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Interspecific Responses of Marigold to Manganese as Influenced by Nitrogen Source

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Abstract. **Responses of two hydroponically grown marigold species, *Tagetes erects* L. 'pumpkin Crush' and *T. patula* L. 'Janie Yellow', to Mn concentrations of 0.5 mg·liter^{-1} or 10 mg·1iter^{-1} with KNO_3 and $Ca(NO_3)_2$ (NO_3 source) or NH_4NO_3 as the N source were investigated. In both species, Mn uptake was enhanced with the NO_3 source while reduced with NH_4NO_3. With Mn supplied at 0.5 mg·liter^{-1} and NO_3 as the N source, *T. erects* absorbed twice the Mn per gram of dry matter as *T. patula. T. erecta* accumulated higher concentration of Mn in the shoot than in the root irrespective of the N source. *T. patula* accumulated higher concentration of Mn in the roots with the NO_3 source while NH_4NO_3 shifted the Mn accumulation to the shoot. Growth of both species was suppressed with 10 mg Mn/liter and the suppression was greater with the NO_3 source than with the NH_4NO_3. These results indicate an interspecific response to Mn concentration as well as an N source influence on the uptake of Mn in marigold grown under hydroponic conditions.**

Manganese-related abnormal growth was encountered in the production of marigold, with Mn toxicity occurring more intensely in some genotypes than in others (Biernbaum et al., 1988). The reason for this differential behavior of marigold genotypes to Mn toxicity was not known. Genotypic differences to Mn toxicity were observed in other plant species and were attributed to the tolerance mechanism of shoots to high Mn concentrations and not to reduced uptake of Mn by plants (Horst, 1980).

Biernbaum et al. (1988) recommended NO_3 (vs. NH_4) fertilization as a cultural practice to reduce the uptake of Mn by marigold. It is generally recognized that Mn availability in the soil is related to soil pH, with acidic soils having a higher concentration of Mn in the soil solution than alkaline soils. Since nitrate fertilization increases soil pH, use of this N source should result in a decreased concentration of Mn in the soil solution and consequently uptake by plants. However, nitrate or NH_4 influences not only the rhizosphere pH but also the uptake of other ions by plants (Barker and Mills, 1980), and this latter factor must also be considered independent of Mn availability to plants as a consequence of rhizosphere pH changes.

This study was conducted to evaluate the Mn uptake as influenced by plant species, Mn solution concentration, and N source in marigold grown under hydroponic conditions.

An experiment was conducted in the greenhouse in the spring (day/night cycle 25C/20C; natural day length, 13 h). Seeds of 'Pumpkin Crush' and 'Janie Yellow' marigolds (Park Seed Co., Greenwood, S. C.) were germinated in perlite and after 2 weeks transferred to 15-liter nutrient solution containers (four plants per container). The nutrient solution composition was (mg·liter^{-1}): 70 N, 20 P, 81 K, 72 Ca, 20 Mg, 2.5 Fe (as FeEDTA), and 0.5 each of B, Zn, Cu, and Mo. Nitrogen was supplied as all nitrate [as KNO_3 and $Ca(NO_3)_2$] or in a 50:50 ratio of NH_4 plus NO_3 (as NH_4NO_3). Manganese (as $MnCl_2$) was supplied at 0.5 or 10 mg·liter^{-1}. Each treatment was replicated three times in a randomized complete-block design. The nutrient solutions were changed weekly with evapotranspiration water losses replaced daily.

The pH of the fresh nutrient solutions was 5.5. The pH of the used nutrient solutions was measured at the end of each week. Nitrate nutrition increased the pH, whereas NH_4NH_3 nutrition decreased the pH. These changes were greater as the plant size increased. However, the pH values did not drop below 5 (with NH_4NO_3) or above 6 (with NO_3) in any week.

Manganese and N uptake was measured weekly as the difference between initial and final concentrations of these ions in the nutrient solutions. After 5 weeks in the solution culture, the plants were harvested with roots, shoots, and flowers separated, and their dry weights determined. The plant parts were ground through a 20-mesh screen in a Wiley mill and then dry-ashed for Mn determina-

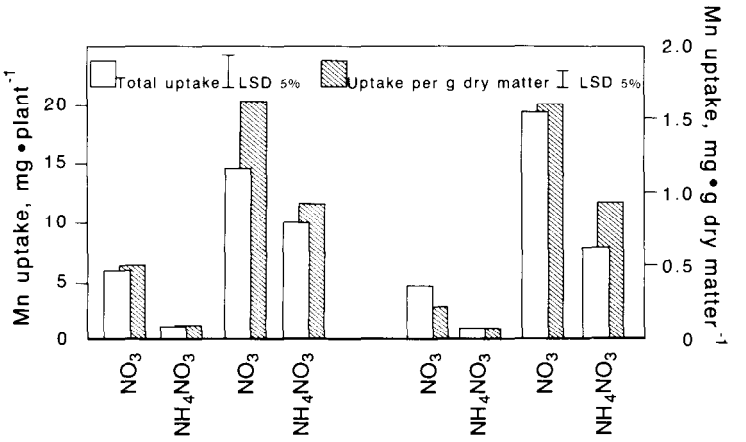

Fig. 1. Cumulative Mn uptake over 5 weeks by marigold species as influenced by Mn concentration and N source.

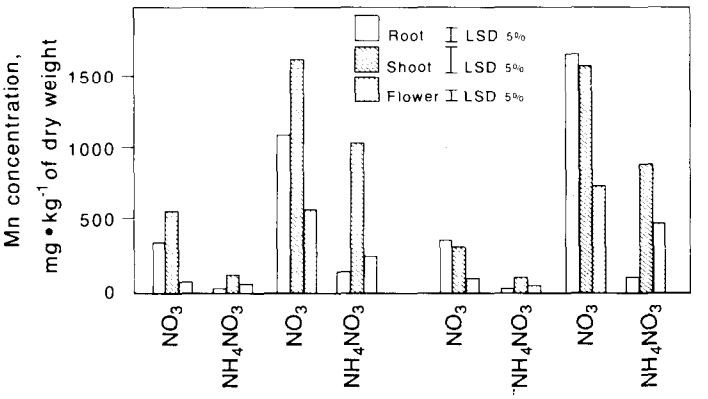

Fig. 2. Manganese concentration in plant parts of marigold species at harvest as influenced by Mn concentration and N source.

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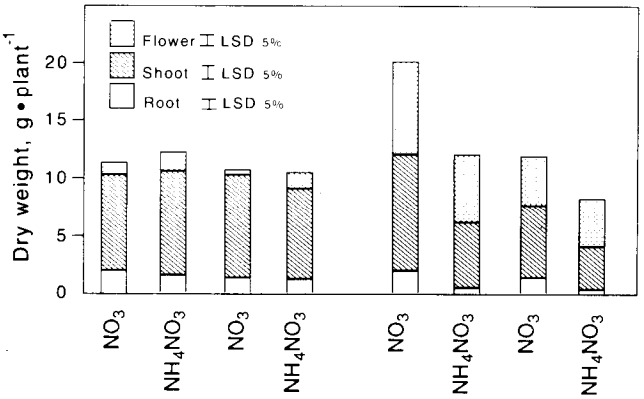

Fig. 3. Production and distribution of dry matter in marigold species as influenced by Mn concentration and N source.

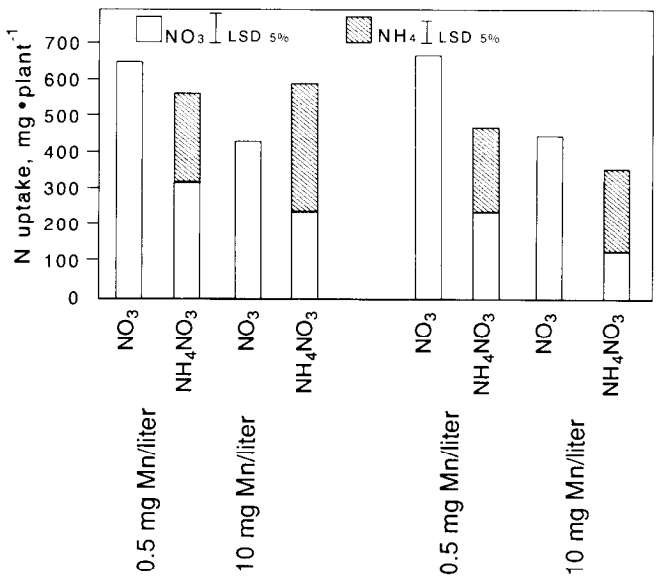

Fig. 4. Cumulative N uptake over 5 weeks by marigold species as influenced by Mn concentration and N source.

tion (Jones, 1985). Manganese in the nutrient solutions and plant tissues was determined by plasma emission spectrometry (Jones, 1985). Nitrate and NH_4 in the nutrient solutions and plant tissue N following the Kjeldahl digestion were determined calorimetrically using an AutoAnalyzer (Jones, 1985).

The data were analyzed by analysis of variance and the treatment means were compared by least significant difference. The trends of Mn and N uptake in each week were similar throughout the experiment; therefore, only the cumulative uptake data are presented.

In both species, the NO_3 source enhanced Mn uptake while NH_4NO_3 restricted Mn uptake (Fig. 1). When compared with the NO_3 source, NH_4NO_3 resulted in Mn uptake levels that were 75% lower in both species at 0.5 mg Mn/liter. At 10 mg Mn/liter, NH_4NO_3 resulted in 30% lower Mn uptake levels in *T. erecta* and 60% in *T. patula* compared with the NO_3 source. At 0.5 mg Mn/liter, Mn uptake per gram of dry matter by *T. erecta* was four times higher with the NO_3 source than with NH_4NO_3, while the corresponding Mn uptake by *T. patula* was two times higher. At 0.5 mg Mn/liter, when NO_3 was the only N source, *T. erecta* absorbed twice the Mn per gram of dry matter as *T. patula*. However, this capability by *T. erecta* to take up Mn was not evident with NH_4NO_3 or even with the NO_3 source at 10 mg Mn/liter.

T. erecta contained higher Mn concentration in shoots than roots, regardless of the N source (Fig. 2). However, Mn concentration in the roots and shoots of *T. patula* differed with the N source. With the NO_3 source, Mn concentration in the roots was higher than in the shoots, while with NH_4NO_3 Mn concentration was higher in the shoots. These results indicate that Mn accumulation in the shoots was influenced by the interaction of species × N source.

In both species, the ratio of root : shoot Mn concentration was higher with the NO_3 source, indicating that a greater proportion of Mn accumulated in the roots with the NO_3 only than with NH_4NO_3. The proportion of the Mn that accumulated in the roots more than doubled between 0.5 and 10 mg Mn/liter. Thus, Mn accumulation was not restricted to the shoot alone, and with excess Mn the roots also acted as a sink. The enhanced Mn uptake with both the NO_3 source and 10 mg Mn/liter resulted in the flowers also acting as a sink, with higher Mn concentrations found in the flowers.

At 10 mg Mn/liter, although typical Mn toxicity did not appear on either species, > 10% growth reduction was observed compared with 5 mg·liter^{-1} (Fig. 3). The reduction in growth was greater with the NO_3 source than with NH_4NO_3.

Both *T. erecta* and *T. patula* absorbed more N with the NO_3 source than with NH_4NO_3 at 0.5 mg Mn/liter (Fig. 4). At 10 mg·liter^{-1}, *T. erecta* absorbed more N with NH_4NO_3 while *T. patula* still absorbed more N with the NO_3 source. In both species, at 0.5 mg Mn/liter, the uptake of NH_4-N was 40% of the total N absorbed, but at 10 mg·liter^{-1} the uptake of NH_4-N increased to 60%.

From these results, it is evident that variable responses to Mn can occur in marigold depending on the genotype and N source. For example, under identical growing conditions when fertilized with KNO_3 and $Ca(NO_3)_2$, *T. erecta* would absorb higher Mn than *T. patula.*

It is also evident from these results that the NO_3 source enhanced Mn uptake under hydroponic conditions although solution pH increased. This result is contrary to the situation in soils. However, Korcak (1988) noted that the effect of pH on Mn uptake is influenced by the type of growth medium, with Mn uptake increasing with increasing pH in solution cultures and decreasing with increasing pH in soils. This difference may be due to the organic matter in soils. In soils, Mn maybe complexed with soluble organic matter, which is greater at higher pH. Hence, in soils as well as in other media amended with organic matter, NO_3 nutrition and accompanying pH rise may increase Mn complexion and thus decrease Mn uptake. In contrast, in hydroponics and media without organic matter and consequently Mn complexation, a NO_3 source may enhance, whereas NH_4 may lower, Mn uptake, as observed in this experiment. The decrease in Mn uptake when NH_4 was part of the N source may be due to the competition between both cations.

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