Original Research Article

Soil Fertilization and Texture on Boron Accumulation and Wood Volume in *Corymbia citriodora* (Hook) K.D. Hill & L.A.S Johnson

ABSTRACT

This study aimed to evaluate the effects of soil fertilization and texture on leaf Boron (B) accumulation and its relation with wood volume of *Corymbia citriodora* Hill & Johnson. The experiment was set in randomized block with four replications, four B fertilization levels (0, 1.1, 2.2 and 4.4 g.plant^{-1}) in two soils types (sandy and clayey). To determine leaf B content, 25 leaves were collected from the median portion of four trees for each treatment. Leaves were dried on oven and B content was determined by the Azomethine-H method using extract obtained by dry digestion. The diameter at breast height and the total height of 25 trees were collected in all treatments and wood volume was calculated. Data were submitted to analysis of variance and the means adjusted to regression equations. The regression coefficients were evaluated by *t-test* at 1 and 5% probability. It was verified that clay soil produces more wood, compared to sandy soil. There was a gain increase in foliar B as B doses increased in both soil types. Leaf B affected *Corymbia citriodora* productivity only in clay soil.

Keywords: eucalyptus, nutrition, fertility, productivity.

1. INTRODUCTION

The increase in wood production, especially after the evolution of clonal propagation and improvements on genetic techniques, has led to clones that are more demanding in a nutritional view. Micronutrient deficiency symptoms have been more commonly observed, mainly boron (B), which, according to Malavolta and Kliemann [1], is the micronutrient that presents more limiting levels in forest soils. B deficiency occurs frequently in eucalyptus and has been related to many other factors such as nutrients accumulation, soil type and others [2, 3, 4].

The genera Eucalyptus and Corymbia are the main forest essences cultivated in Brazil today. Among the species, *Corymbia citriodora* KD Hill & LAS Johnson stands out for having easy adaptation, rapid growth, good quality wood and uses of essential oils production [5]. The planting of this species has grown greatly, especially in areas with water and nutritional restrictions, as occurs in the Northern region of Minas Gerais, Brazil. In these areas, the use of drought-tolerant genetic materials, associated with B fertilization, has been shown to be effective in mitigating water deficit effects [6].

Among the main B functions are cell wall formation and components synthesis, such as pectin, cellulose and lignin [7]. Thus, species with a cell wall rich in pectin, such as dicotyledons, usually have high B requirements, compared to other species [8].

Barreto et al. (2007) [9] found that clones of Eucalyptus grandis x Eucalyptus urophylla responded to Bfertilization in both shoot growth and biomass production, with gains in height and biomass, 240 days after transplanting in pots, 35-54%, and 21-64%, respectively. Silva et al. [10] reported that B foliar application improved nutrition of this nutrient levels in eucalyptus clones leaves, even under water stress conditions.

The B absorption occurs mainly by mass flow, which is directly affected by soil texture and its water retention capacity [11]. Mattiello et al. [12] studying B transport in the soil and its absorption by eucalyptus, verified that maximum production of dry shoot matter was obtained in the B doses corresponding to 0.96 and 1.82 $mg.dm^{-3}$ in -10 and -40 kPa water potentials, respectively.

Nutritional factors have been important for reducing production of planted forests in Brazil since they limit plant growth and consequently reduce productivity [12]. Therefore, researches that seek to maximize forest productivity through more adequate fertilization have fundamental importance.

Considering these factors, this study aims to evaluate the effects of soil fertilization and texture on B foliar accumulation and its relation with wood volume in *Corymbia citriodora*, considering the importance of this species for the economy and the high cost-benefit ratio for implementing adequate nutrition programs in forest species.

2. MATERIAL AND METHODS

2.1 Location and soil characterization

The experiment was set in João Pinheiro (sandy soil) and Três Marias (clayley soil) cities, located in Minas Gerais, Brazil. The climate is classified as dry-subhumid tropical. João Pinheiro city has an average annual temperature of 22.6 ° C and rainfall of 1406 mm. Três Marias has an average annual temperature of 23.5 °C and rainfall of 1214 mm. Both cities have long dry periods, mainly between May and September. The experimental area João Pinheiro city is located at 17 ° 00 'south latitude; 45 ° 50 'west longitude and altitude of 500-550 m. The experimental area in Três Marias city is located at 18 ° 08 'south latitude; and 45 ° 12 'west longitude and 700 m altitude.

The main physical and chemical soils characteristics of experimental areas are described in Table 1.

Table 1. Chemical soil characteristics for each experimental area.

Area	$pH^{(1)}$ (H_2O)	$Al^{3+\,(2)}$	$Ca^{2+(3)}$	$Mg^{2+(3)}$	$P^{(3)}$	$K^{(3)}$	B_{daq}	$OM^{(5)}$	Sand	Silt	Clay
		$cmol_c/dcm^3$			mg kg^{-1}		(g kg^{-1})			(%)	
Sandy	4.48	0.8	0.43	0.1	3	58	0.3	0.85	79	4	17
Clayley	4.7	1.27	0.55	0.39	3	109	0.6	2.74	11	20	69

$^{(1)}$ Ratio 1:2,5; $^{(2)}$ KCl Extractor 1 $mol.L^{-1}$; $^{(3)}$ $Mehlich^{-1}$ Extractor; $^{(4)}$ Hot water Extractor (65 °C) e $^{(5)}$ Organic Matter: Walkley & Black Method.

2.2 Plant cultivation and treatments

The *C. citriodora* seedlings were planted at 3x2 m spacing, with a useful area per plant of 6 m^2 and a population density of 1,666 plants/ha. Before the planting, liming (Ca:Mg ratio of 4:1) was applied to soil aiming the percent base saturation of 80%. At the planting, fertilization (N, P, K) was applied in grooves and performed according to the soil analyze and type [13]. The fertilization of K and N were divided into two stages, at planting and 6 months later. For both experimental areas, three months after planting, B fertilization was carried out with the application of 0; 1.1; 2.2; and 4.4 $g.plant^{-1}$ in the soil. At 15 months, additional fertilization (levels 1, 2 and 4) with 3.6 and 4.4 $g.plant^{-1}$ of borax ($Na_2B_4O_7.10H_2O$) in Três Marias (clay soil) and João Pinheiro (sandy soil), respectively. The management consisted of normal cultural practices with periodic weeding during the entire experiment.

2.3 Evaluations

All evaluations were performed with plants at seven years. The diameter at 1.30 m height (DBH) of 25 plants in all treatments was measured with a tape measure. The trees' heights were obtained using a hypsometer and the volume in m^3/ha of both species was also calculated.

To determine leaf B content, 25 leaves removal from the median portion of four trees for each treatment were collected. After that, they were dried in a forced circulation air oven at 70 °C until weight stabilized. The samples were ground and the B content was obtained by the Azomethine-H method, using extract obtained by dry digestion [14].

2.4 Experimental design and statistical analysis

The experiment was arranged in a randomized complete block design (RCB) in a subdivided plots scheme, with 4 fertilization levels, 2 types of soils, 1 eucalyptus species and 4 replications. The analysis of variance joint was performed according to Banzatto and Kronka [15]. Data of wood diameter and leaf B were submitted to analysis of variance and regression. The regression coefficients were evaluated by the t-test at 1 and 5% probability.

3. RESULTS AND DISCUSSION

The analysis of variance showed no significant interaction between soil and boron for wood volume. However, for leaf Boron, this interaction was significant. These results show dependence or independence of these factors for different analysis. (Table 2).

Table 2. Analysis of variance of wood volume and leaf Boron by *C. citriodora* under crescent boron doses (g/plant) on two soils with different textures

		Mean square	
Source of variation	**df**	**Wood volume**	**Leaf Boron**
Soil	1	15044.81 **	75763.23**
Boron	3	2818.86 **	66371.17**
Block	3	785.92**	148.93**
S x B	3	231.33 ^{ns}	1850.84**
Error	31	514.05	136.11
CV (%)		14.64	11.70

Note. ns, **: non significant and significant by F test (P < 0.01).

The wood production of *C. citriodora* after different B doses application had a higher efficiency in the clayey soil, compared to sandy soil by the *t-test*, at 5 % probability (Table 3). The clayey soil has great natural fertility (Ca^{2+}, Mg^{2+}, K^{+} and B$_{daq}$) and its granulometry associated with a higher organic matter content (Table 1) allows abetter water retention, which may explain its higer performance when compared to sandy soil.

The studied area had a low rainfall distribution at the beginning of the year, with an intense water deficit between May and August. Thus, a greater water capacity retention had fundamental importance to guarantee gains in productivity. Ramos et al. [2009] [16] describes soil moisture as an important parameter to B uses in the soil by *C. citriodora*. It's also important to emphasize that water deficit interferes in B uptake in eucalyptus, causing shoot dieback, especially in young plants. In this context, Dias et al. [17] observed a relevant occurrence of this disease in treatments without addition of B and in the more restrictive water regime. In addition, acocording these autors, the fertilization with 0.55 g boron plant^{-1} in soil was sufficient to avoid shoot dieback.

Organic matter is the biggest source of B in tropical soils [18]. As shown in Table 3, the sandy soil has organic matter content almost three times lower, compared to the clayey soil. The same was observed to B content, thus, there is a correlation between organic matter and B content in the soil.

Table 3. Wood volume means ($m^3.ha^{-1}$) produced by *C. citriodora* under crescent boron doses (g/plant) on two soils with different textures.

Boron ($mg.plant^{-1}$)	Clayey (Três Marias)	Sandy (João Pinheiro)	Means
0	133.69	134.19	133.94
1.1	154.36	126.86	140.61
2.2	157.7	142.36	150.03
4.4	165.53	150.53	158.03
Means	152.86 a	138.53 b	-

Note. a > b by test F (P < 0,05).

In general, wood volume ($m^3.ha^{-1}$) increased as B doses increased. According to the regression equation, the B dose required to reach the highest wood volume (161.01 $m^3.ha^{-1}$) would be 6.49 $g.plant^{-1}$ (Fig. 1).

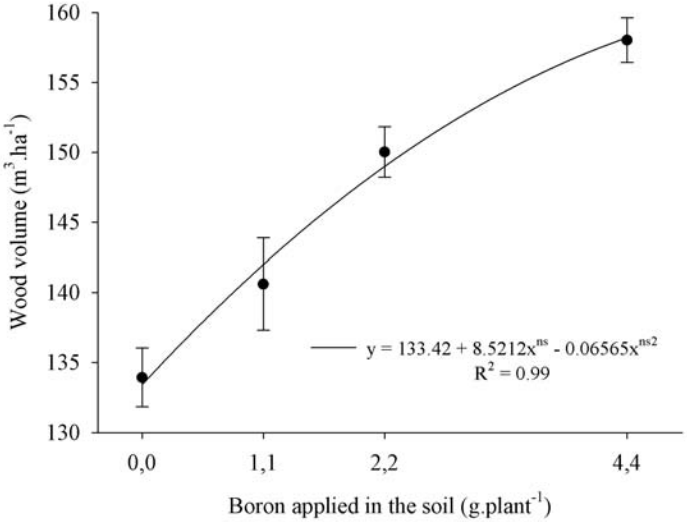

Fig. 1. Volume of wood produced by *C. citriodora* in response to application of different B doses in the soil ($g.plant^{-1}$). ns: non significant, Bars: standard deviation.

The results show that the fertilization using B is fundamental to reach higher yields in the forest plantations. B plays a key role in stem growth and is directly related to volume increment, mainly acting on cell walls formation in the wood [18]. Similar results were obtained by Sgarbi et al. [20, 21], evaluating nutritional status and soil fertility in *Eucalyptus grandis* plantations in two different areas. In these studies, it was observed that B is one of the nutrients that most limit this species growth in these studied areas. Furthermore, a positive relation of this element and Eucalyptus productivity was observed.

It is observed that in the very clayey soil, the maximum level of leaf B is 108.37 $mg.kg^{-1}$, which by the curve would be equivalent to an application of 3.35 $g.plant^{-1}$ of B (Figure 2). In the soil with a sandy-loam texture, the maximum point of leaf B is 256.31 mg.kg-1, which is reached when 8.05 g of $boron.plant^{-1}$ is applied.

In environments with low water availability, B is the micronutrient that more affects tree growth. Moreover, this micronutrient is associated with a series of metabolic reactions such as sugar transport, cell wall synthesis, respiration and others. Thus, the B deficiency may lead to disorders in these processes, further aggravating problems related to water deficit [22].

Tirloni et al. [23] observed that fertilization using B influenced *C. citriodora* growth, evaluating height and diameter only when was performed at the beginning of the rainy season and when plants were already at 29 months old. In younger plants, there was no increase in height or diameter with B application, independent the dry or rainy seasons. According to Paula [24], no differences related to eucalyptus wood volume was verified when plants were fertilized with different B doses and evaluated at 20 and 24 months old. In the present work, the observed influence of B can be related a many factors, such as genotype and climate.

In the sandy soil, it is expected that B availability, absorption and translocation are lower mainly because its absorption by mass flow and due to lower water retention capacity [25, 26]. However, in this study was verified that the leaf B concentration was higher in grown trees in sandy soil than in clayey soil (Fig. 2).

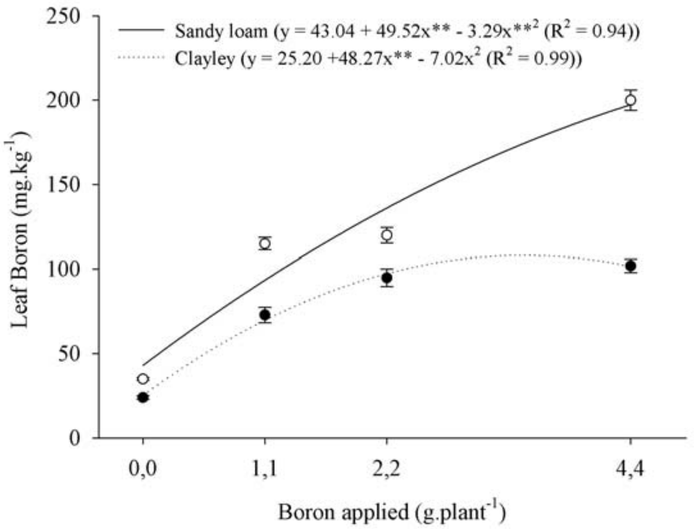

Fig. 2. Leaf boron level of *C. citriodora* under different boron fertilizing doses on two different soil types. **: significant ($P < 0.01$), Bars: standard deviation.

The clayey soil has a greater water retention capacity, which would facilitate the absorption of B. However, due to a greater presence of iron and aluminum oxides, the availability of these nutrients is compromised once adsorption of these elements occurs. According to Barros and Novais [27], B occurs in the soil in the form of boric acid or borate and can be adsorbed to organic and inorganic fractions. Ferreira [28] describes that different minerals types of the soil's clay fraction play a fundamental role in controlling the available B content. The adsorption of B is mainly due to iron and aluminum oxides, since these oxides influence more than any other silicate clay type.

Tirloni et al. [23] reports that in very weathered soils, such as those observed in the cerrado, eucalyptus usually presents symptoms of B deficiency. These symptoms appear mainly when the rainfall regime is characterized by prolonged periods of water deficit [17]. Mattiello et al. [12] concluded that the water deficit elevates the external requirements of B and promotes a higher nutrient concentration in the plant tissue.

In sandy soils B may be leached during the rainy season, on the other hand, in clayey soils, B may be adsorbed in the organic and inorganic fraction, being the soil type directly related to nutrient deficiency occurrence [29]. Ramos et al. [16] observed that B distribution in plant tissues of *C. citriodora* was directly influenced by the amount of nutrient available, in other words, by nutritional status. Ferreto et al. [3] evaluated the relation between B and liming in Eucalyptus cultivated in sandy soils and observed that limed soils showed higher B availability at the same time taht plants showed a higher B concentration in shoots and roots.

It is important to note that other important factors must be considered. In general, B translocation and redistribution in plant tissues are related to its low mobility in the phloem and are also strongly influenced by the plant transpiration flow, which depends not only on soil texture, but also on relative humidity, temperature and light intensity [30, 31, 32]. Being a dry sub-humid tropical climate in the experimental areas, the plants underwent different dry cycles, which may have influenced the translocation of B.

The leaf B content and the wood volume increment ($m^3.ha^{-1}$) of *C. citriodora* for both soil types are shown in Fig. 3.

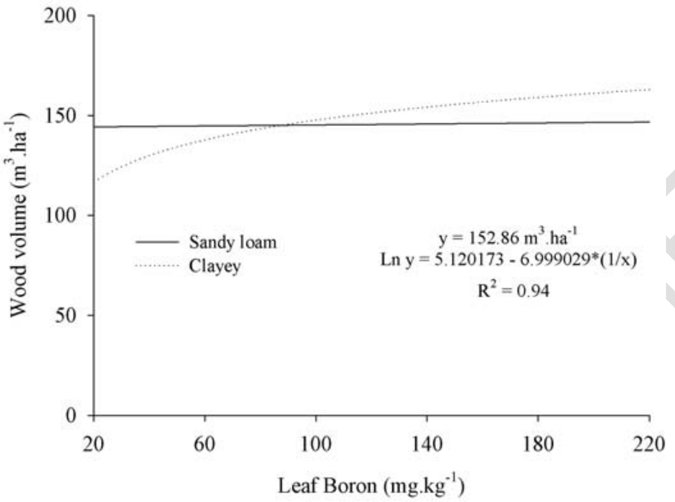

Fig. 3. Relation between wood volume increment ($m^3.ha^{-1}$) and leaf boron ($mg.kg^{-1}$) of *C. citriodora.* cultivated in two different soil types.

For the sandy-loam soil, there was no significant difference in wood volume increment ($m^3.ha^{-1}$) as increasing leaf B dose, suggesting that in this soil the B absorbed was not directed to physiological processes related to the increase of the wood volume, although there is great absorption of this nutrient. On the other side, in clayey soil, there was an increase in wood volume as increasing B absorption. Biomass production and nutrient content present in the eucalyptus are positively related to each other. In addition, biomass production depends on water availability and the plant's ability to absorb, distribute and use this nutrient [33].

4. CONCLUSION

The clayey soil has been shown to be more efficient in the production of wood than the sandy soil because it has a higher natural fertility and a higher content of organic matter, which allows a greater retention of water. Under the studied conditions, 4.4 $g.plant^{-1}$ of B allows figher leaf accumulation and volume of wood in *Corymbia citriodora*.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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