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Copper Contamination of Sandy Soils and Effects on Young Hamlin Orange Trees

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During perennial tree production, soil properties are constantly affected by the type, rate and method of application of soil and/or foliar amendments. These amendments are applied repeatedly over a number of years as a part of routine production practices. In the case of amendments containing mobile elements, the residual effect is negligible. However, application of amendments containing immobile elements results in accumulation of those elements in the topsoil. This is usually the case with respect to trace metals such as Cu, Zn, Fe and Mn which are essential for plant growth. In the event of extreme deficiencies of these elements, growth and production are adversely affected. However, in perennial tree crops such as citrus, the quantity of trace metals removed in harvested fruit is extremely small (Smith 1966). Therefore, repeated applications of these trace metals over the years result in their buildup in the topsoil. A case in point is the buildup of Cu in many citrus grove soils in the central ridge area of Florida as a result of routine application of Cu at relatively high rates with fertilizers (Alva and Graham 1991). Copper deficiency related citrus dieback symptoms were observed as early as the 1840's (Smith, 1966). Experimental evidence of Grossenbacker (1916) and Floyd (1917) indicated that application of copper sulfate corrected dieback symptoms, therefore, application of copper sulfate became a routine practice in Florida citrus production during the early 1900's. By the early 1940's, application of Cu in routine citrus fertilization program was often as high as 34 kg/ha. In addition, the routine fungicide spray program added 9 kg Cu/ha annually. Repeated application of Cu in the above doses resulted in buildup of Cu causing Cu toxicity (Reuther and Smith, 1954). In order to meet the fruit quality standards, production practices of groves destined to fresh fruit market require more pesticide spray programs as compared to the groves destined to produce fruit for juice processing. As a result, Cu contribution through pesticide

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program is greater in the former than that in the latter production practices. High input of Cu due to historical production practices may have an impact on the subsequently planted young trees. The most common impact of excess soil Cu is the deficiency of Fe (Smith and Specht, 1952; Reuther and Smith, 1953, Spencer, 1966).

The freezes of the 1980's killed substantial acreage of mature citrus trees in the Central Florida ridge area. Therefore, during the recent years, replanting has been accelerated in this region. Swingle citrumelo [Citrus paradisi Macf. x Poncirus trifoliata (L.) Raf.] rootstock, which is extremely sensitive to Cu toxicity (A. K. Alva, unpublished data), was widely used during the recent plantings. The effects of high Cu concentrations can be ameliorated by raising the soil pH from 6.5 to 7.0 (Koo et al. 1984).

In this study, the variations in soil chemical properties and growth of 5 year old Hamlin [Citrus sinensis (L.) Osb.] orange trees on Swingle citrumelo rootstock were studied in relation to past production practices.

MATERIALS AND METHODS

The grove chosen for this study was on Candler fine sand (uncoated, hyperthermic, Typic Quartzipsamments) in Polk County, Florida. The entire grove of 10 ha was planted in 1987 with Hamlin orange trees on Swingle citrumelo rootstock (6.08 m x 3.04 m). Prior to the new planting, the grove was subdivided into three blocks. Two subblocks of 3.2 ha each on the far end of the block were previously under white Marsh grapefruit trees and the middle block of 3.6 ha was previously under Valencia orange trees. The tree rows of new plantings ran across the three former blocks.

The sampling was done along a single row of 190 trees. The entire row was divided into 38 sampling units, i.e., plots of five trees each. Within each plot, soil samples were taken 0 to 15 cm depth, two cores (2.5 cm diameter) on either side of the tree along the dripline inside the canopy area. Therefore, each soil sample from a plot consisted of a composite sample of 10 cores. Fibrous roots (< 2.0 mm diameter) were also sampled from 0 to 15 cm from all five trees within a plot and composited. Visual ratings were made for leaf chlorosis on a scale of 0 to 5; with 0 being no symptom and 5 being severe chlorotic symptoms.

Soil pH was measured in water and 0.01 M $CaCl_2$ at 1:1 ratio of soil:solution (wt/vol). Soil samples were extracted with Mehlich 3 extraction (Mehlich 1984) and concentrations of Ca, Cu and Fe were measured using inductively coupled plasma emission spectroscopy (ICPES, Plasma 40, Perkin-Elmer, Inc.).

Fibrous root samples were washed in tap water, rinsed in distilled water, dried at 70°C for 48 hr, ground and dry ashed at 500°C for 6 hr. The ash was dissolved in 20 mL 1M HCl and concentrations of Cu and Fe were measured by ICPES.

The data were analyzed to evaluate the changes in concentrations of extractable Cu in the soil and that of feeder root Cu as influenced by the past production practices which were dictated by the type of citrus grown prior to replanting. Relationships between concentrations of Cu or Fe in the feeder roots and extractable soil Cu as well as leaf chlorosis score vs. extractable soil Cu or concentration of feeder root Cu were examined by regression model.

RESULTS AND DISCUSSION

Soil pH varied considerably among the plots (Fig. 1). This variation was not related to past production practice. The changes in concentration of M3-Cu followed very closely with past production practice. Soil Cu status was greater in the area which was under grapefruit as compared to orange prior to the new planting. This is clearly an indication of differences in magnitude of Cu fungicides used for grapefruit production vs. juice type orange production.

The chlorosis rating was greater in the plots with high amounts of Cu as compared to those with lower Cu contents (Fig. 1). Soil Fe content did not vary much among the plots despite the large variation in soil Cu content (Fig. 1). However, consistently greater chlorotic symptoms on trees in plots containing high levels of residual Cu content suggests the interaction between high soil Cu and Fe uptake/translocation. The effects of high soil Cu on Fe nutrition of citrus have been reported previously (Graham et al. 1986; Kuykendall et al. 1957; Reuther and Smith 1952, 1953; Smith and Specht 1953a, b; Spencer 1966).

Copper concentrations in the aboveground plant parts may be of less value in diagnosing copper toxicity (Robson and Reuther, 1981). This is primarily due to Cu interfering with the uptake of other nutrients, for example iron (Reuther and Smith, 1953). High concentrations of Cu may be held in roots against transport to shoots (Loneragan, 1981). However, Cu concentrations in fibrous roots can be used as an index of soil-Cu status (Alva et al. 1993; Fiskell and Leonard 1967;

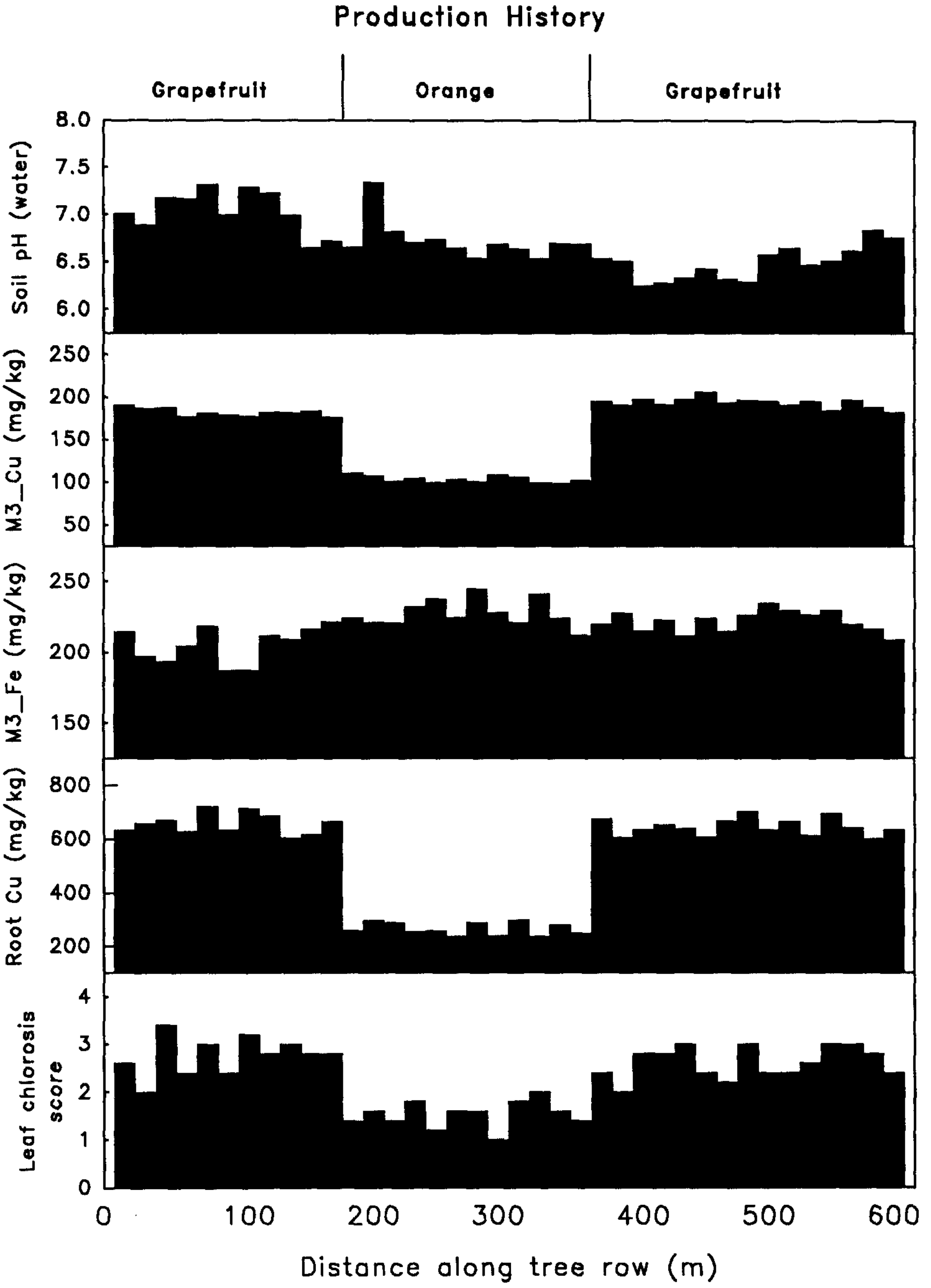

Figure 1. Variations in soil pH and Mehlich 3 extractable Cu and Fe in soil samples (0 to 15 cm) taken over an area representing three blocks which were under white Marsh grapefruit + Valencia orange and white Marsh grapefruit production prior to new planting in 1987 of Hamlin orange trees on Swingle citrumelo rootstock over the entire area. Chlorosis rating of 4 year old Hamlin orange trees is also shown.

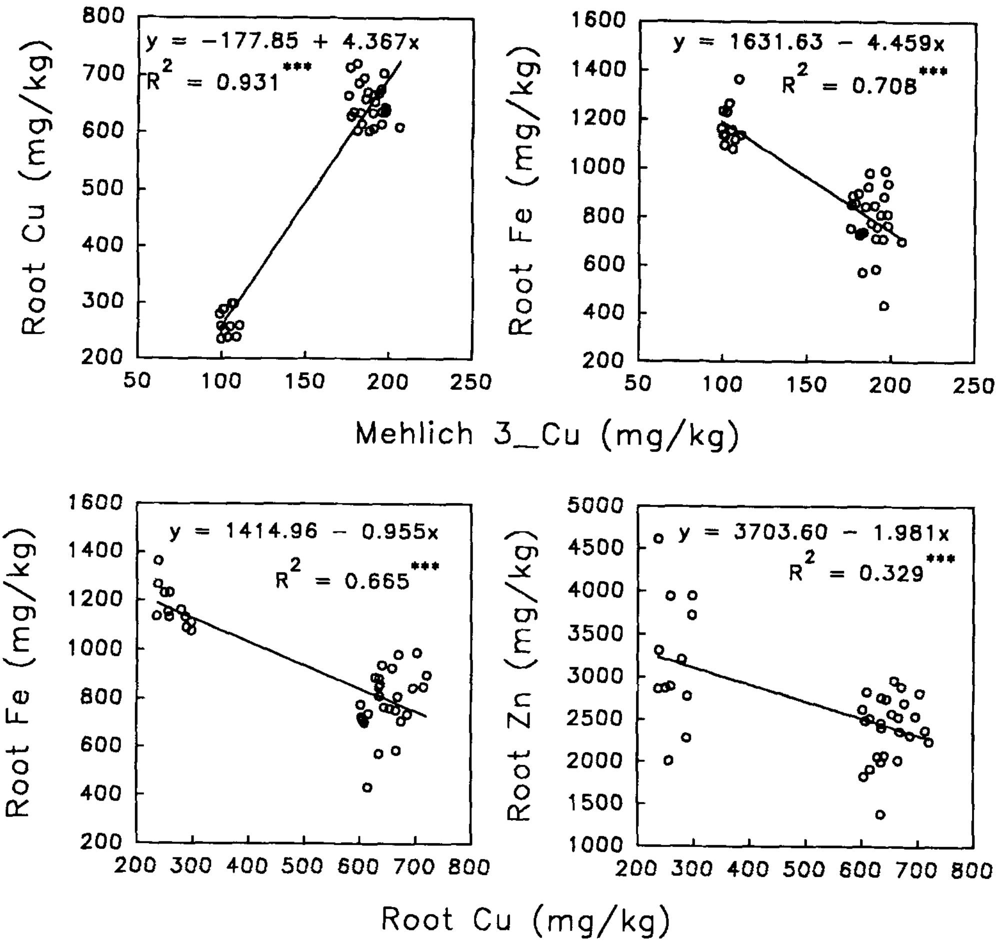

Figure 2. Concentration of Cu and Fe in fibrous roots of 4 year old Hamlin orange trees on Swingle citrumelo rootstock in relation to concentrations of Mehlich 3 extractable Cu in 0 to 15 cm depth soil. Concentrations of Fe and Zn in relation to Cu in fibrous roots are also shown. The variation in soil Cu was due to different production practices prior to the new planting.

Graham et al. 1986). In the current study, the concentration of Cu in the fibrous roots was related to soil Cu extractable by Mehlich 3 (R^2 = 0.931***) (Fig. 2). There was a significant negative relationship between the concentration of Fe in the fibrous roots and soil Cu (R^2 = 0.708) and root Cu (R^2 = 0.665***) (Fig. 2). This supports the

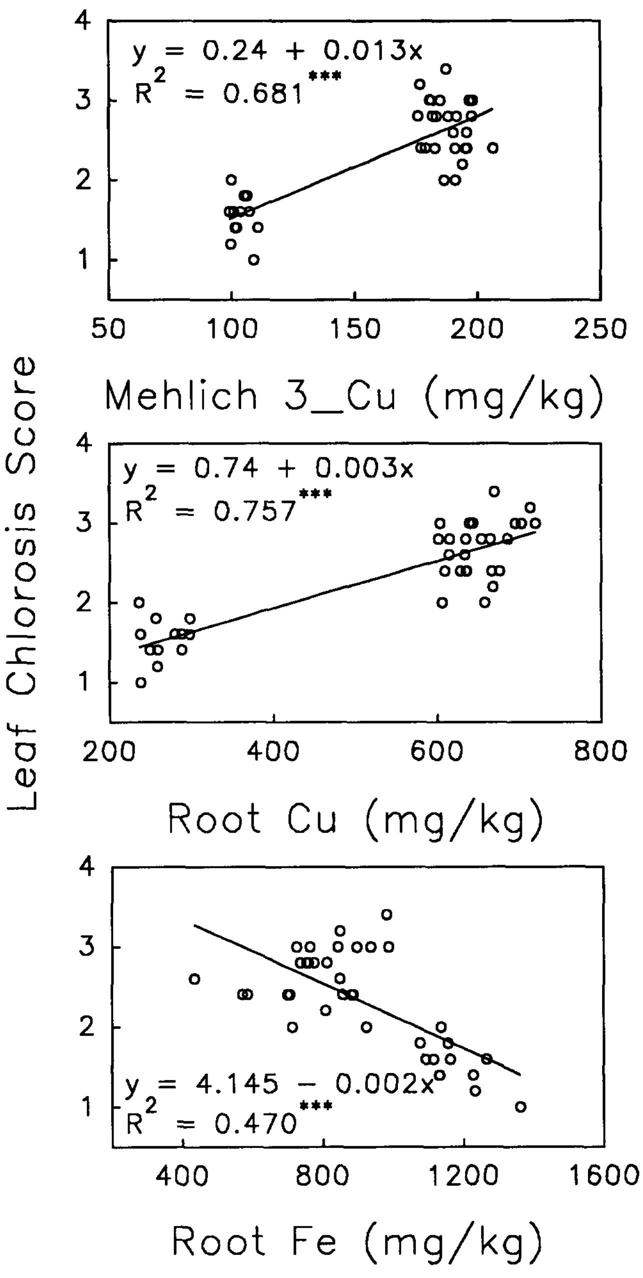

Figure 3. Leaf chlorosis rating of 4 year old Hamlin orange trees on Swingle citrumelo rootstock in relation to Mehlich 3 extractable Cu and concentration of Cu and Fe in the fibrous roots.

earlier findings on interference of Cu on uptake of iron (Reuther and Smith 1953). The concentration of Zn in the roots also decreased with an increase in concentration of Cu in the roots (Fig. 2).

Leaf chlorosis rating was significantly dependent on soil Cu (R^2 = 0.681***) (Fig. 3). This confirms the role of soil Cu in inducing Fe deficiency as indicated by characteristic Fe chlorosis symptoms. Based on the fibrous root analyses data, it appears that the cause of Cu-induced Fe chlorosis is due to disruption of Fe uptake as evident from decreasing concentration of Fe in the fibrous roots with an increase in status of soil Cu and root Cu (Fig. 3).

This study demonstrates the buildup of soil Cu as a result of routine grove management practice which depends on citrus type. Apparently, the contribution of Cu in the routine pesticide program varied considerably between white grapefruit for fresh market and Valencia orange for processing market. Detailed records of past-management practice with respect to Cu program for each block were not available. However, the boundaries of differential soil Cu levels clearly matched those of previous blocks which were under a different Cu program. The residual Cu remains in the top soil for several years. The soil Cu plays an important role when an old grove site is replanted with a Cu-sensitive rootstock such as Swingle citrumelo.

The chlorosis of 4 year old Hamlin orange trees increased proportionately with an increase in soil Cu status. The concentration of Cu in the fibrous roots increased while that of Fe decreased with an increase in soil Cu status. Soil Fe levels were uniform across all plots with variable soil Cu status. Thus, the increased severity of Fe chlorosis associated with high levels of residual soil Cu indicates Cu-induced Fe deficiency on subsequently planted young citrus trees.

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