

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

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**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<sup>-1</sup>) 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.

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*Keywords: eucalyptus, nutrition, fertility, productivity.*

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**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 B fertilization 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

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34 al. [10] reported that B foliar application improved nutrition of this nutrient levels in eucalyptus  
35 clones leaves, even under water stress conditions.

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

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

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

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## 51 2. MATERIAL AND METHODS

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### 53 2.1 Location and soil characterization

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

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

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66 **Table 1. Chemical soil characteristics for each experimental area.**

Area	pH <sup>(1)</sup>	Al <sup>3+</sup> <sup>(2)</sup>	Ca <sup>2+</sup> <sup>(3)</sup>	Mg <sup>2+</sup> <sup>(3)</sup>	P <sup>(3)</sup>	K <sup>(3)</sup>	B <sub>daq</sub>	OM <sup>(5)</sup>	Sand	Silt	Clay
	(H <sub>2</sub> O)	cmol <sub>c</sub> /dcm <sup>3</sup>			mg kg <sup>-1</sup>		(g kg <sup>-1</sup> )	(%)			
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

67 <sup>(1)</sup> Ratio 1:2,5; <sup>(2)</sup> KCl Extractor 1 mol.L<sup>-1</sup>; <sup>(3)</sup> Mehlich<sup>-1</sup> Extractor; <sup>(4)</sup> Hot water Extractor (65 °C) e

68 <sup>(5)</sup> Organic Matter: Walkley & Black Method.

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### 70 2.2 Plant cultivation and treatments

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72 The *C. citriodora* seedlings were planted at 3x2 m spacing, with a useful area per plant of 6 m<sup>2</sup>  
73 and a population density of 1,666 plants/ha. At the planting, fertilization with 200 kg.ha<sup>-1</sup> of  
74 simple superphosphate was applied in grooves. For both experimental areas, three months after  
75 planting, B fertilization was carried out with the application of 0; 1.1; 2.2; and 4.4 g.plant<sup>-1</sup> in the  
76 soil. At 15 months, additional fertilization (levels 1, 2 and 4) with 3.6 and 4.4 g.plant<sup>-1</sup> of borax  
77 (Na<sub>2</sub>B<sub>4</sub>O<sub>7</sub>·10H<sub>2</sub>O) in Três Marias (clay soil) and João Pinheiro (sandy soil), respectively. The  
78 management consisted of normal cultural practices with periodic weeding during the entire  
79 experiment.

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### 81 2.3 Evaluations

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

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87 To determine leaf B content, 25 leaves removal from the median portion of four trees for each  
88 treatment were collected. After that, they were dried in a forced circulation air oven at 70 °C until  
89 weight stabilized. The samples were ground and the B content was obtained by the  
90 Azomethine-H method, using extract obtained by dry digestion [13].

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## 92 2.4 Experimental design and statistical analysis

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94 The experiment was arranged in a randomized complete block design (RCB) in a subdivided  
95 plots scheme, with 4 fertilization levels, 2 types of soils, 1 eucalyptus species and 4 replications.  
96 The analysis of variance joint was performed according to Banzatto and Kronka [14]. Data of  
97 wood diameter and leaf B were submitted to analysis of variance and regression. The  
98 regression coefficients were evaluated by the t-test at 1 and 5% probability.

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## 100 3. RESULTS AND DISCUSSION

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

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

Source of variation	df	Mean square	
		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 <sup>ns</sup>	1850.84**
Error	31	514.05	136.11
CV (%)		14.64	11.70

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

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116 The studied area had a low rainfall distribution at the beginning of the year, with an intense  
117 water deficit between May and August. Thus, a greater water capacity retention had  
118 fundamental importance to guarantee gains in productivity. Ramos et al. [2009] [15] describes  
119 soil moisture as an important parameter to B uses in the soil by *C. citriodora*. It's also important  
120 to emphasize that water deficit interferences in B uptake in eucalyptus, causing shoot dieback,  
121 especially in young plants. In this context, Dias et al. [16] observed a relevant occurrence of this  
122 disease in treatments without addition of B and in the more restrictive water regime. In addition,  
123 according these authors, the fertilization with 0.55 g boron plant<sup>-1</sup> in soil was sufficient to avoid  
124 shoot dieback.

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126 Organic matter is the biggest source of B in tropical soils [17]. As shown in Table 3, the sandy  
 127 soil has organic matter content almost three times lower, compared to the clayey soil. The same  
 128 was observed to B content, thus, there is a correlation between organic matter and B content in  
 129 the soil.

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

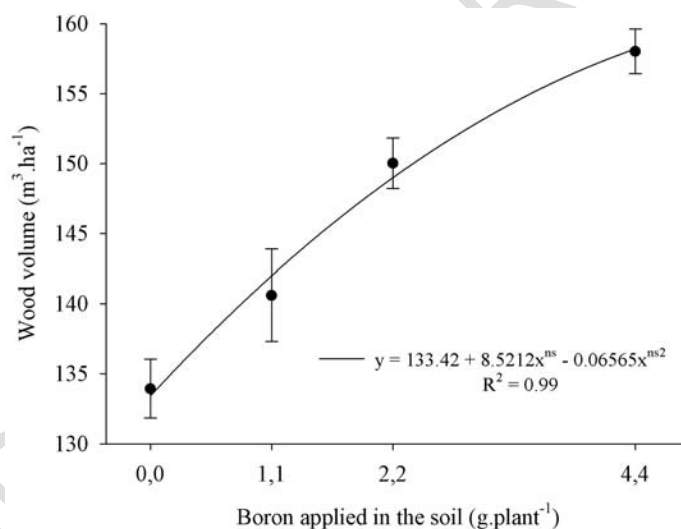
Boron ( $\text{mg} \cdot \text{plant}^{-1}$ )	Clayey (Três Marias)	Sandy (João Pinheiro)	Means
0	133.69	134.19	133.94
1.1	154.36	126.86	140.61
2.2	157.7	142.36	150.03
4.4	165.53	150.53	158.03
Means	152.86 a	138.53 b	-

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

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

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

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144 The results show that the fertilization using B is fundamental to reach higher yields in the forest  
 145 plantations. B plays a key role in stem growth and is directly related to volume increment, mainly  
 146 acting on cell walls formation in the wood [18]. Similar results were obtained by Sgarbi et al. [19,  
 147 20], evaluating nutritional status and soil fertility in *Eucalyptus grandis* plantations in two  
 148 different areas. In these studies, it was observed that B is one of the nutrients that most limit this  
 149 species growth in these studied areas. Furthermore, a positive relation of this element and  
 150 *Eucalyptus* productivity was observed.

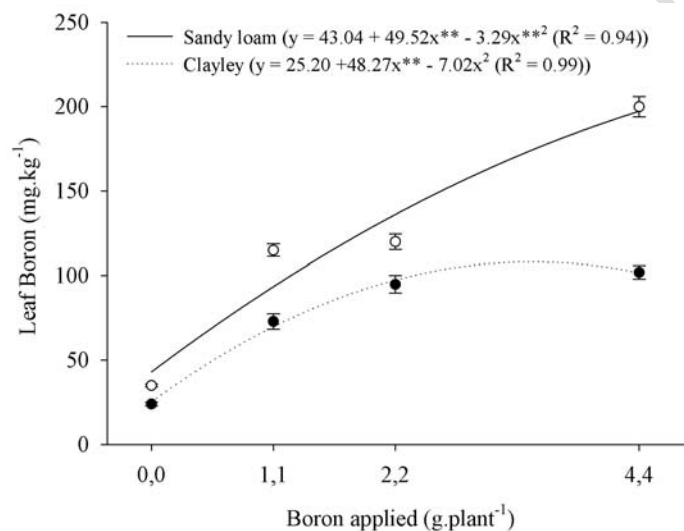
151 It is observed that in the very clayey soil, the maximum level of leaf B is  $108.37 \text{ mg} \cdot \text{kg}^{-1}$ , which  
 152 by the curve would be equivalent to an application of  $3.35 \text{ g} \cdot \text{plant}^{-1}$  of B (Figure 2). In the soil  
 153 with a sandy-loam texture, the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

155 In environments with low water availability, B is the micronutrient that more affects tree growth.  
156 Moreover, this micronutrient is associated with a series of metabolic reactions such as sugar  
157 transport, cell wall synthesis, respiration and others. Thus, the B deficiency may lead to  
158 disorders in these processes, further aggravating problems related to water deficit [21].

159 Tirloni et al. [22] observed that fertilization using B influenced *C. citriodora* growth, evaluating  
160 height and diameter only when was performed at the beginning of the rainy season and when  
161 plants were already at 29 months old. In younger plants, there was no increase in height or  
162 diameter with B application, independent the dry or rainy seasons. According to Paula [23], no  
163 differences related to eucalyptus wood volume was verified when plants were fertilized with  
164 different B doses and evaluated at 20 and 24 months old. In the present work, the observed  
165 influence of B can be related a many factors, such as genotype and climate.

166 In the sandy soil, it is expected that B availability, absorption and translocation are lower mainly  
167 because its absorption by mass flow and due to lower water retention capacity [24, 25].  
168 However, in this study was verified that the leaf B concentration was higher in grown trees in  
169 sandy soil than in clayey soil (Fig. 2).

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

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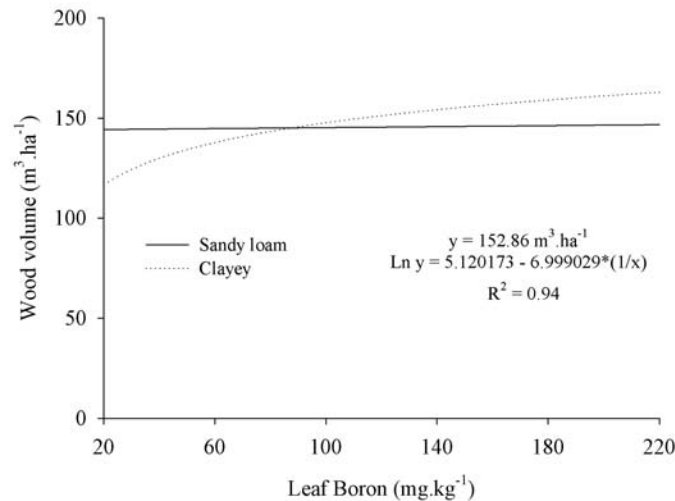
175 The clayey soil has a greater water retention capacity, which would facilitate the absorption of B.  
176 However, due to a greater presence of iron and aluminum oxides, the availability of these  
177 nutrients is compromised once adsorption of these elements occurs. According to Barros and  
178 Novais [26], B occurs in the soil in the form of boric acid or borate and can be adsorbed to  
179 organic and inorganic fractions. Ferreira [27] describes that different minerals types of the soil's  
180 clay fraction play a fundamental role in controlling the available B content. The adsorption of B  
181 is mainly due to iron and aluminum oxides, since these oxides influence more than any other  
182 silicate clay type.

183 Tirloni et al. [22] reports that in very weathered soils, such as those observed in the cerrado,  
184 eucalyptus usually presents symptoms of B deficiency. These symptoms appear mainly when  
185 the rainfall regime is characterized by prolonged periods of water deficit [16]. Mattiello et al. [12]  
186 concluded that the water deficit elevates the external requirements of B and promotes a higher  
187 nutrient concentration in the plant tissue.

188 In sandy soils B may be leached during the rainy season, on the other hand, in clayey soils, B  
189 may be adsorbed in the organic and inorganic fraction, being the soil type directly related to  
190 nutrient deficiency occurrence [28]. Ramos et al. [15] observed that B distribution in plant  
191 tissues of *C. citriodora* was directly influenced by the amount of nutrient available, in other  
192 words, by nutritional status. Ferreto et al. [3] evaluated the relation between B and liming in  
193 Eucalyptus cultivated in sandy soils and observed that limed soils showed higher B availability  
194 at the same time taht plants showed a higher B concentration in shoots and roots.

195 It is important to note that other important factors must be considered. In general, B  
196 translocation and redistribution in plant tissues are related to its low mobility in the phloem and  
197 are also strongly influenced by the plant transpiration flow, which depends not only on soil  
198 texture, but also on relative humidity, temperature and light intensity [29, 30, 31]. Being a dry  
199 sub-humid tropical climate in the experimental areas, the plants underwent different dry cycles,  
200 which may have influenced the translocation of B.

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



203 **Fig. 3. Relation between wood volume increment ( $\text{m}^3 \cdot \text{ha}^{-1}$ ) and leaf boron ( $\text{mg} \cdot \text{kg}^{-1}$ ) of *C.***  
204 ***citriodora* cultivated in two different soil types.**  
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206 For the sandy-loam soil, there was no significant difference in wood volume increment ( $\text{m}^3 \cdot \text{ha}^{-1}$ )  
207 as increasing leaf B dose, suggesting that in this soil the B absorbed was not directed to  
208 physiological processes related to the increase of the wood volume, although there is great  
209 absorption of this nutrient. On the other side, in clayey soil, there was an increase in wood  
210 volume as increasing B absorption. Biomass production and nutrient content present in the  
211 eucalyptus are positively related to each other. In addition, biomass production depends on  
212 water availability and the plant's ability to absorb, distribute and use this nutrient [32].  
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#### 216 4. CONCLUSION

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

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#### 223 COMPETING INTERESTS

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225 Authors have declared that no competing interests exist.

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