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Differential tolerance to iron deficiency of citrus rootstocks grown in nutrient solution

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Abstract

We studied the effects of Fe deficiency on physiological parameters of citrus rootstocks grown in nutrient solution. Three 4-week old rootstocks ('Troyer' citrange – *Citrus sinensis* (L.) Osb. × *Poncirus trifoliata* (L.) Raf., *Citrus taiwanica* Tan. and Shim., and 'Swingle' citrumelo – *Poncirus trifoliata* (L.) Raf. × *Citrus paradisi* Macf.) were grown in nutrient solutions with 0, 5, 10, 15 and 20 μmol Fe dm^{-3}. Calcium carbonate (1 g dm^{-3}) was added to all solutions to mimic the natural conditions in calcareous soils. For each rootstock, shoot length, number of leaves, and root and shoot dry weights were measured at the end of experiment. Chlorophyll concentration was estimated using a portable SPAD-502 meter calibrated for each rootstock. The amount of nutrients (P, K, Mg, Ca, Fe, Zn, Mn, and Cu) was determined in shoots. Chlorophyll fluorescence parameters (F_0: basal fluorescence; F_m: maximum fluorescence; $F_v = F_m - F_0$: variable fluorescence) were measured with a portable fluorimeter. 'Troyer' citrange rootstock was the most tolerant to Fe deficiency. These plants grew more and accumulated more chlorophyll and nutrients than the others in the presence of low levels of Fe (10 μmol Fe dm^{-3}). 'Swingle' citrumelo plants needed 20 μmol Fe dm^{-3} in the

Abbreviations: Chl, leaf chlorophyll; NS, not significant; *P*, level of significance; R^2, correlation coefficient

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nutrient solution to secure adequate growth. 'Taiwanica' orange rootstock had an intermediate behaviour, but could be distinguished from 'Troyer' citrange based on fluorescence parameters, since there was a variation in the basal fluorescence in the former, whereas in 'Troyer' citrange the basal fluorescence was not affected by the supply of Fe.

Keywords: Citrus sp.; Biomass allocation; Chlorophyll fluorescence; Lime-induced chlorosis; Mineral composition; Rootstocks; SPAD

1. Introduction

It is estimated that from 20 to 50% of fruit trees grown in the Mediterranean basin suffer from Fe deficiency (Jaegger et al., 2000). The most prevalent cause of Fe deficiency in this region is the presence of high levels of bicarbonate ions in the calcareous soils. These soils often have more than 20% of calcium and magnesium carbonates and are strongly buffered, with a pH between 7.5 and 8.5. The high level of bicarbonate ions in the soil affects metabolic processes in roots and leaves, decreasing soil and plant Fe availability (Mengel, 1995), leading to the condition known as lime-induced iron chlorosis. The most evident effect of Fe chlorosis is a decrease in photosynthetic pigments, resulting in a relative enrichment of carotenoids over chlorophylls (Chl), leading to the yellow colour characteristic of chlorotic leaves (Abadía and Abadía, 1993; Morales et al., 1998). When Fe is in short supply, Fe-efficient genotypes develop controlled responses, which include physiological, biochemical and morphological changes (Schmidt, 1999).

In fruit trees, lime-induced Fe deficiency results in considerable loss of yield (Pestana et al., 2003), delayed fruit ripening, and impaired fruit quality, as reported in peach (Sanz et al., 1997) and orange (Pestana et al., 2001a). The success of citrus production depends on the availability of suitable rootstocks. Their tolerance to lime-induced Fe chlorosis varies (Hamzé et al., 1986; Wutscher, 1979), with trifoliate orange (*Poncirus trifoliata* (L.) Raf.) being very susceptible and sour orange (*C. aurantium* L.), various mandarins (*C. reticulata* Blanco, *C. nobilis*), limes (*C. limonia* Osb.), and lemons (*C. jambhiri* Tan.) being more tolerant than trifoliate orange. However, differential tolerance to other factors such as citrus tristeza virus limits the choice of rootstocks that can be used. Genetic improvement of rootstocks to enhance chlorosis-resistance would be the best solution to Fe chlorosis, but this is a long-term approach. Meanwhile, screening techniques to identify tolerant genotypes need further development, and for that additional information on morphological, physiological and molecular mechanisms involved in the different genetic responses to Fe chlorosis is required.

The screening of cultivars to iron deficiency in hydroponics systems with bicarbonate has been used for herbaceous (Alhendawi et al., 1997; Campbell and Nishio, 2000; Lucena, 2000; Pissaloux et al., 1995) and woody species (Alcántara et al., 2000; Cinelli et al., 1995; Nikolic et al., 2000; Romera et al., 1991a, 1991b; Shi et al., 1993; Sudahono et al., 1994).

The aim of this study was to evaluate the effects of Fe deficiency on three citrus rootstocks ('Troyer' citrange, 'Taiwanica' orange and 'Swingle' citrumelo) using different growth parameters and physiological characteristics.