Journal of Integrative Agriculture 2017, 16(7): 1609–1616

Available online at www.sciencedirect.com

ScienceDirect

RESEARCH ARTICLE

Soil boron fertilization: The role of nutrient sources and rootstocks in citrus production

Dirceu Mattos Jr[1], Franz W R Hippler[1], Rodrigo M Boaretto[1], Eduardo S Stuchi[2], José A Quaggio[3]

[1] *Centro de Citricultura Sylvio Moreira, Instituto Agronômico, Cordeirópolis (SP) 13490-970, Brazil*
[2] *Estação Experimental de Citricultura de Bebedouro, Bebedouro (SP) 14700-970, Brazil*
[3] *Centro de Solos e Recursos Ambientais, Instituto Agronômico/Barão de Itapura, Campinas (SP) 13020-902, Brazil*

Abstract

Boron (B) is a key element for citrus production, especially in tropical regions, where the nutrient availability is commonly low in the soil. In addition, information about doses, fertilizer sources, methods of application, and particularly, differential nutrient demand of scion/rootstock combinations are required for efficient fertilization of commercial groves. In a non-irrigated sweet orange orchard (*cv*. Natal), grafted onto Rangpur lime, Swingle citrumelo or Sunki mandarin, we studied the application of two sources of B: boric acid (17% B, soluble in water) and ulexite (12% B, partially soluble in water) at four levels of supply (control without B, and soil application of 2, 4 and 6 kg ha^{-1} yr^{-1} of B). The experiment was carried out for three years (2004–2006). Boron availability in the soil and concentration in the leaves, as well as the fruit yield and quality of trees were evaluated. Soil B extracted with hot water and total leaf B positively correlated with doses of the nutrient applied to the trees. Levels of B in the soil and in the leaves did not vary with fertilizer sources. Fruit yield of trees grafted onto Rangpur lime and Swingle citrumelo was more responsive to B doses than those grafted onto Sunki mandarin. The maximum fruit yield of trees grafted onto Swingle was obtained with 3.2 kg ha^{-1} yr^{-1} of B, and leaf B level of 280 mg kg^{-1} that point out to a highest demand for B when this combination was compared with other rootstocks. Furthermore, fertilization with B did not affect the quality of fruits, but correlated with B and potassium (K) concentrations in the leaves. These results also support that the current recommendations for levels of B in leaves should be revisited.

Keywords: boric acid, ulexite, fertilization *via* soil, leaf analysis, fruit quality, citrus

1. Introduction

Boron (B) deficiency has affected a significant area of citrus orchards in the world (Liu *et al.* 2014; Zhou *et al.* 2014; Wang *et al.* 2015), especially those in the tropical regions. This is a consequence of lower availability of this nutrient in soil and longer periods of drought or excess rainfall, which reduce the absorption of this nutrient by plants (Huang *et al.* 2005). In recent years, the citriculture in the State of São Paulo, the major producing region in Brazil,

Received 23 May, 2016 Accepted 12 September, 2016
Correspondence Dirceu Mattos Jr, Tel/Fax: +55-19-35461399, E-mail: ddm@ccsm.br

doi: 10.1016/S2095-3119(16)61492-2

has moved to less traditional growing region in the South, where temperatures are milder and rainfall more abundant, compared to the North and Northwest. In such new area, plant transpiration rates are lower and, consequently, the B deficiency is more severe.

B absorbed by roots is transported *via* xylem, mostly driven by plant transpiration, and then distributed to all plant tissues (Huang *et al.* 2005; Mertens *et al.* 2011; Wimmer and Eichert 2013; Mesquita *et al.* 2016). However, this nutrient exhibits low mobility in the phloem of citrus (Boaretto *et al.* 2008) and, consequently, limited redistribution in the trees (Liu *et al.* 2012). Such characteristic interferes with the definition of the best nutrient management practices in orchards (Mattos *et al.* 2005). Basing on the closed correlation between the dose of B applied to the soil and the fruit yield of sweet oranges (*Citrus sinensis* (L.) Osbeck), the maximum fruit yield is estimated at a dose of 4 kg ha^{-1} of B and soil levels at ~1.0 mg dm^{-3} of B in the 0–20 cm depth layer (Quaggio *et al.* 2003). Moreover, the application of B on the soil is more efficient than leaf fertilization (Boaretto *et al.* 2011). Taking these information together, official guidelines for nutrient recommendation for citrus growers have been revised and B supply *via* soil in citrus orchards recommended. Thereafter, more data on nutrient sources and horticultural responses of rootstock varieties are still required to improve the efficiency of soil B applications.

Borax ($Na_2B_4O_7 \cdot 10H_2O$) and boric acid (H_3BO_3) are the most common fertilizers that contain B, which are soluble in water. Others, such as ulexite ($NaCaB_5O_9 \cdot 8H_2O$) and colemanite ($Ca_2B_6O_{11} \cdot 5H_2O$) are less soluble in water (Bell and Dell 2008; Abat *et al.* 2015). Then, different water solubilities of these sources could be important for management of fertilization, since soil application of the more soluble sources could increase the risk of B losses from the soil profile by leaching (Brennan *et al.* 2015; Sá and Ernani 2016) or cause toxicity when applied in high doses in regions with low rainfall (Gimeno *et al.* 2012).

The availability of a micronutrient for agricultural crops is determined primarily by the texture, pH and the content of organic matter in the soil, as well the water availability for the plants. Over the last few decades there has been a necessity to substitute the rootstocks commonly used in the Brazilian citriculture, such as the Rangpur lime and Volkamer lemon (*Citrus volkameriana* V. Ten. & Pasq.), due to diseases that appeared during the 1970s and late 1990s, for example, citrus blight and citrus sudden death (Bassanezi *et al.* 2003). Swingle citrumelo (*Citrus paradisi* Macfad.×*Poncirus trifoliata* (L.) Raf.) and the mandarins Cleopatra (*Citrus reshni* hort. ex Tanaka) and Sunki (*Citrus sunki* (Hayata) hort. ex Tanaka) are tolerant to these diseases (Pompeu and Blumer 2008).

Besides rootstock varieties optimize plant tolerance to biotic and abiotic stresses (Syvertsen and Garcia-Sanches 2014), they also affect physiological and nutritional characteristics of trees (Quaggio *et al.* 2010; Hippler *et al.* 2016; Mesquita *et al.* 2016). In sweet oranges, a higher nutritional demand for B was verified when scions were grafted onto Swingle compared to Rangpur lime (Boaretto *et al.* 2008; Mattos *et al.* 2008). Additionally, observations taken from commercial citrus orchards showed that B deficiency symptoms were more frequent in trees grafted onto Swingle. Poorly developed plants characterize these symptoms, which also present small leaves on shortened branches coming from excessive sprouting of axillary buds due to the loss of stem apical dominance (Mattos *et al.* 2005; Liu *et al.* 2012). Fruits from deficient trees can also appear deformed and prematurely drop off (Wang *et al.* 2015).

The present research tested the hypothesis that differences in the water solubility of B fertilizer sources and the horticultural characteristics of the rootstocks affect fruit yield of orange trees in response to B applied *via* soil. Therefore, this study was carried out with the objective to evaluate the fertilization efficiency with B applied to the soil surface at four doses of the nutrient supplied by two sources and the fruit yield of sweet orange trees grafted onto three different rootstocks. We also sought to establish calibration curves between soil and leaf analyses, and fruit quality and production of orange trees.

2. Materials and methods

The experiment was carried out in the municipality of Bebedouro-SP from 2004–2006, 20°54´30.5´´S, 48°30´57.34´´W, in a dystrophic Oxisol with a medium texture (pH ($CaCl_2$))=5.7; cation exchange capacity (CEC)=55 $mmol_c$ dm^{-3} and B=0.2 mg dm^{-3} in the 0–20 cm soil layer). Before setting up the experiment, dolomitic limestone was applied (acid neutralizing capacity of 70%) to elevate the soil base saturation to 70% (Quaggio *et al.* 2010). The climate in the region by the Köppen classification is Cwa, a dry winter and a hot and humid summer with an average annual temperature of ≥23°C.

The experiment was set up in a three-year-old orchard of sweet orange trees *cv*. Natal (*C. sinensis* (L.) Osbeck), planted at 7 m×4 m and grafted onto the rootstock Rangpur lime (*C. limonia* Osbeck), Swingle citrumelo (*P. trifoliata* (L.) Raf.×*C. paradisi* Macf.) or Sunki mandarin (*C. sunki* (Hayata) hort. ex. Tanaka). The treatments were constituted by the three rootstock varieties distributed in blocks; two sources of the fertilizer containing B, applied to the soil (boric acid (H_3BO_3) and ulexite ($NaCaB_5O_9 \cdot 8H_2O$)) and four doses of the micronutrient (control without B, 2, 4 and 6 kg ha^{-1} yr^{-1}; or 5.5, 11.0 and 16.5 g $tree^{-1}$, respectively). The experiment was set up in a 3×2×4 factorial design with four replicates, each consisting of 24 plants. The experimental plots defined by three planting rows, with six trees each; the four central trees