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Enhancement of P, K, Ca, Zn and Fe Accumulation in Gardenia Plants (*Gardenia jasminoides*) Grown in Nutrient Solution as a Function of P and Fe Interaction

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Abstract

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Gardenia (*Gardenia jasminoides*) plants were grown in black plastic bags containing perlite and sand (1:1). The plants were irrigated with 16 modified half strength Hoagland No2 nutrient solutions containing four Fe concentrations (0, 0.5, 1 and 2 mg L^{-1}) in the form of Fe-EDDHA (Fe 6g $100g^{-1}$) in combination with four P concentrations (0, 31, 62 and 124 mg L^{-1}).

Increasing P and Fe concentrations in the nutrient solution significantly increased leaf P and K concentrations. However, leaf Ca concentration was slightly decreased by increasing P concentration in the nutrient solution. No significant effects of P and Fe concentration were found concerning leaf Mg and Mn concentrations. Furthermore, the leaf Zn concentrations in plants treated with 0, 31 and 62 mg L^{-1} P and 0 mg L^{-1} Fe were significantly increased. By increasing Fe concentration in the treatments containing 62 and 124 mg L^{-1} P, leaf Fe concentration was increased.

In gardenia roots, the increase of P and Fe concentration in the nutrient solution led to a general increase of root P concentration. Concerning Ca, it was significantly increased in the roots, when P concentration in the nutrient solution increased. There were no significant effects of P and Fe concentration of solution in Mg concentration of roots. Manganese and Zn concentration in roots was only increased in plants treated with 124 mg L^{-1} P plus 0 or 0.5 mg L^{-1} Fe. Finally, not significant differences were recorded in root Fe concentration among the studied treatments. In conclusion, the combined PxFe fertilization in gardenia may solve also other nutritional problems like K, Ca and Zn deficiencies.

Key word: chlorosis, deficiency, nutrition, ornamental

Introduction

Iron chlorosis is a nutrient disorder caused by Fe deficiency. Iron is an essential micronutrient that linked to proteins and participates in chlorophyll synthesis and in electron transport in the photosynthetic chain. The typical symptoms described as an interveinal chlorosis. Iron chlorosis is generally recognized as a real or potential problem in many crop species (Clark and Gross, 1986). The main factors which interfere in the Fe absorption of plants and contribute to the efficiency of Fe utilization are the form of its supply, high or low temperatures, high water content or soil compaction, carbonates present in the soil, P nutritional status of plants and genotypic differences (Wei et al., 1994). Phosphorus interferes with Fe nutrition and enhances Fe chlorosis. Iron deficiency of gardenia plants is one of the most important nutritional problems resulting in significant income losses. However, Fe deficiency is not always related to its absence in soil because in some cases it was observed even when the Fe concentration of soil solution is sufficient. Iron deficiency is related to high pH and P concentration and Ca-salts in soils, which affect Fe availability in soil.

Susceptibility differences between species and varieties in Fe chlorosis are well known years ago. In comparative studies between a resistant sunflower variety, and a non-resistant to Fe deficiency cornflower variety, Venkat and Marschner (1972) found that Fe deficiency in sunflower caused pH reduction in the nutrient solution.

According to Wei et al. (1995) the susceptible varieties of subclover translocate more P and Fe in their leaves, compared to resistant varieties. Other workers stressed that high P concentration in leaves could induce Fe chlorosis in plants (Inskeep and Bloom, 1983; Coulombe et al., 1984). It was found that high P concentration reduced Fe concentration in clover (Pastor et al., 1995), suggesting that increase of P concentration in soil solution caused a reduction in Fe absorption by plants.

Gardenia is a plant sensitive to Fe deficiency but the relative bibliography about Fe and P absorption is lacking. The objective of this paper is to find out how the interaction of P and Fe nutrition can improve Fe and P nutrition and how this combination may improve the concentration of other nutrients.

Materials and Methods

Gardenia (*Gardenia jasminoides*) leafy cuttings with four leaves were prepared from healthy mother plants. The base of the cuttings was treated for five seconds with 2000 mg L^{-1} indolebutyric acid (IBA) dissolved in 50% ethanol. The cuttings were planted in 40x40 cm containers filled with a mixture (1/1) of peat and perlite and placed under a fog system for 6 weeks. The roots of the rooted plants were washed in tap and subsequently in distilled water, in order to remove any adhering peat and perlite particles. Afterwards, the plants were grown in 1L black plastic bags containing perlite and sand (1:1). Every 2 days the plants were irrigated with 250 mL of a modified half strength Hoagland No2 nutrient solution (Hoagland and Arnon, 1950) prepared with distilled water containing four Fe concentrations (0, 0.5, 1 and 2 mg L^{-1}) in the form of Fe-EDDHA (Fe 6g $100g^{-1}$), in combination with four P concentrations (0, 31, 62 and 124 mg L^{-1}). The volume of irrigation solution was enough to moisten the planting medium and to allow some leaching from the bottom of plastic bags, to avoid salt accumulation. Five plants (replicates) used per each treatment, arranged randomly and maintained in a greenhouse for three months. The experiment was terminated when visible Fe deficiency symptoms appeared in top leaves of the treatments lacking Fe or treated with 0.5 mg Fe L^{-1}. At the termination of the experiment, the plants were divided into leaves, shoot and root and were washed twice with tap and once with deionized water. Furthermore, the samples (leaves and roots) were dried at 75^{o}C for 48h, ground in a mill to pass a 20-mesh screen, ashed at 500-550^{o}C and analyzed for K, Ca, Mg, Fe, Mn and Zn by atomic absorption spectroscopy (Perkin-Elmer 2340) and for P by the phosphovanadomolybdate method (Sparks, 1996). Means were compared using the Duncan multiple range test ($P<0.05$).

Results

Increasing P concentration in the nutrient solution led to an increase in leaf P concentration (Figure 1). The maximum P concentration in leaves was observed in plants treated with 124 mg L^{-1} P plus 0.5 mg L^{-1} Fe. Also, leaf K concentration was significantly and positively affected by P concentration in the nutrient solution. Leaf Ca concentration was negatively affected by P concentration in the nutrient solution and the lowest value was observed in the treatments with 124 mg L^{-1} P, which contained also Fe. No significant trends were found in leaf Mg and Mn concentrations. Leaf Zn concentration in plants treated with 0, 31 and 62 mg L^{-1} P plus 0 mg L^{-1} Fe was significantly increased. Furthermore, in the treatments containing 62 and 124 mg L^{-1} P leaf Fe concentration increased, by increasing Fe level in the nutrient solution.

In gardenia roots (Figure 2), the increase of P concentration in the nutrient solution led to a general increase in P concentration of roots. The increase of Fe concentration in the nutrient solution of the treatments with 0 and 31 mg L^{-1} P did not affect P concentration in roots. The inclusion of 1 or 2 mg L^{-1} Fe in the nutrient solution in the treatments with 31, 62 and 124 mg L^{-1} P increased K concentration in roots. Hence, it created a K reserve that could be translocated later to tops. Concerning Ca, it was significantly reduced in the roots of the plants treated with a nutrient solution lacking P.

There were no differences in Mg concentration values in roots among the studied treatments. Manganese concentration in roots was unaffected with 0, 31 and 62 mg L^{-1} P and was only increased in plants treated with 124 mg L^{-1} P plus 0 or 0.5 mg L^{-1} Fe. Similarly, the inclusion of 124 mg L^{-1} P plus 0 or 0.5 mg L^{-1} Fe in the nutrient solution led to a significant increase in root Zn concentration. Finally, not significant differences were recorded in root Fe concentration among the studied treatments.

Discussion

The increase of P concentration in the nutrient solution led to an increase of P concentration in gardenia plants. In leaves, P concentration surpassed the value 0.30g $100g^{-1}$, while without P addition P concentration was 0.10-0.15 g $100g^{-1}$. This P content probably derives from P stored in the cuttings used, since the P nutrient solution was prepared with distilled water. In the

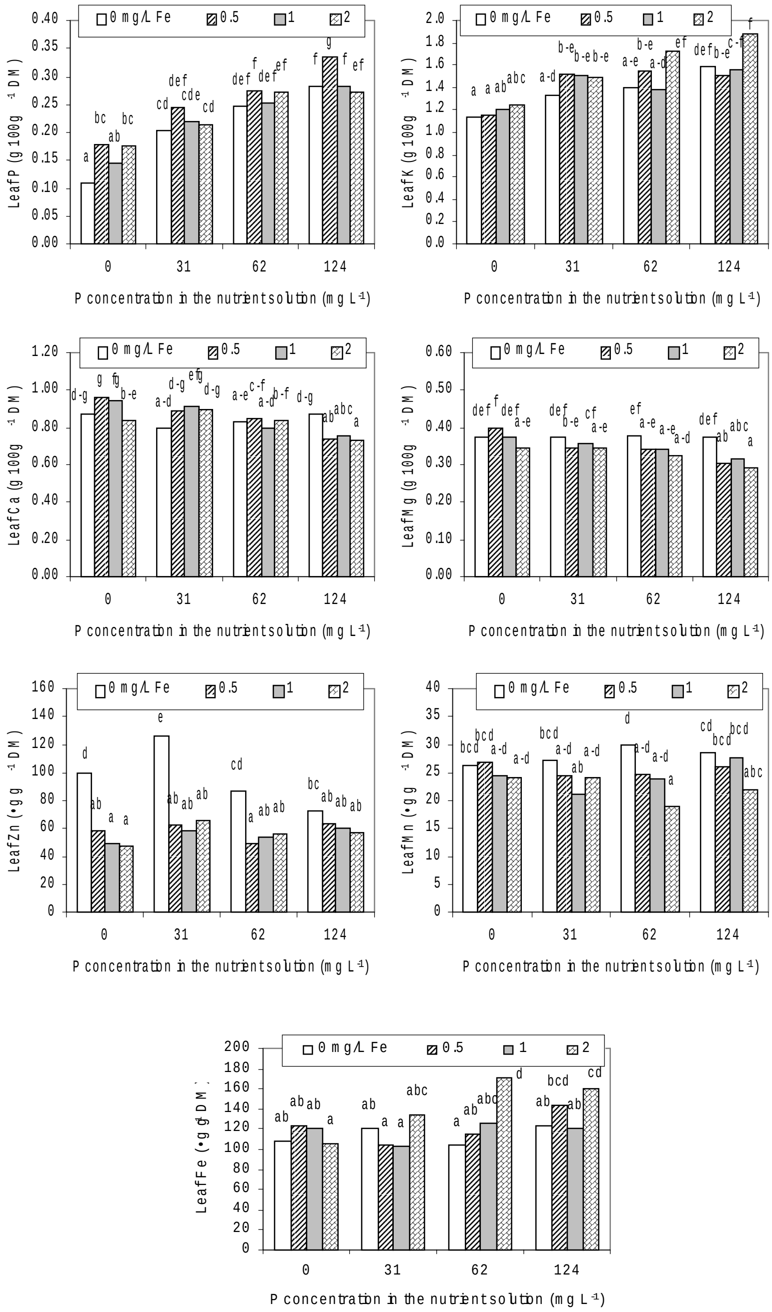

Fig. 1. The concentrations of P, K, Ca, Mg, Zn, Mn and Fe in the leaves of gardenia plants

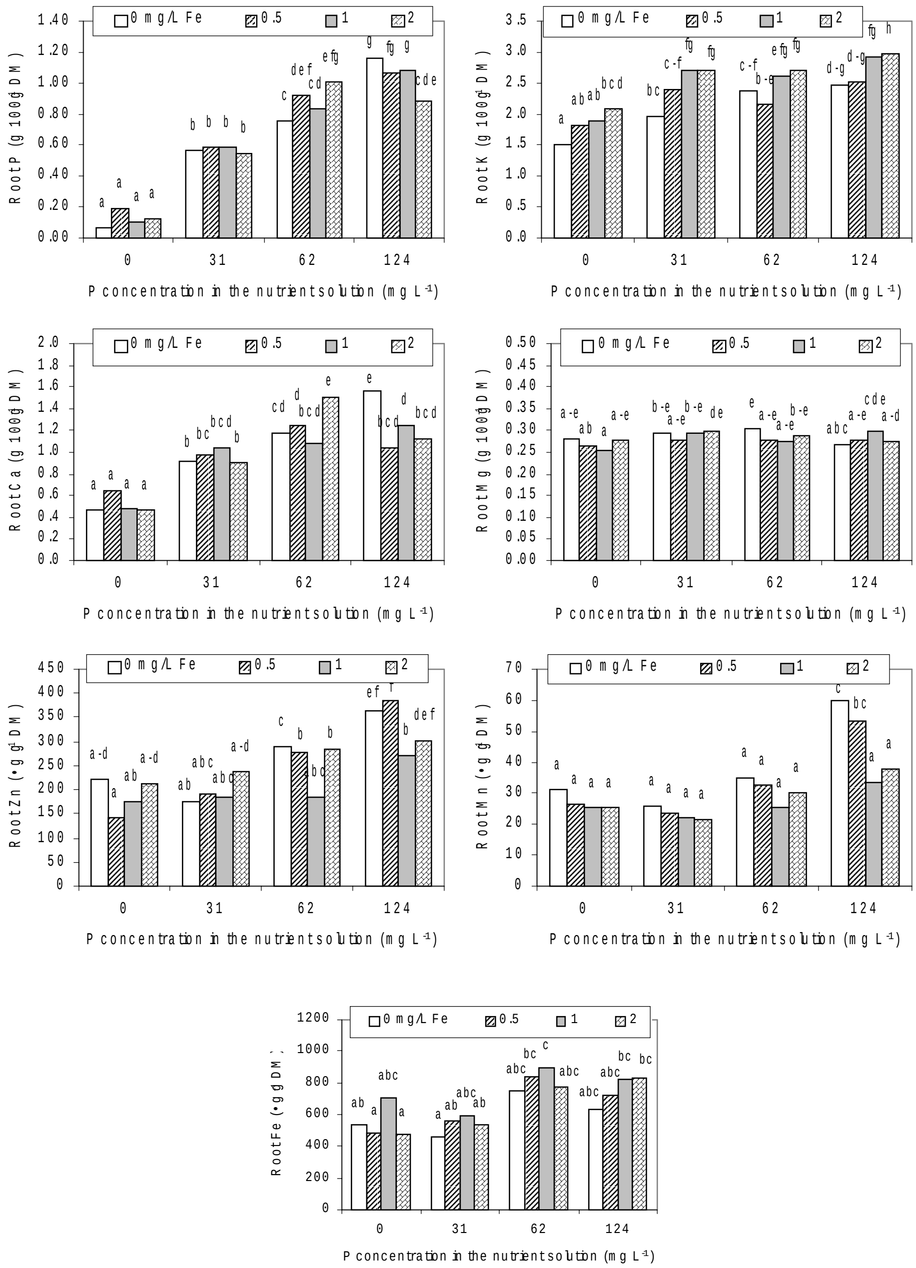

Fig. 2. The concentrations of P, K, Ca, Mg, Zn, Mn and Fe in the roots of gardenia plants

literature, critical P concentration values for gardenia plants do not exist. However, the performance of plants (no P deficiency symptoms) indicated that the concentration 0.10-0.15 g $100g^{-1}$ P in the leaves was adequate. The P concentration value of 0.25 g $100g^{-1}$ was achieved in the treatment with 62 mg L^{-1} P in the nutrient solution, a fact showing that gardenia is a P-demanding and accumulating plant. Our data indicate that P as well as Fe concentration in the nutrient solution can modify P concentration of plants, which disagrees with data reported by other authors for sunflower plants (Mikesell et al., 1973).

Potassium concentration in leaves and roots of gardenia plants followed the same trend of increase, as that of P in the same tissue. The increase of K absorption without any extra effort is a very significant finding, indicating that K nutritional problems could be solved by appropriate P and Fe fertilization. Jolley et al. (1988) suggested that K is essential to the function of the Fe-response mechanism. The relationship between K and PxFe nutrition appears to be more complex when plants were grown in soils and depends on many soil properties, like $CaCO_3$, compared to plants irrigated with nutrient solution.

Calcium concentration in the roots of gardenia increased almost linearly with P concentration in the nutrient solution, creating a Ca reserve for the plant, which plays a significant role for membrane selectivity and semi permeability and nutrient absorption. Similarly, Brown et al. (1959) found that high P was associated with high Ca concentration in soybean plants.

In gardenia leaves the highest concentration of Mn was observed in the treatment without Fe, indicating a Fe-Mn competition, a result confirmed by Sabety and Kashirad (1981). Experimenting with sunflower plants (*Helianthus annuus*) Sabety and Kashirad (1981) found that the use of P increased effectively Mn concentration. However, this is partially in agreement with our results.

Conclusion

Calculation of P/Fe ratios in gardenia leaves indicated that these values ranged from 6.9 to 37.2, which according to DeKock et al. (1974) classified gardenia as an Fe efficient plant, although Fe deficiency is very common. Many years ago DeKock et al. (1974) related the P/Fe ratio with the Fe deficiency in *Sinapis* sp leaves, suggesting that when the P/Fe ratio is lower than the value 40-50, plants are efficient in Fe.

At high P and Fe concentrations in the nutrient solution, Fe concentration of leaves was increased. This observation was confirmed by Wei et al. (1995) who found that the susceptible to chlorosis cultivars of clover had high Fe content, due to P-induced immobilization of a significant part of Fe. Therefore, more total Fe is required to cover the needs of gardenia plants. Thus, the low shoot Fe concentrations in the Fe-chlorosis resistant cultivars suggest lower requirements of Fe for a normal metabolism.

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