

**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⁻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.

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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) 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 al. [10] reported

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34 that B foliar application improved nutrition of this nutrient levels in eucalyptus clones leaves,
35 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⁻³ 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.

51 2. MATERIAL AND METHODS

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 ⁽¹⁾	Al ³⁺ ⁽²⁾	Ca ²⁺ ⁽³⁾	Mg ²⁺ ⁽³⁾	P ⁽³⁾	K ⁽³⁾	B _{daq}	OM ⁽⁵⁾	Sand	Silt	Clay
	(H ₂ O)	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

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

68 ⁽⁵⁾ Organic Matter: Walkley & Black Method.

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 m²
73 and a population density of 1,666 plants/ha. At the planting, fertilization with 200 kg.ha⁻¹ 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⁻¹. At 15
76 months, additional fertilization (levels 1, 2 and 4) with 3.6 and 4.4 g.plant⁻¹ of borax
77 (Na₂B₄O₇.10H₂O) 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.

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 m³/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 factorial
95 scheme, with 4 fertilization levels, 2 types of soils, 1 eucalyptus species and 4 replications. The
96 analysis of variance joint was performed according to Banzatto and Kronka [14]. Data of wood
97 diameter and leaf B were submitted to analysis of variance and regression. The regression
98 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 wood production of *C. citriodora* after different B doses application had a higher efficiency
103 in the clayey soil, compared to sandy soil by the *t-test*, at 5 % probability (Table 2). The clayey
104 soil has great natural fertility (Ca²⁺, Mg²⁺, K⁺ and B_{daq}) and its granulometry associated with a
105 higher organic matter content (Table 1) allows abetter water retention, which may explain its
106 higher performance when compared to sandy soil.

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

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118 Organic matter is the biggest source of B in tropical soils [17]. As shown in Table 2, the sandy
119 soil has organic matter content almost three times lower, compared to the clayey soil. The same
120 was observed to B content, thus, there is a correlation between organic matter and B content in
121 the soil.

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123 **Table 2. Wood volume means (m³.ha⁻¹) produced by *C. citriodora* under crescent boron**
124 **doses (g/plant) on two soils with different textures.**

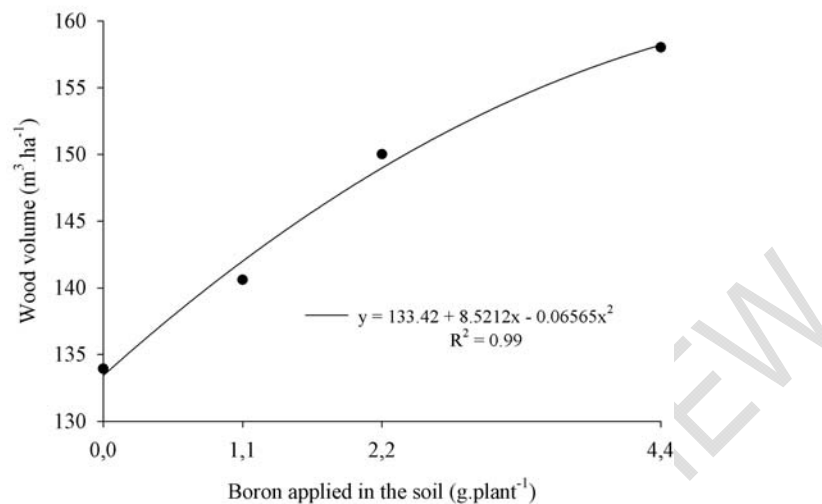
Boron (mg.plant ⁻¹)	Clayey (Três Marias)	Sandy (João Pinheiro)	Means
0	133.69	134.19	133.94
1.1	154.36	126.86	140.61
2.2	157.7	142.36	150.03
4.4	165.53	150.53	158.03
Means	152.86 a	138.53 b	-

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

126

127 In general, wood volume ($\text{m}^3 \cdot \text{ha}^{-1}$) increased as B doses increased. According to the regression
128 equation, the B dose required to reach the highest wood volume ($161.01 \text{ m}^3 \cdot \text{ha}^{-1}$) would be 6.49
129 $\text{g} \cdot \text{plant}^{-1}$ (Fig. 1).



130 **Fig. 1. Volume of wood produced by *C. citriodora* in response to application of different B**
131 **doses in the soil ($\text{g} \cdot \text{plant}^{-1}$).**
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133
134 The results show that the fertilization using B is fundamental to reach higher yields in the forest
135 plantations. B plays a key role in stem growth and is directly related to volume increment, mainly
136 acting on cell walls formation in the wood [18]. Similar results were obtained by Sgarbi et al. [19,
137 20], evaluating nutritional status and soil fertility in *Eucalyptus grandis* plantations in two
138 different areas. In these studies, it was observed that B is one of the nutrients that most limit this
139 species growth in these studied areas. Furthermore, a positive relation of this element and
140 *Eucalyptus* productivity was observed.

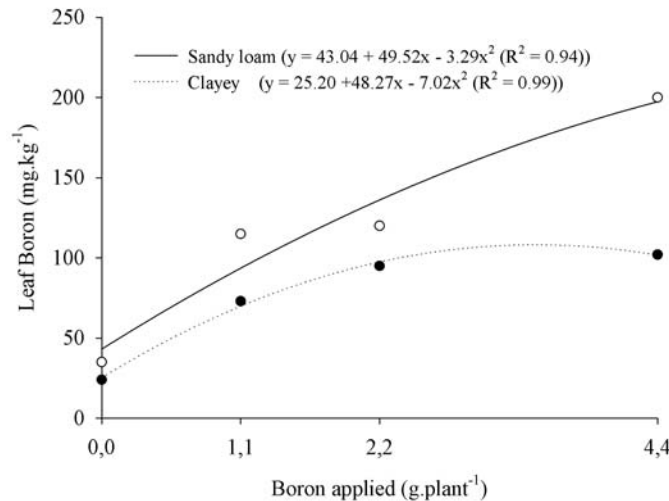
141 It is observed that in the very clayey soil, the maximum level of leaf B is $108.37 \text{ mg} \cdot \text{kg}^{-1}$, which
142 by the curve would be equivalent to an application of $3.35 \text{ g} \cdot \text{plant}^{-1}$ of B (Figure 2). In the soil
143 with a sandy-loam texture, the maximum point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

145 In environments with low water availability, B is the micronutrient that more affects tree growth.
146 Moreover, this micronutrient is associated with a series of metabolic reactions and its deficiency
147 may lead to disorders in these processes, further aggravating problems related to water deficit
148 [21].

149 Tirloni et al. [22] observed that fertilization using B influenced *C. citriodora* growth, evaluating
150 height and diameter only when was performed at the beginning of the rainy season and when
151 plants were already at 29 months old. In younger plants, there was no increase in height or
152 diameter with B application, independent the dry or rainy seasons. According to Paula [23], no
153 differences related to eucalyptus wood volume was verified when plants were fertilized with
154 different B doses and evaluated at 20 and 24 months old.

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

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161 **Fig. 2. Leaf boron level of *C. citriodora* under different boron fertilizing doses on two**
162 **different soil types.**
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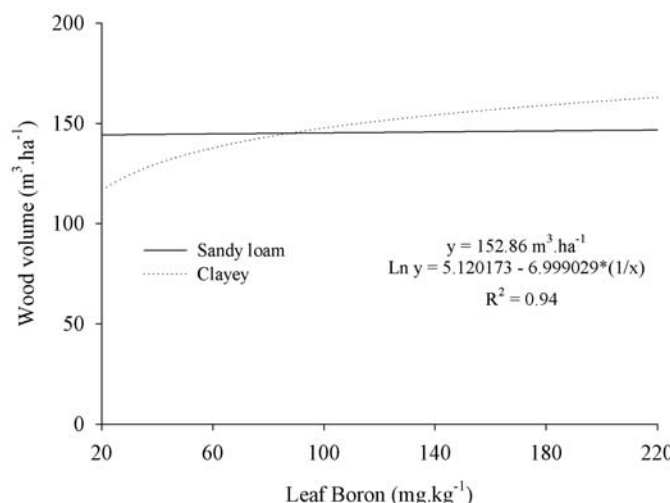
164 The clayey soil has a greater water retention capacity, which would facilitate the absorption of B.
165 However, due to a greater presence of iron and aluminum oxides, the availability of these
166 nutrients is compromised once adsorption of these elements occurs. According to Barros and
167 Novais [26], B occurs in the soil in the form of boric acid or borate and can be adsorbed to
168 organic and inorganic fractions. Ferreira [27] describes that different minerals types of the soil's
169 clay fraction play a fundamental role in controlling the available B content. The adsorption of B
170 is mainly due to iron and aluminum oxides, since these oxides influence more than any other
171 silicate clay type.

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

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

184 It is important to note that other important factors must be considered. In general, B
185 translocation and redistribution in plant tissues are related to its low mobility in the phloem and
186 are also strongly influenced by the plant transpiration flow, which depends not only on soil
187 texture, but also on relative humidity, temperature and light intensity [29, 30, 31].

188 The leaf B content and the wood volume increment (m³.ha⁻¹) of *C. citriodora* for both soil types
189 are shown in Fig. 3.



190
191 **Fig. 3. Relation between wood volume increment ($\text{m}^3.\text{ha}^{-1}$) and leaf boron ($\text{mg}.\text{kg}^{-1}$) of *C.***
192 ***citriodora* cultivated in two different soil types.**

193
194 For the sandy-loam soil, there was no significant difference in wood volume increment ($\text{m}^3.\text{ha}^{-1}$)
195 as increasing leaf B dose, suggesting that in this soil the B absorbed was not directed to
196 physiological processes related to the increase of the wood volume, although there is great
197 absorption of this nutrient. On the other side, in clayey soil, there was an increase in wood
198 volume as increasing B absorption. Biomass production and nutrient content present in the
199 eucalyptus are positively related to each other. In addition, biomass production depends on
200 water availability and the plant's ability to absorb, distribute and use this nutrient [32].

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203 **4. CONCLUSION**

204
205 The clayey soil has been shown to be more efficient in the production of wood than the sandy
206 soil because it has a higher natural fertility and a higher content of organic matter, which allows
207 a greater retention of water. Fertilization using B was essential to achieve higher yields. The
208 increase of leaf B was proportional to B doses applied for both studied soils. Leaf B did not
209 affect the yield of *C. citriodora* in the sandy soil, however, it was observed that in the clayey soil
210 there was an increase in wood volume as increasing B absorption.

211
212 **COMPETING INTERESTS**

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214 Authors have declared that no competing interests exist.

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UNDER PEER REVIEW