Manganese Toxicity and Tolerance in Sweetpotato

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Abstract. The effects of 0.25, 1.0, 2.5, 10, and 100 mg Mn/liter on sweetpotato [*Ipomoea batatas* (L.) Lam] were evaluated in a greenhouse during 2 years using the nutrient film technique. Foliage and storage root dry weights declined linearly as Mn concentration increased in either whole plants or fibrous roots. Foliage and storage root dry weights were equally sensitive to Mn concentration in whole plants but 5 to 15 times more sensitive to increased Mn concentration in the fibrous roots. Foliar N, P, K, Ca, and Mg concentrations were adequate and did not appear to limit plant growth. Manganese concentrations in solution had very little effect on Fe, Zn, or B concentration. Manganese concentration was higher in the foliage than in fibrous roots. Plant roots showed browning at the higher (10 or 100 mg Mn/liter) concentrations in solution, which indicated the presence of oxidized Mn. Characteristic toxicity symptoms were observed in plants receiving 2.5 (moderate), 10, or 100 mg Mn/liter in solution.

Manganese is an essential element for plant growth. Previous work on Mn toxicity has shown that >1 mg Mn/liter in solution was toxic to tobacco (*Nicotiana tabacum* L.) (Jacobson and Swanback, 1932) and potato (*Solanum tuberosum* L.) vines (Berger and Gerloff, 1947). Mishra and Kelly (1967) reported maximum growth of sweetpotato with 0.031 mg Mn/liter in solution, but growth declined significantly at higher concentrations.

Manganese distribution between foliage and roots varies among genotypes (Horiguchi, 1987; Horst, 1980; Reddy and Mills, 1991; Vlamis and Williams, 1964). For example, Horiguchi (1987) reported that rice (*Oryza sativa* L.) and pumpkin (*Cucurbita pepo* L.) accumulated higher amounts of Mn in foliage than in roots regardless of Mn concentrations in solution. In contrast, Mn concentrations were higher in roots than in the foliage of alfalfa (*Medicago sativa* L.), tomato (*Lycopersicon esculentum* Mill.), and barley (*Hordeum vulgare* L.). Variability in Mn distribution between foliage and roots has been attributed to the tolerance mechanism of shoots to high Mn concentrations (Horst, 1980) or to the formation of metal complexes (Fey et al., 1978) and not to reduced uptake of Mn (Horst, 1980).

Although Mn distribution between foliage and roots has been documented for other crop species (Horst, 1980; Reddy and Mills, 1991), to our knowledge, no information is available

for sweetpotato. In addition, although there is available information on Mn deficiency, sufficiency, and toxicity in sweetpotato, again, to our knowledge, no information on sweetpotato tolerance to Mn exists.

The objective of this study was to evaluate early growth response of sweetpotato to various Mn concentrations in culture solution and to determine the level of plant tolerance.

Experiments were conducted in a greenhouse during 2 years to evaluate early growth of sweetpotato using the nutrient film technique to test tolerance to or toxicity of various Mn concentrations. Four vine cuttings (15 cm long) of the breeding clone TU-82-155 were grown in rectangular channels [0.15 × 0.15 × 1.2 m (Morris et al., 1989)] using five concentrations of Mn in a randomized complete block design with two replications.

Each channel was supplied by a 30-liter reservoir. A modified half-strength Hoagland nutrient solution (Hoagland and Amen, 1950) was used. The solution was essentially that of Hoagland and Arnon, except that calcium nitrate was replaced by calcium chloride to achieve a 1 N : 2.4 K ratio. The nutrient solution pH was maintained between 5.5 and 5.6 by adding dilute (1 N) HCl or NaOH and was changed at 2-week intervals. Nutrient solution was pumped from each reservoir to the high end of each channel by small submersible pumps (Teel Model 1P680 A, 1/200 horse power; Dayton Electric, Chicago). The channels had a 1% slope toward each reservoir. The nutrient solution spread across each growing channel in a thin film as it flowed back to each reservoir. The flow rate was set at 1 liter·min⁻¹ by using a bypass line back to each reservoir with a control valve (Mortley et al., 1991). Each of the four vine cuttings was held in place by a flat-plate assembly (Morris et al., 1989) attached to the sides of the channels by a flexible black-and-white vinyl covering.

Plants were grown in complete nutrient solution for 28 days, after which the treat-

ments consisting of 0.25, 1.0, 2.5, 10, and 100 mg Mn/liter were initiated. These concentrations were used to achieve a range of Mn concentrations in the plants. The source of Mn was MnCl₂. Plants were grown in treatment solutions for an average of 43 days, after which they were harvested and separated into foliage and roots (storage and fibrous roots), dried for 48 h at 70°C, and weighed. Plant and fibrous root samples were ground and analyzed for Mn, along with concentrations of N, P, K, Ca, Mg, Fe, Zn, and B, by the Plant and Soil Testing Laboratory at Auburn Univ. (Hue and Evans, 1986). To test for deposition of oxidized Mn, the benzidine and oxalic-sulfuric acid solution assays were done according to Horiguchi's method (1987).

The experiment was repeated and the data were combined and analyzed by regression analyses using the general linear models procedure (SAS Institute, 1985).

Foliage and storage root dry weights declined linearly in response to increasing concentration of Mn in whole plants (Fig. 1) and in the fibrous roots (Fig. 2). For the latter, the

Fig. 1. Relationship of foliage and storage root dry weights to Mn concentration in whole plants of sweetpotato grown using nutrient film technique. The relationship is described by $Y = 21.8450 - 0.1686x$, $r^2 = 0.40$, $P < 0.0001$ for foliage and $Y = 14.1841 - 0.0043x$, $r^2 = 0.224$, $P < 0.006$ for storage roots.

Fig. 2. Relationship of foliage and storage root dry weights to Mn concentration in fibrous roots of sweetpotato grown using nutrient film technique. The relationship is described by $Y = 22.4570 - 0.0151x$, $r^2 = 0.427$, $P < 0.0001$ for foliage and $Y = 13.4264 - 0.0579x$, $r^2 = 0.226$, $P < 0.006$ for storage roots.

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decrease for storage roots was greater, as indicated by the steep slope showing that storage root growth was severely restricted; thus, root and foliage dry weights declined 83% and 28%, respectively. Ohki (1981) defined critical toxicity level as the Mn concentration in leaf blades of 'Bragg' soybeans (*Glycine max* L.) associated with a 10% reduction in dry matter production due to toxicity. Thus, based on this criterion and the slopes of the regression lines, foliage and storage root dry weights were equally sensitive to increased Mn concentrations in whole plants but 5 to 15 times more sensitive to increased Mn concentrations in the sweetpotato fibrous roots. Although Mn concentrations in whole plants are higher than established leaf concentrations for sweetpotato (Jones et al., 1991), these results could enable better understanding of plant nutritional needs and mineral diagnosis.

Roots browned with 10 or 100 mg Mn/liter in the solution, excessive browning was especially evident in roots of plants receiving 100 mg Mn/liter. Browning was darker near the root tips and progressed upward, becoming localized on the older roots.

Plants receiving nutrient solutions with 2.5, 10, or 100 mg Mn/liter exhibited toxicity symptoms, which were more severe at the highest Mn level in the solution. Initial symptoms included interveinal and marginal yellowing along with brown necrotic spotting. As symptoms progressed, leaves eventually senesced and were shed. Plants also exhibited markedly stunted growth, especially at the highest Mn concentration in the nutrient solution. Foliage concentrations of N, P, K, Ca,

and Mg (data not shown) were generally adequate or exceeded the concentrations associated with optimum growth (Jones et al., 1991).

Manganese concentration and accumulation were higher in foliage than in fibrous roots. This finding is consistent with those of Horst (1980) with cowpea (*Vigna* sp.), Reddy and Mills (1991) with marigold (*Tagetes erecta* L.), and Horiguchi (1987) with rice and pumpkin. Manganese tolerance in some species has been attributed to various tolerance mechanisms of the shoots (Horst, 1980) or to the formation of metal complexes in the roots (Fey et al., 1978). Chino (1981) reported that metals with high electronegativity, such as Cu and Co, form stable bonds at the level of the roots and accumulate there, while low-electronegative metals, such as Mn and Zn, are translocated easily to the foliage of rice plants. This tolerance mechanism could partly explain the higher Mn accumulation in the foliage compared with the sweetpotato roots in this study.

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