1.0–0.5 mm | % | 55 |
| 0.5–0.25 mm | % | 38 |
| < 0.10 mm | % | 2 |
| *Soil analysis* | | |
| P | mg/kg | 173 |
| K | mg/kg | 222 |
| Mg | mg/kg | 4 |
| Ca | mg/kg | 4100 |
| Al | mg/kg | 545 |
| Zn | mg/kg | 0.73 |
| Cu | mg/kg | 0.92 |
| B | mg/kg | 0.3 |
| Mn | mg/kg | 1.4 |
| pH | | 7.0 |
| Organic matter | % | 4.0 |
| CEC | $cmol^{(+)}/kg$ | 2.02 |

## 2. Materials and method

### 2.1. Initial growth conditions

The wheat plants were grown in 48 polyethylene pots, measuring 160 mm in height and 155 mm in inside diameter. These pots were lined with an impermeable plastic bag, and filled with 1.5 kg of dry sand wetted to field capacity with 300 ml of distilled water. This soil was obtained from the B-horizon of an Upland series soil profile consisting of 1.2 m of sand overlying marine clay. The sand particle size ranged mainly between 0.25 and 0.5 mm, with 10% (w/w) larger than 0.5 mm and 35% smaller than 0.25 mm. The experimental soil offered a pH of 7.0, rich levels of available P and K at 173 and 222 mg/kg, respectively, and a low cation exchange capacity (CEC) of 2.02 $cmol^{(+)}/kg$, with almost no (0.4%) organic matter (Table 1). Except for the high soil pH, the experimental soil offered a low absorption capacity to maintain a high level of heavy metal solubility, after irrigation. Levels of available

Table 2
Levels of heavy metals typically found in wastewater, irrigation water and crops and tolerated by livestock (Reed et al., 1995)

| Heavy metal | Level of heavy metal | | Regulatory limits[a] | | |
|---|---|---|---|---|---|
| | Raw wastewater (mg/L) | Irrigation water (mg/L) | Irrigation water (mg/L) | Crops (mg/kg) | Livestock feed (mg/kg) |
| Cd | 0.005 | 0.001 | 0.01 | 5–700 | 0.5 |
| Pb | 0.008 | 0.001 | 5 | 2–5 | 30 |
| Zn | 0.04–0.08 | 0.04–0.08 | 2 | 15–150 | 500–1000 |
| Cu | 0.18 | 0.082 | 0.2 | 25–40 | 25–300 |
| Ni | 0.04 | 0.006 | 0.02 | 50–100 | 50–300 |

[a] Recommended limit to prevent toxic effect.