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Prognosis and correction of iron chlorosis in peach trees and relationship between iron concentration and Brown Rot

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ABSTRACT

This study investigates the possible correlations between bark, floral, and leaf iron (Fe) concentrations and SPAD measures to be used as early methods for prognosis of iron chlorosis in peach trees. The results showed that there were significant correlations between bark, floral and leaf Fe concentrations and SPAD measurements. This study shows for the first time the possibility of using bark analysis as an early predictive method of iron chlorosis in peach trees.

Differences in mineral composition of leaves of peach trees, in relation to rootstocks were also found.

This study also investigated the distribution of mineral elements in different parts of peach leaves. Tissue analysis of different leaf parts showed that the peripheral and petiole of leaves had the highest P, Ca, Mg, Zn, Fe, B and Cu concentrations. In contrast, the highest K concentration was found in the internal parts of leaves. High Mn concentration was found in the laminar of leaves, but was lower in the petioles.

In other experiments, the effect of different sources of Fe application on the leaf Fe concentrations and development of Brown Rot in the year of application and one and 2 years later was also examined. No application increased significantly the leaf Fe concentrations in the year of application and 1 year later. Leaf Fe concentrations were significant higher in trees treated with $FeSO_4 \cdot 7H_2O + S$ 2 years after application.

The possible effect of flesh Fe concentration to susceptibility of peach (cv. Sun Crest) to *Monilinia laxa* was also evaluated. The results showed no correlation between flesh Fe concentration and susceptibility of peach to *M. laxa*. Besides, no statistical difference was found in the susceptibility of peach to *M. laxa* collected from the cultivar Sun Crest grafted on different rootstocks.

1. Introduction

Growing of fruit trees in alkaline, calcareous soils is one of the causes of iron chlorosis (Abadía et al., 1989; Tagliavini and Marangoni, 2002). Under these conditions, the trees need Fe supplements through fertilization, since otherwise productivity, fruit quality and tree viability are low (Sanz et al., 1997).

The early detection and correction of Fe deficiency avoids the influence of Fe chlorosis on fruit quality. According to Sanz et al. (1997) correction of Fe deficiency in peach trees improves the fruit size and avoids the delay of fruit ripeness. Therefore, new techniques for early and accurate detection of iron chlorosis are essential. Floral tissue analysis of iron contents has been used as a tool for early prognosis of Fe deficiency in fruit trees (Pestana et al., 2003, 2004; Sanz et al., 1997, 1998; Zarrouk et al., 2005).

The formation of chlorophyll in the leaves of plants depends upon an adequate supply of Fe. Previous studies show a linear relationship between iron content and the rate of chlorophyll formation (Abadía et al., 1989).

Reliability of the chemical composition of plant depends to a great extent on the representativeness of sampling, which appears to be a complex process. In order to perform representative sampling of plants for trace element analysis, exact knowledge of a number of factors such as fluctuations of mineral concentrations in different parts of leaves is required.

Using of fertilizers helps to improve the nutrition of plants, directly by providing the appropriate elements (Hernandez-Fuentes et al., 2004) and indirectly by affecting the soil reactions (soil reaction affects the solubility of mineral nutrients and thus

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their availability to plants) (Huszcza-Ciolkowska and Zawartka, 2003). Probably, the results from a fertilization programme can be extended for more than the first year of application.

Fruit decay caused by *Monilinia laxa* is a major problem of peach (*Prunus persica* (L.) Batsch) causing field losses in the entire world (Sharma and Kaul, 1989), especially in locations where climate conditions are wet. Previous research has reported the role of calcium and boron treatments on the resistance of fruit to *Monilinia* spp. (Biggs et al., 1997; Thomidis, unpublished data) and it has been suggested that Fe may have an important role on the physiology of peach fruits by Fe inducing inking at the physiological fruit pH (Cheng and Crisosto, 1994). In addition, Cheng and Crisosto (1997) reported that skin discoloration of peach is affected by iron-polyphenol complexes. No research, however, has been published examining the possible effect of flesh Fe concentration on decay fruit susceptibility.

The main objectives of this research were: (a) to investigate possible correlations between bark, flower and leaf Fe concentrations and SPAD values as early methods for prognosis of iron chlorosis, (b) to evaluate the effect of five peach rootstocks, AN1/6, DSS, GF677, ID3 and Adafuel on Fe bark, Fe flower and Fe leaf concentrations and SPAD values of the cultivar Sun Crest, (c) to investigate the distribution of mineral elements in different parts of peach leaves, (d) to examine the effect of different sources of Fe soil applications on the leaf Fe concentrations and development of *M. laxa* for a period of 3 years, and (e) to study the effect of flesh Fe concentration on the susceptibility of peach (cv. Sun Crest) to *M. laxa*.

2. Materials and methods

2.1. Experiment 1: correlations between bark, flower and leaf Fe concentrations and SPAD values

The rootstocks used in this study were: GF677 (French natural hybrid, *P. persica* × *P. amygdalus*), DSS (Greek natural hybrid, *P. persica* × *P. amygdalus*), AN1/6 (Greek natural hybrid, *P. persica* × *P. amygdalus*), ID3 (Greek wild peach rootstock, *P. persica*), and Adafuel (Spanish natural hybrid, *P. persica.* × *P. amygdalus*). Trees were planted in 1989 at a spacing of 5 × 5 m in a randomized block arrangement, with six replications, in a field where peach trees had not been cultivated before. Trees were vase-shape trained. Five to six sprinkler irrigations were provided in a vegetative season. The spraying programme included application of Bordeaux mixture at the leaf fall stage. Nitrogen was applied at mid of February as $(NH_4)_2SO_4$ at 120 N units per ha in each year.

Three soil samples, each 500 g (represented 10 sub-samples), were taken from 30 to 60 cm in depth in December. They were transferred to a laboratory, where large chunks of soil were broken up and placed in a forced air oven set between 35 and 55 °C for 24 h. Soil was then crushed in a soil pulverizer to pass through a 20-mesh screen, to achieve sample homogeneity. The soil was silt–clay–loam, alkaline (pH 7.9) and calcareous (active lime 18.3%) containing 1.23% organic matter, 0.0231 g/kg P, 0.201 g/kg K, 4.89 mg/kg Zn, 8.76 mg/kg Fe, 8.89 mg/kg Cu, 31.5 mg/kg Mn and its conductivity in soil extract was 0.61 mmhos/cm.

Bark samples (50 bark pieces per tree which were pooled to one sample) were taken from current year shoots (20 cm tips) in February 1997 and in February 1998. Whole flowers (50 flowers per tree which were pooled to one sample) were sampled at full bloom stage in April 1997 and April 1998. The samples were placed in polyethylene bags and transferred to the laboratory for mineral concentration analysis as described below.

Slight symptoms of iron chlorosis (visual observation) were uniformly observed in all trees used in this experiment. Leaf samples (50 leaves per tree which were pooled to one sample) were collected (90 days after full bloom stage in 1997 and again in 1998) from 8-year-old peach cultivar Sun Crest grafted on the different peach rootstocks. Entire, fully expanded, healthy and mature leaves (from the year's expanding, nonfruiting shoots) from middle- to top portion of the extension shoots were randomly taken at a height of approximately 1.5 m around the tree. Leaves were immediately placed in polyethylene bags and transferred to the laboratory, where chlorophyll was measured by using the portable instrument SPAD 502 (Minolta Corp.) according to the methodology described by Marquard and Tipton (1987), and then analyzed for mineral concentration as described below.

Tissues (flower, bark, leaf) were first cleaned with washing powder (Tide, 2‰), then washed with tap water and finally with distilled water. The samples were dried in the oven at 60 °C for 24 h and ground to pass through a mesh screen to achieve sample homogeneity before mineral concentration analysis. Concentrations of bark, flower and leaf K, Ca, Mg, Fe, Zn, Mn, and Cu were measured by using a PerkinElmer 2380 Atomic absorption spectrophotometer (Meyer and Keliher, 1992) and colorimetry for B (Bingham, 1982). Phosphorus was determined by the vanadomolybdophosphoric yellow colour method (Kalra and Maynard, 1991).

2.2. Experiment 2: distribution of mineral elements in different parts of peach leaves

Katerina trees, grafted on GF677 peach rootstock, were established in 1990 in the experimental orchard of Pomology Institute. Sampling for soil analysis was made as described above. The soil was silt–clay–loam, alkaline (pH 8.1) and calcareous (active lime 22.88%) containing 1.52% organic matter, 0.0203 g/kg P, 0.186 g/kg K, 4.76 mg/kg Zn, 2.69 mg/kg Fe, 13.29 mg/kg Cu, 9.8 mg/kg Mn and its conductivity in soil extract was 0.75 mmhos/cm.

The experimental design and the cultural practices used were the same with those described in the experiment 1. From each of 20 trees (10-year-old), 50 leaves were randomly collected at 15th July. Three different parts of leaves (petioles (about 5% of the total surface of leaf), peripheral (about 20% of the total surface of leaf), internal (about 75% of the total surface of leaf) were analyzed for their mineral contents. Tissue analysis was made following the methodology described above. These experiments were conducted for 2 consecutive years (2000–2001).

2.3. Experiment 3: effect of different sources of Fe soil applications on the leaf Fe concentrations

The test of effectiveness of iron compounds (given as soil applications) was made in the experimental orchard described (see experiment 2), but using different trees. Choosing and doses of compounds used was based on previous preliminary studies conducted in soil with different chemical composition (C. Tsipouridis, unpublished data) and presented in Table 3. Two experiments were established; the first one started in 1996 and completed in 1999 and the second one started in 1998 and completed in 2001. The treatments conducted were Fe-EDDHA (Sequestrene 138 Fe; Giba Geigy Hellas; Fe 6%, K 15%, N 3%), $FeSO_4{\cdot}7H_2O$ (Biolmet AE; 19%), $FeSO_4{\cdot}7H_2O + K_2SO_4$ (Sinel AE; K 50%), $FeSO_4{\cdot}7H_2O + NH_2CONH_2$ (Sinel AE; N 46%), $FeSO_4{\cdot}7H_2O$ + S, $FeSO_4{\cdot}7H_2O$ + organic matter (cow manure), $FeSO_4{\cdot}7H_2O$ + organic matter + K_2SO_4 at doses presented in Table 1 (the application of fertilizers into the soil was made with the method of localized placement). One soil application took place at the first 10 days of April 1996 for the first experiment and the same date of 1998 for the second one.