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Effects of different iron sources on mineral concentration in gardenia (*Gardenia jasminoides* Ellis) plants

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In the present paper, the nutrient concentration of plant organs, when different Fe sources were used in gardenia (*Gardenia jasminoides* Ellis) plants grown in a hydroponic medium containing 1 mg l^{-1} Fe, was studied. Three Fe sources were applied, namely sequestrene-138 (6% Fe, Fe-EDDHA), sequestrene-330 (10%Fe, Fe-DTPA) and $FeSO_4 \cdot 7H_2O$. The analytical data indicated that Fe and Zn concentrations in shoots were very low and were independent of the Fe source applied. Furthermore, K concentration of shoots was higher than K concentration of roots. It appears that in roots, the concentrations of Fe and Zn were very high. In roots, the lowest Fe concentration was found in the sequestrene-138-treated plants, whereas the highest one in the plants treated with $FeSO_4 \cdot 7H_2O$.

Key words: chlorosis, Fe sources, *Gardenia jasminoides*.

INTRODUCTION

Iron is a very important nutrient element for plants, mainly because it affects chlorophyll biosynthesis and chloroplast structure. Iron deficiency is very common on a worldwide basis for many plant species, especially in arid and semi-arid regions and in soils with high pH and $CaCO_3$ content (Loue, 1986). It has been reported that high levels of P reduce Fe uptake in cropping systems in the field (Brown, 1972) and Fe uptake is genotype-dependent in soybean, tomato and corn (Actas & Van Egmond 1979; Olsen & Brown, 1980). Low ($< 15\,^{\circ}C$) or high ($> 30\,^{\circ}C$) soil temperatures induced Fe chlorosis in *Capsicum annuum* plants due to the activity of soil microorganisms which compete with plants for macro- and microelements (Welkie, 1995).

It has been found that Fe concentration of shoots was increased when manure was added (Barness & Chen, 1991). High levels of Fe increased chlorophyll content of leaves (Lee *et al*., 1996). Various products based on organometal complexes (chelates) have been used to correct Fe deficiency. Among these products, those fixed with EDTA and related compounds such as EDDHA, presented a good effectiveness, although ecological and economical constraints limited their use (Loue, 1986; Norvell, 1991). Chelated Fe may affect Fe availability due to increase of total Fe concentration in the soil solution (Lindsay, 1979; Martens & Westermann, 1991). Bassiouny & Biggs (1971) experimenting with *Citrus* plants found a higher concentration of tissue Fe when chelated Fe was used instead of an inorganic Fe source. The effectiveness of several pure and commercial grade chelates for *Lolium multiflorum* has been studied both in soil and in hydroponic cultures (Lucena *et al*., 1987, 1988).

The objective of this work was to study the effect of three different Fe sources on the mineral nutrition of gardenia plants grown in a completely controlled environment.

MATERIALS AND METHODS

Terminal cuttings (5 cm) of gardenia (*Gardenia jasminoides* Ellis) plants were rooted in a fog system after dipping their base in IBA solution for 5 sec. The cuttings were maintained in a fog system for two

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months in a peat-perlite substrate (1:1) for rooting. After rooting, the roots were washed with tap water and subsequently with distilled water. The rooted plants were placed in 1-litre jars filled with nutrient solution. Each treatment included five replicates. The jars were covered with black plastic to prevent light penetration and algae growth. The Hoagland 50% nutrient solution (Hoagland & Arnon, 1950) was used and was aerated by a microtube attached to an air compressor. The experimental plants were maintained for 3 months in a growth chamber with a light intensity of 10,000 lux, relative humidity 80% and temperature 20-25°C.

The Fe compounds added to the nutrient solution were: sequestrene-138 (6% Fe, Fe-EDDHA), sequestrene-330 (10%Fe, Fe-DTPA) and $FeSO_4 \cdot 7H_2O$, all at the same Fe concentration of 1 mg l^{-1}. At the end of a three-month period, the plants were removed from the nutrient solution and their roots were washed with tap water and subsequently with distilled water. Each plant was divided into shoots and roots which were dried at 75°C for three days. Dry shoots and roots were ground in a mill to pass a 20-mesh screen and analyzed for inorganic nutrient elements. From each plant, 0.3-0.5 g of dry matter was ashed at 550°C and extracted with 3 ml HCl (6N). Finally, K, Ca, Mg, Fe, and Zn concentrations were determined by atomic absorption (Perkin-Elmer 2340). For statistical analysis, the statistical package SPSS was used.

RESULTS

Significant differences were recorded between the treatments for K, Fe and Zn, but insignificant ones for P, Ca, Mg and Mn (Table 1). In all treatments, K concentration of shoots was higher than that of roots. Shoot K concentration was higher in sequestrene-138-treated plants than in the sequestrene-330-treated ones. Roots presented the lowest K concentration in the treatments with sequestrene-138 and the highest one with $FeSO_4 \cdot 7H_2O$ (Fig. 1a).

Shoot Fe concentration was low. In the roots, the lowest Fe concentration was recorded when sequestrene-138 was applied, the intermediate one with sequestrene-330 and the highest one (> 1000 mg l^{-1}) with $FeSO_4 \cdot 7H_2O$ (Fig. 1b).

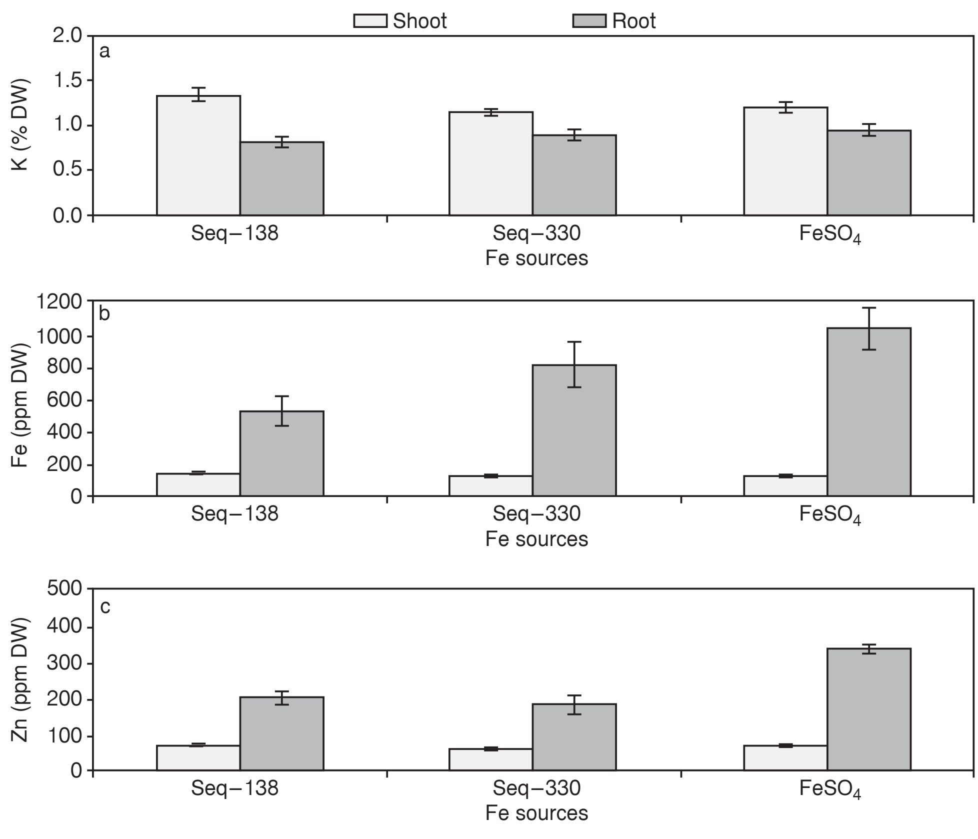

FIG. 1. Influence of Fe sources on a) K, b) Fe and c) Zn concentrations in gardenia plants; n = 5.

TABLE 1. Statistic analysis of concentrations of nutrient elements in gardenia plants, after the addition of different Fe sources in the nutrient solution

	P	K	Ca	Mg	Fe	Mn	Zn
F	0.19	4.20	0.58	1.38	4.98	0.49	16.37
Significance	ns	*	ns	ns	*	ns	**

* significant difference at $p \leq 0.05$ ($F_{0.05} = 3.3$)

** significant difference at $p \leq 0.01$ ($F_{0.01} = 5.4$)

ns: non-significant difference

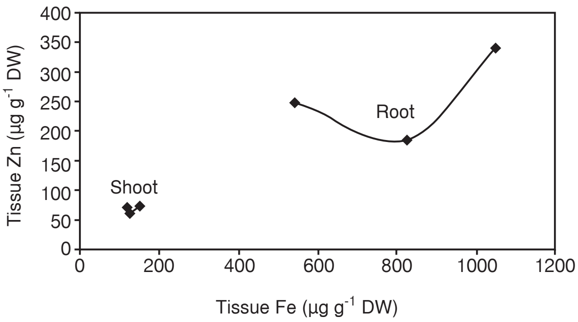

FIG. 2. Correlation between Fe and Zn concentration in gardenia plants.

Zinc concentration of shoots was relatively low and was not affected by the Fe sources in the nutrient solution. Concerning roots, Zn concentration was twice greater with $FeSO_4 \cdot 7H_2O$ than with Fe chelates (Fig. 1c). As shown in Fig. 2, Zn concentration of shoots decreased with increasing Fe concentration in the same organ. A similar relationship between Fe and Zn was recorded in the roots.

DISCUSSION

Potassium concentration of gardenia shoots was higher when sequestrene-138 was applied, whereas inorganic Fe led to an intermediate K concentration. Root K was the lowest and this could presumably be ascribed to K mobility into the plant. Some researchers found a beneficial effect of K nutrition on Fe uptake (Barak & Chen, 1984); however, for gardenia plants this point should be investigated.

Shoot Fe concentration of gardenia plants treated with Fe-EDDHA was higher than that of plants treated with the other Fe sources. Similar results were reported by Morris & Swanson (1980) experimenting with silver maple plants. Probably, there is a relationship between high root Fe and its mobilization to the shoots, particularly when a high concentration of $CaCO_3$ exists in the soil. Kosegarten & Koyro (2001) found that a significant amount of total Fe was located in the roots and precipitated to the outer surface of the roots, therefore it was trapped in the root apoplast.

However, it is not clear what proportion of the absorbed Fe was retained in the roots or was transported to the canopy where it underwent a second reduction before entering the mesophyll cells. These data are confirmed by Mengel (1994) suggesting that in a chlorotic leaf, Fe pools are somehow inactivated. The fact that an amount of Fe coming from the roots does not pass through the leaf cell plasmamembranes and may become fixed to the apoplast, is still being investigated. Romheld (2000) proposed that Fe inactivation is a side effect occurring in the leaves, after the appearance of Fe chlorosis.

Zinc was not affected by the Fe sources in the leaves. This agrees with the results reported by Ewell (1975) for Fe concentration of peach leaves. However, in roots, Zn was accumulated and Fe concentration was high, especially with $FeSO_4 \cdot 7H_2O$.

Some of our results may differ from those of other researchers experimenting with soil cultures. However, these data are indicative of Fe nutrition under field conditions. A stirred nutrient solution is mostly homogenous in the soil, except for the film adjacent to the roots. On the contrary, diffusion results in a steep gradient of soluble chelating agents with a high concentration near the root surfaces. Consequently, a high Fe concentration near the roots may modify the availability of many macronutrients. This steep chelate gradient may result in a diffusion of the chelating agents into the plant, thus explaining how the concentration of the chelating agents may promote metal uptake and also the increase of nutrient concentration of leaves and stem. Therefore, experiments with hydroponic cultures provide with data, which may differ somewhat in comparison to data with experiments in the soil. In complete investigations, these experimental hydroponic cultures should be followed by further studies in soil or other substrates.

In conclusion, $FeSO_4 \cdot 7H_2O$ at pH 5.5-6.0 is the most suitable Fe source in order to avoid Fe chlorosis in potted gardenia plants.

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