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THE BEHAVIOR OF APPLE PLANTS (cv. REDCHIEF) GROWN ON ACID SOIL IN RELATION TO BORON NUTRITION

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Abstract

The experiment was carried out outdoors on 2-year-old 'Redchief' apple plants planted in containers filled with two soils (pH 4 and 6.5) and fertilized with B (0, 1, 3 and 5 mg kg^{-1} soil). At the end of the experiment, B concentration in soil was significantly and positively correlated with the B doses applied. Increasing the doses of added B, the fresh weight of plants and B concentration in leaves were significantly increased. However, leaf N concentration was negatively correlated with B concentration in soil. The number and length of lateral shoots and the height of plants were not influenced by B nutrition. Chlorophyll concentration in leaves was reduced at higher B treatments only in plants grown in acid soil.

Key words: acid soil, apple, boron, mineral nutrients, pH

INTRODUCTION

Apple culture in Greece is a potential fruit culture that occupies an area of 12,000 ha with an annual production of 234,700 tons per year (FAO, 2008). The strong influence of site, genetic material as well as fertilization on apple tree nutrition and growth, fruit size and yield is well known (Fallahi et al., 1984; West et al., 1988; Tagliavini et al., 1992). Boron (B) is a micronutrient whose specific role is unclear. It seems to be involved in membrane integrity and nucleic acid synthesis. In apple, B deficiency results in physiological disorders of fruits such as cork spot. Plants absorb B as undissociated boric acid (H_3BO_3) but the whole process is not yet well understood. Low quantities of other B forms such as $B_4O_7^{2-}$, $H_2BO_3^-$, HBO_3^{2-} and BO_3^{3-} may exist but do not contribute much in plant nutrition (Tisdale et al., 1993). Among the soil parameters that affect B uptake from plants, pH is the most significant (Gupta, 1979). Boron adsorption in soil increases as a result of increasing soil solution pH from 3 to 9 (Mezuman and Keren, 1981) leading to a decline in B uptake by plants. Therefore, B deficiency may occur in heavy-textured soils with high pH because under these conditions B is readily absorbed. Moreover, B may also be adsorbed by clay particles in soils with low pH (<5.5). Soil acidosis is a world-wide problem, with the area expanding (Haug, 1984). It has serious impacts upon crop growth and agricultural production. There is an increasing global concern about acidification of agricultural soils and its effects on plant growth (Manoharan et al., 2007). Boron has a number of useful properties related to reduction in toxicity for plants growing in acidic soils. Recent studies have shown that high B concentrations may prevent or alleviate aluminum toxicity (Wojcik, 2003; Hossain et al., 2004), which is significant for improving plant growth in acidic soils.

MATERIAL AND METHODS

Two-year-old, uniform, apple (Malus domestica Borkh 'Redchief') plants budded on MM106 rootstock were planted in 5-L plastic pots containing acid soil (pH 4.0, soil 1) or the soil 1 amended with 5.5 g CaO per litre soil (pH=6.5, soil 2). Concerning the texture of soil, it was classified as loam (clay 8.4%, sand 41.07%, silt 50.53%) and its electrical conductivity was 0.99 mS cm^{-1} (soil 1) and 1.44 mS cm^{-1} (soil 2). The plants were grown outdoors in Orestiada city (long 26°53', lat 41°51'; altitude 29 m) during the period 9 May 2009 – 19 September 2009 and the mean temperature ranged between 20.1 and 26.9°C. After fertilization with boric acid (0 (B0), 1 (B1), 3 (B3) and 5 (B5) mg B kg^{-1} soil) the plants were irrigated every 2-3 days with 500 mL tap water per pot. At harvest, the plants were separated into leaves, stems (scion and rootstock) and roots. All samples were washed twice with distilled water, dried at 75°C for 48 h and ground in a mill to a fine powder to pass through a thirty-mesh screen. Tissue B extraction was made by dry ashing of 0.5 g dried sample in a muffle furnace at 500°C for 6 h. The ash was dissolved in 10 mL of 0.1 N hydrochloric acid (HCl) and B was determined colorimetrically (420 nm) by the Azomethine-H method (Wolf, 1971). The analytical determination of N was performed using the Kjeldahl method (Chapman and Pratt, 1961). The chlorophyll concentration in leaves was determined in fully developed leaves (4^{th} to 5^{th} leaf from the apex of the plant), according to Wintermans and Mots (1965) and expressed on a fresh matter basis. Data were subjected to the Duncan multiple range test for comparison of means ($P \leq 0.05$) using the SPSS statistical package

RESULTS AND DISCUSSION

During the experiment, B concentration in soil declined in all treatments (Fig. 1). On the 55^{th} day of the experiment the highest B concentration in soil was found in the treatment B5. Moreover, in the above treatment B concentration in soil 2 maintained in higher levels than in the rest treatments (Fig. 1b). At the end of the experiment, B concentration in soil was significantly and positively correlated with the B doses applied (soil 1, r^2=0.627 and soil 2, r^2=0.996). In general, during the experiment the concentration of B in soil was reduced up to -69.1%.

Leaf B concentration during the experiment declined in all treatments, except for that of 5 mg B kg^{-1} in soil 1. At the end of the experiment, the plants treated with 5 mg B kg^{-1} soil presented the highest leaf B concentration i.e. 73.2 and 55.4 mg B kg^{-1} in the soils 1 and 2, respectively (Fig. 2a). The lowest B concentrations in leaves were found in control plants, that is 34.1 mg B kg^{-1} soil (soil 1) and 39.6 mg B kg^{-1} soil (soil 2). Regarding the sufficiency levels of B in apples (Shear and Faust, 1980; Almaliotis et al., 2005), only the leaf B concentration in treatment B5

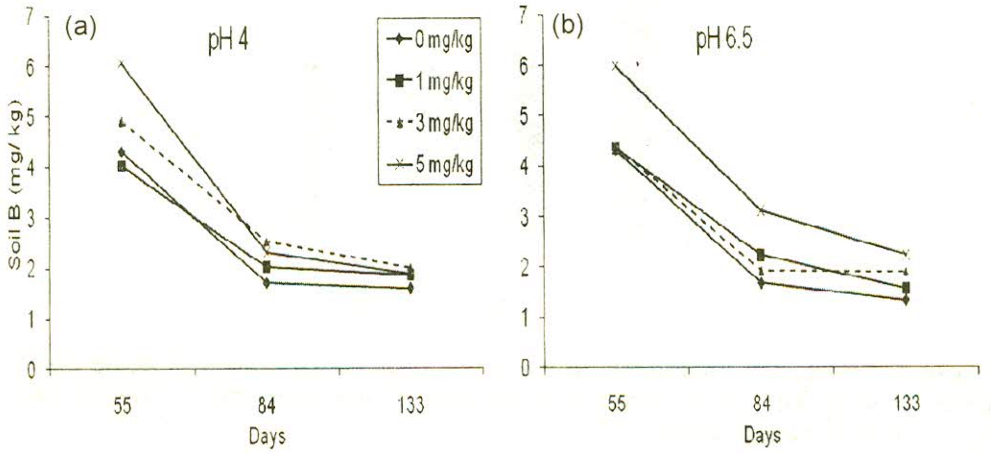

Figure 1. Variation of boron concentration in soils with pH 4 and 6.5 during the experiment.

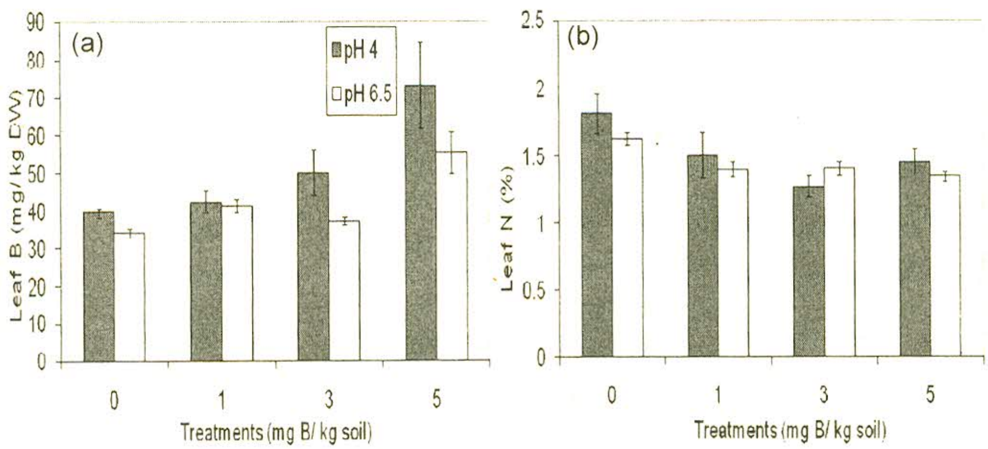

Figure 2. Effect of B treatments on leaf boron (a) and leaf nitrogen concentration of apple plants grown in soils with pH 4 and 6.5 at the end of the experiment. Vertical bars represent ±standard deviation.

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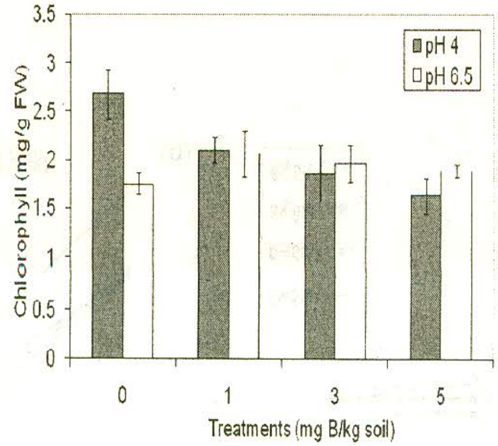

Figure 3. Effect of B treatments on leaf chlorophyll concentration of apple plants grown in soils with pH 4 and 6.5 at the end of the experiment. Vertical bars represent ±standard deviation.

slightly exceeded the upper limit of 60 mg B kg^{-1}. These results may be indicative of the high risk of B excess in apples grown in acid soils, when treated with improper quantity of B fertilizers or irrigated with high B water. Interestingly, below 10% of the total B in plants was distributed in leaves (data not shown). Moreover, among the plant parts, the highest amount of B was remained in roots (41.7%-49.5%) and, specifically, the treatment 3 mg B kg^{-1} soil presented the highest values in both soils.

Leaf N concentration at the end of the experiment ranged between 1.27% and 1.81% (Fig. 2b). According to the critical values reported by Shear and Faust (1980) and Almaliotis et al. (2005), all treatments except control in soil 1 presented insufficient leaf N concentrations. The application of B led to a decrease in N concentration in leaves, in both pH. Similarly, in another study with B nutrition and olives the highest leaf N concentration was recorded in the −B treatment and the correlation between the applied B dose and N in leaves was negative (Chatzissavvidis et al., 2005). Therefore, to avoid possible deficiency problems, the doses of B fertilizers in soils with low pH should be calculated very thoroughly.

The number and length of lateral shoots and the final height of plants were not significantly affected by B nutrition (data not shown). However, the increase (%) of total plant fresh weight (FW) [FW increase % = (final FW- initial FW) X 100/ initial FW] was positively correlated with the amount of B applied in soil 1, whereas there was no consistent effect in soil 2 (data not shown).

The total chlorophyll concentration in leaves at the end of the experiment was reduced in the plants grown in soil 1 and treated with 3 or 5 mg B kg^{-1} soil (Fig. 3). In line with these results, experimenting with the apple rootstock MM106, Mouhtaridou et al. (2004) found that leaf chlorophyll contents declined as B concentration of the culture medium increased. Since B may influence either the uptake or the transport of mineral elements within the plants, this result may be ascribed to the decrease of some elements (e.g. Fe) essential for chlorophyll synthesis (Mortvedt et al., 1991). However, the leaf chlorophyll content in the plants grown in soil 2 was not affected.

CONCLUSIONS

In the present work, the studied apple cultivar presented significant differences as concerns their B, N and chlorophyll status. Further studies on the physiology of apple plants grown in acid soils are important for better understanding the mechanisms involved in B nutrition.

REFERENCES

1. Almaliotis, D., D. Velemis, C. Chatzissavvidis, T. Sotiropoulos, and S. Bladenopoulou. 2005. Sufficiency leaf nutrient levels of apple trees in relation to fruit yield. Journal of Balkan Ecology 8: 151-157.
2. Chapman, H. D., and P. F. Pratt. 1961. Methods of analysis for soils, plants and waters. Riverside, USA: Division of Agricultural Sciences, University of California, 309 p.

3. Chatzissavvidis, C. A., I. N. Therios, and A. N. Molassiotis. 2005. Seasonal variation of nutritional status of olive plants as affected by boron concentration in nutrient solution. Journal of Plant Nutrition 28: 309–321.
4. Fallahi, E., M. N. Westwood, M. H. Chaplin, and D. G. Richardson. 1984. Influence of apple rootstock and K and N fertilizers on leaf mineral composition and yield in high density orchard. Journal of Plant Nutrition 7: 1161-1177.
5. F.A.O. (Food and Agriculture Organization of the United Nations). 2008. http://faostat.fao.org.
6. Gupta, U. C. 1979. Boron nutrition of crops. Advances in Agronomy 31: 273-307.
7. Haug, A. 1984. Molecular aspects of aluminum toxicity. CRC *Critical Reviews* in Plant Sciences Vol.1, CRC Press, Boca Raton, pp. 345–373.
8. Hossain, A. K., M. A. Hossain, H. Koyama, and T. Hara. 2004. Effects of aluminum and boron supply on growth of seedlings among 15 cultivars of wheat *(Triticum aestivum* L.) grown in Bangladesh. Soil Science and Plant Nutrition 50: 189–195.
9. Manoharan, V., P. Loganathan, R. W. Tillman, and R. L. Parfitt. 2007. Interactive effects of soil acidity and fluoride on soil solution aluminum chemistry and barley (*Hordeum vulgare* L.) root growth. Environmental Pollution 145: 778–786.
10. Mezuman U., and R. Keren. 1981. Boron adsorption by soils using a phenomenological adsorption equation. Soil Science Society of America Journal 45: 722-726.
11. Mortvedt, J. J., F. R. Cox, I. M. Shuman, and R. M. Welch. 1991. Micronutrients in agriculture. SSSA, Madison.
12. Mouhtaridou, G. N., T. E. Sotiropoulos, K. N. Dimassi, and I. N. Therios. 2004. Effects of boron on growth, and chlorophyll and mineral contents of shoots of the apple rootstock mm 106 cultured *in vitro*. Biologia Plantarum 48: 617-619.
13. Shear, C. B. and M. Faust. 1980. Nutritional ranges in deciduous tree fruits and nuts. Horticultural Reviews 2: 142-163.
14. Tagliavini, M., D. Scudellari, B. Maragoni, A. Bastianel, F. Franzin, and M. Zamborlini. 1992. Leaf mineral composition of apple tree: Sampling date and effects of cultivar and rootstock. Journal of Plant Nutrition 15: 605-619.
15. Tisdale, S. L., W. L. Nelson, J. D. Beaton, and J. L. Havlin. 1993. Soil Fertility and Fertilizers, 5th edition, Macmillan publishing company.
16. West, S., and E. Young. 1988. Effects of rootstock and interstock on seasonal changes in foliar nutrient (N, P, K and Ca) composition of 'Golden Delicious' apple. Fruit Varieties Journal 42: 9-14.
17. Wintermans, J. F., and A. Mots. 1965. Spectrophotometric characteristics of chlorophylls a and b and their pheophytins in ethanol. Biochimica et Biophysica Acta 109: 448-453.
18. Wojcik, P. 2003. Impact of boron on biomass production and nutrition of aluminium stressed apple rootstocks. Journal of Plant Nutrition 26: 2439–2451.
19. Wolf, B. 1971. The determination of boron in soil extracts, plant materials, composts, manures, water and nutrient solutions. Communications in Soil Science and Plant Analysis 2: 363–374.