SOUTHERN BRAZILIAN JOURNAL OF CHEMISTRY
SOUTH. BRAZ. J. CHEM., Vol. 9 , Nº 10, 2001

RESPONSE OF THE COMMON CABBAGE (*Brassica oleracea* L. var. capitata L.) TO BORON FERTILIZATION

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ABSTRACT: *The response of the common cabbage (Brassica oleracea L. var. capitata L.) to boron fertilization in soils of the state of Paraná, Brazil, is provided. Six types of soils, LRd; LRe, Ca_1; Ca_2, TRd and LEd were selected, treated with macronutrient fertilizer, their pH was corrected, according to routine. Experiment was conducted in 2.5-L capacity pots, with 2 kg of each soil, in a greenhouse. Each type of soil, in triplicate samples, received boron treatment with boric acid: 0.0 g; 0.1 g; 0.2 g. Pots were kept at 70% water capacity retention during 7 days, after which they received 6 cabbage shoots. Two shoots were maintained and later only one was kept in each pot. Duration of experiment was 8 weeks, after which harvest was undertaken. Plants were dried in stoves, weighted, ground and conditioned for further analysis. Extractor HCl 0.05 mol L^{-1} was used to determine boron in soils. Although soils Ca_1, LRd and LEd gave significant responses to treatments, concentrations of available boron over 4 $\mu g\ g^{-1}$ were toxic to cabbages.*

Key words: boron; micronutrients, cabbage, fertilization.

RESUMO: *O presente trabalho teve como objetivo avaliar a resposta do repolho (Brassica oleracea L., var. capitata L.) à adubação boratada em solos do Estado do Paraná. Para isto, foram selecionados 6 tipos de solos: LRd; LRe; Ca_1; Ca_2; TRd; LEd; nos quais realizaram-se a adubação com o micronutriente boro e a correção do pH, seguindo-se a análise de rotina. Em casa de vegetação foi montado o experimento em vasos de 2,5-L. Em triplicata, cada solo recebeu tratamento com B (boro): 0,0 g; 0,1 g; 0,2 g na forma de ácido bórico. Os vasos foram mantidos a 70% da capacidade de retenção água durante 7 dias, quando receberam 6 mudas de repolho, conservando-se posteriormente duas, e em seguida apenas uma planta em cada vaso. O experimento foi conduzido por 8 semanas, quando foram feitas as coletas das plantas, as quais, foram secadas em estufa, pesadas, moídas e acondicionadas em frascos plásticos para posterior análise. O extrator utilizado para determinar o boro no solo foi a solução de HCl 0,05 mol L^{-1}. Os solos Ca_1, LRd e LEd mostraram respostas significativas aos tratamentos realizados e as concentrações superiores a 4 $\mu g\ g^{-1}$ mostraram serem tóxicas para o repolho.*

DOI: 10.48141/SBJCHEM.v9.n10.2001.12_2001.pdf

INTRODUCTION

Soil nutrients are divided into two important classes: macronutrients found in large quantities in the plant dry matter (%) and micronutrients found in smaller quantities (ppm). Micronutrients are essential chemical elements, such as Fe, Cu, Mn, Zn, Mo, Cl and B required by plants in small quantities[1]. Maze and later on Warigton stressed that boron is essential[2].

The researchers Wear and Berger and Truog, *apud* Ribeiro and Sarabia[3], showed that only a tiny fraction of total boron in soil is available to plants. Deficiencies are shown in clay soils with low activity clay, poor in organic matter and low CTC[4].

The soil low fertility, great upheavals during the harvest of some cultivated plants and the increasing use of lime and phosphate manure cause lower availability of this specific micronutrient[5]. Boron fertilization is necessary to avoid decrease of produce in places where heavy K fertilization and intense cultures are practiced[6].

Coffee and citric plants, sunflowers, tomatoes and other vegetable species are especially sensitive to boron deficiencies in soil[7] with consequent losses in productivity[8]. Boron deficiency in plants may be detected when its concentrations in soil range between 0.1 and 0.7 $\mu g\ g^{-1}$, Buzetto and Muroka[9].

In plants its functions amount to carbohydrate metabolism, sugar transportation, synthesis of nucleic acids, phytohormones, formation of cell walls and cell division[10, 11]. Boron deficiency symptoms are generally found in the plant younger sections. In the alfalfa and clover boron deficiency is marked by color variation (yellow-red). Toxicity is confirmed by the appearance of burns or tanning in the leaves edges. One of the chief effects of boron deficiency in plants is the excessive decrease of nitrate in leaves[12]. The concentration of boron between 20 and 50 $\mu g\ g^{-1}$ is considered basic for the development of plants[13] (Gupta, 1991). More than the cabbage, the genus *Brassica*, represented by the cauliflower and broccoli, is more sensitive to boron deficiencies[14].

The general objective of the present research work is the collection of data for the monitoring of deficiency and toxicity of micronutrients in arable soil. Its specific aim is the analysis of the response of boron fertilization in six different types of soil. The plant used is the cabbage since it is conspicuous in Brazilian food, it is consumed both uncooked and otherwise, it is a cheap nutrient source, albeit rich in mineral salts and vitamins.

MATERIALS AND METHODS

Sampling

Six types of soils of five different classes from the state of Paraná, Brazil, were used: dystrophic Red Latosol (LRd); eutrophic Red Latosol (LRe); allic Cambisol (Ca_1); allic Cambisol (Ca_2); structured Dark Red Latosol (TRd); dystrophic Dark Red Latosol (LEd). The above-mentioned soils were also used by Favero[15] in another experiment to evaluate response of the cotton plant to boron application.

Physical analysis of soils

Folk's granulometric classification[16] and Suguio's methodology[17] were employed in the Pedology, Sedimentology and Palinology Laboratory of the Department of Geography of the State University of Maringá, Maringá PR Brazil.

Experiment

Pots of 2.5-L capacity, internally lined with plastic bags, were filled with 2 kg of six types of soil, respectively. Pots were organized as follows: LRd was placed in pots from 1 to 9, corresponding to the three soil boron treatments in triplicate; LRe in pots from 10 to 18; Ca_1 in pots from 19 to 27; CA_2 in pots from 28 to 36; TRd in pots from 37 to 45; LEd in pots from 46 to 54. Soils were fertilized with 3.72 g of $NH_4H_2PO_4$, 4.5 g of K_2SO_4 and lime according to routine analysis. Boron treatments consisted of 0.0; 0.1 and 0.2 g of boric acid (H_3BO_3) corresponding to: 0,0; 0,010 and 0,10 g kg^{-1}, with three replications, respectively. After the soils were placed in the pots and fertilized, distilled and de-ionized water was added until humidity of 70% of water retention capacity was reached. Irrigation continued for 7 days in the greenhouse. Six cabbage plants were then planted in each pot. Plants with low development were discarded and only one was finally left. Plants were maintained at 70% field capacity during 8 weeks, after which they were harvested.

Yield of vegetal material and samples of soil in the pots

After eight weeks the plants were harvested close to the ground, washed with distilled and de-ionized water, dried in porcelain capsules in a stove at 60 °C to constant weight. Evaluation of the total mass of plants after treatment was accomplished by weighing of the samples.

After harvest, soils were removed from the pots, air-dried, triturated, and passed though 2mm-mesh sieves, homogenized and placed in plastic bags for further analysis.

Extraction and determination of boron in soils

Volumes of 20 mL of HCl 0.05 mol L^{-1} were added to each 10 g of sample of air-dried fine soil, shaken for 5 minutes and then filtered with a n^0. 42 Whatman filter paper. Analyses of boron concentration in soils were undertaken from extracts by UV-Vis spectrophotometry with Azomethina-H[18].

Statistics

Variance analysis was applied to the results. When significant difference ranged between 5 and 1%, Tukey test was employed for differentiation at the same levels of significance.

RESULTS AND DISCUSSION

Table 1 shows the characteristics of soils *in natura* used in the experiment. pH values varied from 5.7 to 7.2, with highest value in LEd. Low rate of organic matter and the high percentage of sand in LEd showed that the added and solved limestone in samples of this soil practically remained in the solution. Consequently, it had the highest pH value. Soils TRd and LRd contained the highest percentage of clay.

Table 1. Chemical and Physical Properties of Pre-Treatment Soils.

Parameters	Ca_1	Ca_2	TRd	LRd	LRe	LEd
pH (H_2O)	5.7	5.7	6.6	6.2	6.3	7.2
C (%)	3.49	3.99	2.01	2.21	1.37	0.74
O.M.(%)	6.00	6.86	3.46	3.80	2.36	1.27
Clay (%)	39.57	52.62	65.40	65.47	38.77	9.65
Silt (%)	55.43	45.38	33.60	31.53	34.55	3.35
Sand (%)	5.0	2.0	1.0	3.0	6.0	87.0

$Ca_{(1\ and\ 2)}$ - allic Cambisol; LEa - allic Dark Red Latosol; TRd - Structured Dark Red Soil; LRd - Dystrophic Red Latosol; LRe - eutrophic Red Latosol; LEd - dystrophic Dark Red Latosol.

Treatments caused a 5% significant increase in boron level in soil, as may be seen in Table 2.

Table 2. Tukey's Test at 5% Level in Boron Concentration Means in Soil Solution, in $\mu g\ g^{-1}$, per Treatment after Harvest.

Soil	Ca_2	Ca_1	TRd	LRd	LRe	LEd
Reference	0.910 *b*	0.36 *b*	0.09 *c*	0.19 *c*	0.57 *b*	0.41 *c*
Treatment 1	1.48 *b*	2.19 *a*	1.55 *b*	1.75 *b*	1.25 *ab*	3.86 *b*
Treatment 2	2.91 *a*	3.40 *a*	3.20 *a*	4.09 *a*	2.31 *a*	8.36 *a*

$Ca_{(1\ and\ 2)}$ - allic Cambisol; TRd - structured dystrophic Red Soil; LRd - dystrophic Red Latosol; LRe - eutrophic Red Latosol; LEd - dystrophic Dark Red Latosol; Reference – soil reference with no boric acid; Treatment 1 – treatment with 0.1 g boric acid; Treatment 2 – treatment with 0.2 g boric acid; (*a*, *b*, ...) -Values followed by the same letter are not significantly different at 5% level, using the Tukey's test (SANEST software).

Many boron concentrations in reference treatments without boron fertilization were within micronutrient deficiency levels, or rather, 0.7 μg g^{-1}, according to Buzetto and Muroka[9]. Soils Ca_2 and LEa are exceptions.

Soils TRd, LRd and LEd had highest increase in available boron levels, as Table 2 shows. In treatments 1 and 2 LEd had highest concentration of extractable boron, 3.86 and 8.36 μg g^{-1} respectively. This may be due to the fact that LEd is a sandy soil with low concentration of clay and organic matter. Practically almost all added boron is available (or present) in the soil solution.

Figure 1 shows values in grams of dry mass of cabbage plants cultivated in three treatments in six types of soil.

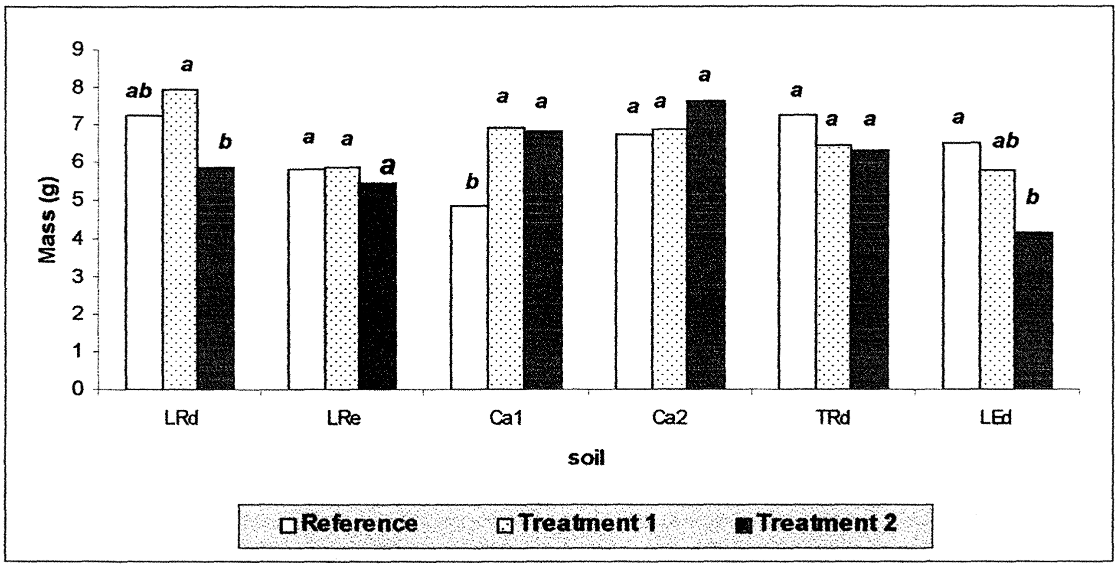

Figure 1. Mass of Plants (in grams) with Respective Treatments.

According to variance analysis there was a significant difference between masses of plants cultivated in treatments with Ca_1, LRd and LEd. It may be remarked that in the case of Ca_1 the plant response to boron fertilization was positive. On the other hand, growth of plants in treatments of LEd was impaired. Negative effect to fertilization is shown by decrease of dry matter of plants to Treatment 1 and more pronounced to Treatment 2. Although in the case of LRd plants response was positive to Treatment 1, fertilization for this type of soil in Treatment 2 was toxic to plants and impaired their growth. The same fact has been noted by Luchese *et al.*[19] with the cotton plant.

Treatments in LEd, LRd and Ca_2 had the most significant response with regard to mass of cabbage plants and boron concentration in soils. Figure 2 shows this correlation in detail. Curve *a* and *b* of the figure show that boron concentrations up to 2 μg g^{-1} in these soils did not impair the development of cabbage plants. Treatments with 0.2 g of boric acid caused an increase of over 4 μg g^{-1} in available boron concentrations for LEd and LRd. Plants cultivated in these soils presented toxicity levels when concentrations were higher than 4 μg g^{-1}. This proves that levels between deficiency and toxicity in this micronutrient for the plant under analysis are relatively low[20].

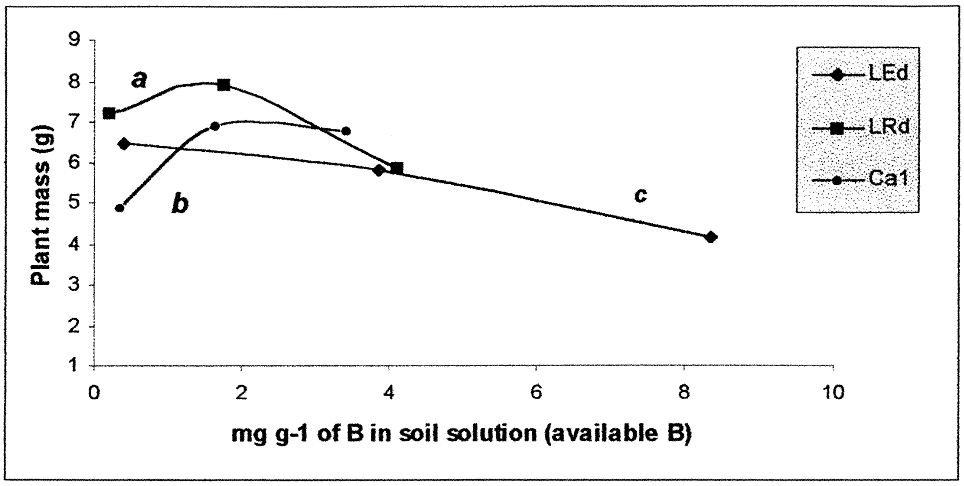

Figure 2. Relation between Boron Concentrations in Soil Solution (available B) and Dry Masses of Plants for Treatments in LRd, LEd and Ca_1.

Soil LRd has low sand concentration, high concentration of clay and organic matter. These factors caused a greater development of the plants in response to fertilization with 0.1 g of boric acid. However, fertilization with 0.2 g surpassed the 4 μg g^{-1} of boron available concentration in the soil solution and a lower development of plants occurred. In the case of LEd high presence of sand and low presence of clay and organic matter gave the soil a greater tendency of ion concentration in the solution and more boron was available to the plants. Consequently their growth was impaired, as may be seen in curve *c* of Figure 2.

CONCLUSION

Boron concentration extractable by HCl 0.05 mol L^{-1} in soil samples showed that with treatments (0,00 g kg; 0,010 g kg and 0,10 g kg) there was a significant increase in the level of available boron in the soil.

The cabbage presented a diagnosis of deficiency and toxicity of the boron micronutrient in the six types of soil. Tukey's test showed significant differences in the dry masses of plants in LEd, LRd and Ca_1. In Ca_1 there was a positive response of the plant to boron fertilization. In LEd the response was negative, and in soil LRd only Treatment 2 impaired the plant development.

Treated soils with available boron concentrations over 4 μg g^{-1} may be toxic to the cabbage plant.

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The SOUTHERN BRAZILIAN JOURNAL OF CHEMISTRY (ISSN: 2674-6891; 0104-5431) is an open-access journal since 1993. Journal DOI: 10.48141/SBJCHEM.
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