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Zinc and copper uptake by plants under two transpiration rates. Part II. Buckwheat (*Fagopyrum esculentum* L.)

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

Abstract

To evaluate the environmental risks of irrigating crops with treated wastewater, a study was undertaken to quantify heavy metal uptake by 4-week old buckwheat (*Fagopyrum esculentum* L.) plants during 18 days of irrigation with 8 different Cu and Zn solutions under two transpiration rates (TR). At 4 weeks, potted buckwheat plants were transferred into one of the two growth chambers, offering either a high or low vapour pressure deficit (VDP) for, respectively, a high or low TR. Triplicate pots received one of the 8 irrigation treatments containing one of two Zn levels (0 and 25 mg/L) combined with one of four Cu levels (0, 5, 10 and 15 mg/L). Daily TR were measured by weighing the evapo-transpired water lost from the planted pot, less was the evaporation loss measured from triplicate non-planted pots. After 0, 6, 12 and 18 days of treatment, the stems and leaves of three randomly selected plants were harvested and after 18 days, the roots were harvested to determine Cu and Zn uptake. The treatments did not affect TR in terms of dry plant mass, indicating the absence of toxic effects. Irrigating with Zn, without Cu, increased dry biomass production, whereas the lowest biomass occurred with 15 and 30 mg/L of Cu with and without 25 mg/L of Zn, respectively, because higher applications of heavy metal significantly reduced soil pH. Plant Cu and Zn uptake increased with TR. With higher levels of Cu, Zn uptake by buckwheat was significantly reduced, while Zn had a slight but non-significant impact on Cu uptake. Previously and in a study exposing wheat plants to the same conditions, Cu significantly increased Zn uptake, while Zn had a slight but insignificant negative effect on Cu uptake. The buckwheat roots contained the greatest levels of Cu and Zn, indicating their role in moderating heavy metal uptake. Also, both Cu and Zn had a synergetic effect on each other in terms of root levels, and a similar observation was made in the earlier similar experiment using wheat plants. Irrigating a buckwheat crop with treated wastewater, with more natural Cu and Zn levels of 0.08 mg/L, could be quite beneficial without endangering the quality of the crop and acidifying the soil pH. The most concentrated experimental solutions contained 300 times more Cu and Zn, to obtain measurable differences.

Keywords: Contamination; Buckwheat; Copper; Heavy metal; Transpiration; Zinc

1. Introduction

In many parts of the world, water scarcity has been limiting agricultural production (Postel, 1996) as this sector demands about 70% of global fresh water resources (World Resource Institute, 1995) and irrigated crops represent nearly 40% of world food production, yet covers 17% of cultivated land area. The use of treated wastewater for irrigation can alleviate this water shortage increasing with world population and industrial needs. However, even after conventional biological treatment, treated urban wastewater still contains heavy

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metals (Tam and Wong, 1996), which may constitute a hazard not only to the crop, but also to the consumers (Smith and Cook, 1996; Kastori et al., 1992).

The factors controlling speciation and thus mobility and plant uptake of heavy metals are first of all soil pH and organic matter, soil cation exchange capacity (CEC) along with its carbonate and oxides, and the levels of heavy metals in the soil solution (Williams et al., 1987; Alloway and Jackson, 1991; Smith, 1994; Cancès et al., 2003). Above a pH of 6.0, heavy metal precipitation results from the complexes they form with free hydroxides and carbonate (Tyler and Olssan, 2001).

In an earlier experiment, wheat (*Triticum æstivum* L.) plants were exposed to two transpiration rates (TR) and 8 different irrigation solutions, each containing Cu and Zn, singly or in combination. The present experiment was designed to investigate the Cu and Zn uptake of another crop, buckwheat (*Fagopyrum esculentum* L.), exposed to the same conditions. As for wheat, this experiment investigated:

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

Buckwheat was used in this second experiment because it is a popular crop often used in poor and acidic soil, making it even more susceptible to heavy metal uptake (Marshal and Pomeranz, 1984; Pomeranz, 1984) than wheat which requires a high soil pH and richer soil conditions.

2. Materials and methods

2.1. Experimental material

The experiment was conducted using 4-week old buckwheat plants, grown in a glass greenhouse at the Macdonald Campus of McGill University, Montreal, Canada. Some 24 buckwheat seeds were planted in 155 mm diameter polyethylene pots each filled with 1.5 kg of dry sand wetted to field capacity with 300 ml of tap water. The sand was held in a plastic bag to prevent any leakage and to be able to conduct a water mass balance analysis later on, in the growth chambers. A total of 48 pots were seeded to evaluate in triplicate, 8 irrigation treatments exposed to two TR. Each pot was seeded with 24 wheat seeds treated with the fungicide Captan (*N*-trichloromethyl-4-cyclohexene-1,2-dicarboximide). At emergence, all pots were thinned down to 18 plants, for a uniform plant population among treatments.

The pots were irrigated with a fertilized solution once every 2 weeks, from plant emergence onwards, at a rate of 135 mg/pot each of N, P and K or at a rate of 76 kg/ha. The fertilizer also contained traces of heavy metals, but these were insignificant as compared to the treatments. At the end of the fourth week, when the plants had reached a height of 0.65–0.68 m, they were transferred to the growth chambers.

The experimental soil was a sand obtained from the B-horizon of a soil profile of the Upland series, which consists of 1.2 m of sand overlying a marine clay. The particle size distribution of the sand ranged mainly between 0.25 and 0.5 mm, with 10% of its mass larger than 0.5 mm and 2% smaller than 0.10 mm. This sand that had a pH of 7.0, was relatively rich in available P and K (173 and 222 mg/kg of dry soil), had a low cation exchange capacity of 2.02 $cmol^{(+)}$/kg (Tani and Barrington, submitted for publication) and offered a very low level of organic matter at 0.4%. This experimental sand was selected because of its low CEC and organic matter, therefore its low heavy metal absorption capability. The neutral soil pH was high enough to counter balance the negative effect on plants, of the low pH (5.5) of the irrigation solutions. Nevertheless, this high soil pH contributed to the precipitation of the heavy metal applied early in the experiment.

At 4 weeks after emergence, 24 treatment pots and 3 non-planted pots were transferred to each of two identical growth chambers (Model E15, Conviron Ltd., Winnipeg, Manitoba, Canada). One of the growth chamber was maintained at a relative humidity (RH) of 70%, while the other was maintained at a RH of 90%, leading to vapour pressure deficits (VPD) of 0.530 and 0.265 kPa, respectively, and a high and low TR for a daytime temperature of 22 °C. A 12 h day, 12 h night cycle was imposed, with a daytime lighting intensity of 250 μ lux at the top of the canopy. The chamber had an available floor area of 1.5 m^2 (1.0 m × 1.5 m) and pots were randomly arranged on a rectangular grid 50 mm apart, rim-to-rim, in both directions. The two growth chambers were controlled at 16 and 22 °C during the night and day periods.

Copper and Zn solutions were prepared from $ZnCl_2$ and $CuCl_2$ salts dissolved in distilled water. The natural pH of these solutions was relatively low (5.5), and thus, soil pH was measured at the end of the experiment. Irrigation treatments used two levels of Zn (0 and 25 mg/L) combined with four levels of Cu (0, 5, 15 and 30 mg/L): Cu_0/Zn_0, Cu_0/Zn_{25}, Cu_5/Zn_0, Cu_{15}/Zn_0, Cu_{30}/Zn_0, Cu_5/Zn_{25}, Cu_{15}/Zn_{25}, Cu_{30}/Zn_{25}. The quantities of metal used in the irrigated waters were more concentrated than normally found in raw and treated wastewater (Tani and Barrington, submitted for publication), to have a measurable impact on the Cu and Zn plant content, without causing any toxic effects.