Fertilization via soil with boric acid in *Dipteryx odorata* (Aubl.) Willd. seedlings

LUCIANO DE SOUZA MARIA (luciano.maria@unesp.br)
Universidade Estadual Paulista Júlio de Mesquita Filho https://orcid.org/0000-0002-2533-7182

Gustavo Caione
UNEMAT: Universidade do Estado de Mato Grosso

Renato de Mello Prado
UNESP: Universidade Estadual Paulista Julio de Mesquita Filho

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Abstract

Background and aims: The importance of boron (B) in the growth and development in native tree species are relevant to establish quality indexes for seedlings. The objective of the present study was to evaluate the effect of boron application on the development of *Dipteryx odotara* seedlings.

Methods: The experimental design was a completely randomized design, five treatments with four replications. The treatments consisted of B doses, in the form of boric acid (17% of B), being: 0; 1.0; 10; 20 and 40 mg B kg-1. We evaluated the seedlings were at 60 days after transplanting.

Results and Conclusions: The dose 1 mg B kg-1 and absence of application in *Dipteryx odotara* seedlings provided the highest values of stem diameter, shoot height, root volume and dry mass of shoot, root and total. It also provided better quality indexes for seedlings: shoot height/shoot dry matter, shoot dry mass/root dry mass and Dickson quality index, did not show symptoms of B toxicity in plants. Unlike the other doses that affected the growth and development of *Dipteryx odotara*seedlings.

Introduction

Cumaru (*Dipteryx odotara* (Aubl.) Willd.) (Fabaceae) is a tree species from the Amazon and its wood is noble and has high structural strength, used in constructions that require mechanical strength (Maltarolo et al., 2016). Sampaio et al. (2018) reported that have use in pharmaceutical, food and biocosmetics products. Pinto et al. (2008) also emphasizes the importance of reforestation, but the requires adequate knowledge of selection species forest. Seedling production evidence the substrate fertilization process is important for appropriate nutritional conditions (Gonçalves et al., 2012). However, trees forests particularly native, information on their nutritional needs during their initial growth is still incipient (Smideele et al., 2016; Souza et al., 2011).

Makes it evident that the importance of macronutrients and micronutrients in promoting plant growth and development (Yadegari, 2016). In relation to micronutrients, it participates in most enzymatic reactions and they also play an indirect role through the synthesis of various growth regulators (Yadegari, 2015). Among the micronutrients boron (B) stands out for its participation in plant physiological processes such as sugar transport, cell wall synthesis, lignification, cell wall structure, carbohydrate metabolism, RNA metabolism, respiration, IAA metabolism, phenolic metabolism, germination and pollen tube growth (Malavolta, 2006; Prado, 2008; Marschner, 2012).

Proper use of boron supplied to plants is very relative, being one of the major concerns in fertilizers due to the narrow range of suitable content and toxic content in the soil solution (Flores et al., 2018). It is noteworthy that the ideal amount of boron for a given species can promote or retain the growth of other species (Brighenti and Muller, 2014).

Thus, two hypotheses are raised: (a) the species *Dipteryx odotara* needs low fertilization with B (b). The species has tolerance to increase B applications via soil application.

Gonçalves et al. (2012) recommended application of 1 kg B ha^{-1} in the soils with low B contents (B < 0.21 mg kg^{-1}) for eucalyptus. In the cultivation of citrus boron levels greater than 50 to 100 mg kg^{-1} can cause leaf toxicity symptoms and in more severe cases they may lead to reduced production (Bologna, 2003). Therefore, the objective of the present study was to evaluate the effect of boron application on the development of *Dipteryx odotara* seedlings.

Material And Methods

Experimental site

The experiment was carried out in a greenhouse and Soil, Fertilizer and Leaf Analysis Laboratory (LASAF), at Mato Grosso State University – UNEMAT (09°51’42” S and 56º04’07” W). The region's weather is tropical rainy with a dry season., according to Köppen classification, with temperatures of 20–38 ° C and average annual rainfall of 2200 mm, and an average altitude of 320 m (Rodrigues et al., 2017).

The soil used as substrate was in an Oxisoil, and chemical and particle size characteristics, described in Table 1.

Table 1
Chemical and physical attributes of the Dystrophic Red-Yellow Latosol

Attributes	**Value**
pH ($CaCl_2$)	4.9
Organic Carbon (g kg^{-1})	18.30
P (mg kg^{-1})	1.5
K^+ ($mmol_c$ kg^{-1})	2.4
Ca^{2+} ($mmol_c$ kg^{-1})	10.2
Mg^{2+} ($mmol_c$ kg^{-1})	3.8
Al^{3+} ($mmol_c$ kg^{-1})	1.0
H^+ + Al^{3+} ($mmol_c$ kg^{-1})	22.3
CEC ($mmol_c$ kg^{-1})	39.4
V (%)	41.62
B (mg kg^{-1})	0.15
Cu (mg kg^{-1})	1.89
Fe (mg kg^{-1})	56.00
Mn (mg kg^{-1})	17.60
Zn (mg kg^{-1})	2.95
Sand (g kg^{-1})	589
Silt (g kg^{-1})	57
Clay (g kg^{-1})	354

pH ($CaCl_2$); P e K (Mehlich 1); Ca^{2+}, Mg^{2+} e Al^{3+} (KCl 1 mol L^{-1}); H^++Al^{3+} (calcium acetate pH 7.0); $CEC_{(potencial)}$ - Cation exchange capability ; V%; e Sand, Silt e Clay (EMBRAPA, 2009).

Recommended dose of fertilisers

Dipteryx odotara seedlings of 150 days were transplanted in polypropylene bags with capacity of 2 dm³ of soil. For seedlings have been applied 200 mg P kg^{-1} in the form of ammonium monophosphate (50%

of P_2O_5), 150 g K kg^{-1} in the form of potassium chloride (60% of K_2O) e 150 g N kg^{-1} in the form of urea (45% of N) were applied in all plots, according to the methodology of Malavolta (1981).

2.3 Treatments

The experimental design used was a completely randomized design, five treatments with four replications. Treatments consisted of boron doses (B), in the form of boric acid (17% de B), being: 0; 1.0; 10; 20 e 40 mg B kg^{-1}. We applicated the B to 10 days after transplantation, at a distance of 3 cm from the steam diameter around the base of the seedlings.

Growth Variables

At 60 days after transplanting, shoot height (SH) was measured in cm and stem diameter (SD) was measured in mm, using a graduated ruler and digital caliper, respectively. For determine root volume (RV) used a 50 ml beaker with water, it was measured in mg plot (Maria et al., 2018). For determining the leaf content of boron considered sample composed of four diagnostic leaves per pot was used to verify the nutritional status of the seedlings. As diagnostic leaf was used the third fully mature leaf without new leaves (Cruz Neto et al., 2015).

Dry matter Variables

Then, the components of the shoot and root were separately packed in paper bags, weighed and placed in an oven with forced air circulation at ± 65º C until reaching a constant mass. After determination of shoot dry matter (SDM), root dry matter (RDM) and total dry matter (TDM) the material was milled in a Willey type stainless steel mill with a 20-mesh sieve according to Bataglia et al. (1983).

2.6 Estimation of boron

For the determination of the boron leaf content, dry digestion was used, with half a gram of the powdered dry leaf sample in a silica crucible and after used an electric muffle incineration at a temperature of 450 ° C to 550 ° C (Mills and Jones, 1996). There was acidification of the gray sample with HCl and remaining in a water bath for 15 minutes, composed 25 ml with deionized water. Thus, the boron leaf content by spectrophotometry with azomethine-H, the absorbance was read at 420 nm using the UV-VIS spectrophotometer (Malekani and Cresser, 1998).

Seedling quality variables

From the obtained data it was possible to calculate the Dickson quality index (DQI), according to the formula of Dickson et al. (1960):

$$\mathrm{DQI} = \frac{\mathrm{TDM}\,(\mathrm{g})}{\left[\frac{\mathrm{SH(mm)}}{\mathrm{SD(mm)}}\right] + \left[\frac{\mathrm{SDM(g)}}{\mathrm{RDM(g)}}\right]}$$

Where: TDM- Total dry matter, SH- Shoot height, SD- Stem diameter, SDM- Shoot dry matter and RDM- Root dry matter

B use efficiency

For the boron use efficiency was calculated by the equation below, proposed by Siddiqi and Glass (1981):

$$\mathrm{BUE} = \frac{\mathrm{SDM}^2\,(\mathrm{g})}{\mathrm{BLC}\,(\mathrm{mg})}$$

Where: BUE- Boron use efficiency, SDM- Shoot dry matter and BLC- Boron leaf content.

Estimation of critical boron levels in soil and leaf

For the critical level used in response to the plateau quadratic (PQ), beyond the level where its addition no longer increases dry matter production. It also estimates the maximum attainable yield with the level of applied boron dose. It is observed that the plateau happens from when a quadratic curve reaches or maximum point. The maximum point or a quadratic curve reach is hit for plateau quadratic (Bullock and Bullock, 1994).

Statistical analysis

The results, for normality (Shapiro-Wilk) and homoscedasticity, were analyzed. The analysis of variance (ANOVA) was done with F test ($p < 0.05$), and the means compared through Tukey test at 5% of significance, using SISVAR software (Ferreira, 2015). In regression analysis, the coefficients of the components of each model were tested and the models with the highest coefficients of determination (R^2) were chosen.

Results

We found results had significant effect with increasing levels of boron for variables of BLC, SD, SD, RV, BUE and DQI at $P < 0.01$ significance level (Fig. 1A, B, C, D, E and F).

The application of B showed a linear increase in leaf B content in *Dipteryx odotara* seedlings (Figura 1A), and we found the largest increment for variable the SD with the dose 2.30 mg B g^{-1}, occurring a quadratic effect (Fig. 1B). For variable of SH with application above of 10 mg B kg^{-1} there was significantly reduced in height growth (Fig. 1C).

For variable of RV we found the largest increment with application of 7.3 mg B kg^{-1}, but there was significant reduction in root growth with in applications higher than 10 mg B kg^{-1} (Fig. 1D). For variable of BUE we found that with application of 27.5 mg B kg^{-1} there was lower efficiency of using of B (Figure

E). And for variable of DQI we found that with application of 7.5 mg B kg^{-1} there was a greater increase in the quality of seedlings of *Dipteryx odotara* (Fig. 1F).

Seedling dry mass yield had significant effect with B application at P < 0.01 significance level (Fig. 2) and the RDM we found the largest increment with application of 2.30 mg B g^{-1}. Noted that for variable of SDM we found the largest increment with application of 14 mg B kg^{-1} B and for variable of TDM we found the largest increment with application of 12 mg B kg^{-1} (Fig. 2) observed the occurring a quadratic effect in all dry mass variables.

The applications of B in *Dipteryx odotara* seedlings considering 90% of shoot dry matter production, we determined the critical leaf B levels. Then 66 mg B kg^{-1} in the leaves were considered adequate for *Dipteryx odotara* seedlings (Fig. 3).

Discussion

Increasing doses of B showed negative effect for variable height of shoot of *Dipteryx odotara* seedlings. Munguambe et al. (2018) stated that height is one of the most important variables measured in plants, as it is possible to select and classify seedlings, besides being a characteristic of easy evaluation. Reid et al. (2004) mentioned that high soil B concentrations inhibit shoot growth. *Dipteryx odotara* seedlings we found that applications greater than 10 mg B kg^{-1} there was reduction in height values and initially presented symptoms of toxicity in old leaves. The results corroborate with this study (Flores et al., 2018; Celestrino et al., 2015: Ferreto et al., 2015). Zahoor et al. (2011) stated that the excessive B level results in imbalance of different enzymes leading to reduced plant height.

For variable of SD we found negative effect with com reduction of 47% with the dose of 40 mg B kg^{-1} compared to the absence of application and we noted necrotic and burnt leaves. There are results several clarify that a toxicity of B causes an interruption of photosynthesis inhibiting plant growth (Reide et al., 2004; Chen et al., 2013, Rehman et al., 2018). For this reason, burnt and necrotic leaves were widely used to evaluate B toxicity. (Sutton et al., 2007).

For variable of RV with appication of 1 mg B kg^{-1} there were 22% and 68% de increase compared to the application of 20 mg B kg^{-1} and 40 mg B kg^{-1}, respectively. Choi et al. (2006) stated that excess boron causes changes in root morphology in different agricultural and forest crops, including high branching and thin root formation. Princi et al. (2016) noted that there was a reduction in cell division and elongation in the root system with high doses of B. Thus, the lower values for variable of RV with higher applications of B were explained by the high concentrations of B soil.

Increasing doses of B provided quadratic effect for variable of DQI (Fig. 1F) and with the dose of 1 mg B kg^{-1} there was 27% of increment compared with the application of 20 mg B kg^{-1}. Zuffo et al. (2014) pointed out that the highest values of DQI provide better quality and more vigorous seedlings. Caione et al. (2012) complemented that the parameter DQI is a good quality indicator, because in its calculation we consider several relevant parameters used to observe the quality of the forestry seedlings.

The observed results the dose of 1 mg B kg^{-1} in *Dipteryx odotara* there was the highest value of the variables of SD, SH, RV, TDM, RDM and SDM. And also, there was the best seedling quality index and no symptoms of B toxicity are evident in plants. With application greater than 10 mg B kg^{-1} noted negative effect in the variable RDM (Fig. 1B). Flores et al. (2017) observed toxicity effects with B at a dose greater than 4 kg B ha^{-1} (Boric acid) in eucalyptus seedlings. Inhibiting root growth would have a negative impact on growth due to the reduction in root area available for water and nutrient absorption. (Princi et al., 2016), depending on the toxicity of B (Trautmann et al., 2014). Then, seedlings with smaller increments of RDM tend to slow growth and increase maintenance values in forest plantations (Behling et al., 2014; Freitas et al., 2017).

In the application of 10 mg B kg^{-1} there was a greater reduction for seedling dry matter variables, due the toxicity effect, there was a reduction of 44% SDM and 65% TDM with application of 20 mg B kg^{-1}, compared to the absence of application, caused by the toxic effect. Paparnakis et al. (2013) noted that excess B initially causes symptoms of chlorosis on leaf tip and leaf margin. This is justified by the accumulation of B transported through in the transpiration in the seedling (Reid et al., 2004).

Studies with other forest species, noted that the doses of 2 a 2.5 mg B kg^{-1} in *Eucalyptus citriodora* (Ramos et al., 2009); *Schizolobium amazonicum* (Lima et al., 2003); *Khaya senegalensis* (Araújo et al., 2017), showed a reduction SDM. Corroborating this study of *Dipteryx odotara* seedling.

The critical level of leaf B of 66,2 mg B kg^{-1} in *Dipteryx odotara* seedling (Table 2) were consistent with the values of two native forest species *Croton urucurana* e *Cytharexyllum myrianthum* studied by Sorreano et al. (2012), observed a critical level of 65 mg B kg^{-1}. Note that the hypothesis was accepted since, because the *Dipteryx odotara* seedling showed good development with low dose of B.

Conclusions

The hypothesis that the species has tolerance to the elevation of B applications via soil application was rejected, because the values greater than of 66 mg B kg-1 were considered critical toxicity levels as they affected growth and development in *Dipteryx odotara* seedling, as reported by the lowest values of variables of SD, SH, TDM, SDM, RDM, DQI and BUE in *Dipteryx odotara* seedling.

Declarations

Conflict of Interest:

The authors declare that they have no conflict of interest.

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Table 2

Table 2 is not available with this version.

Figures

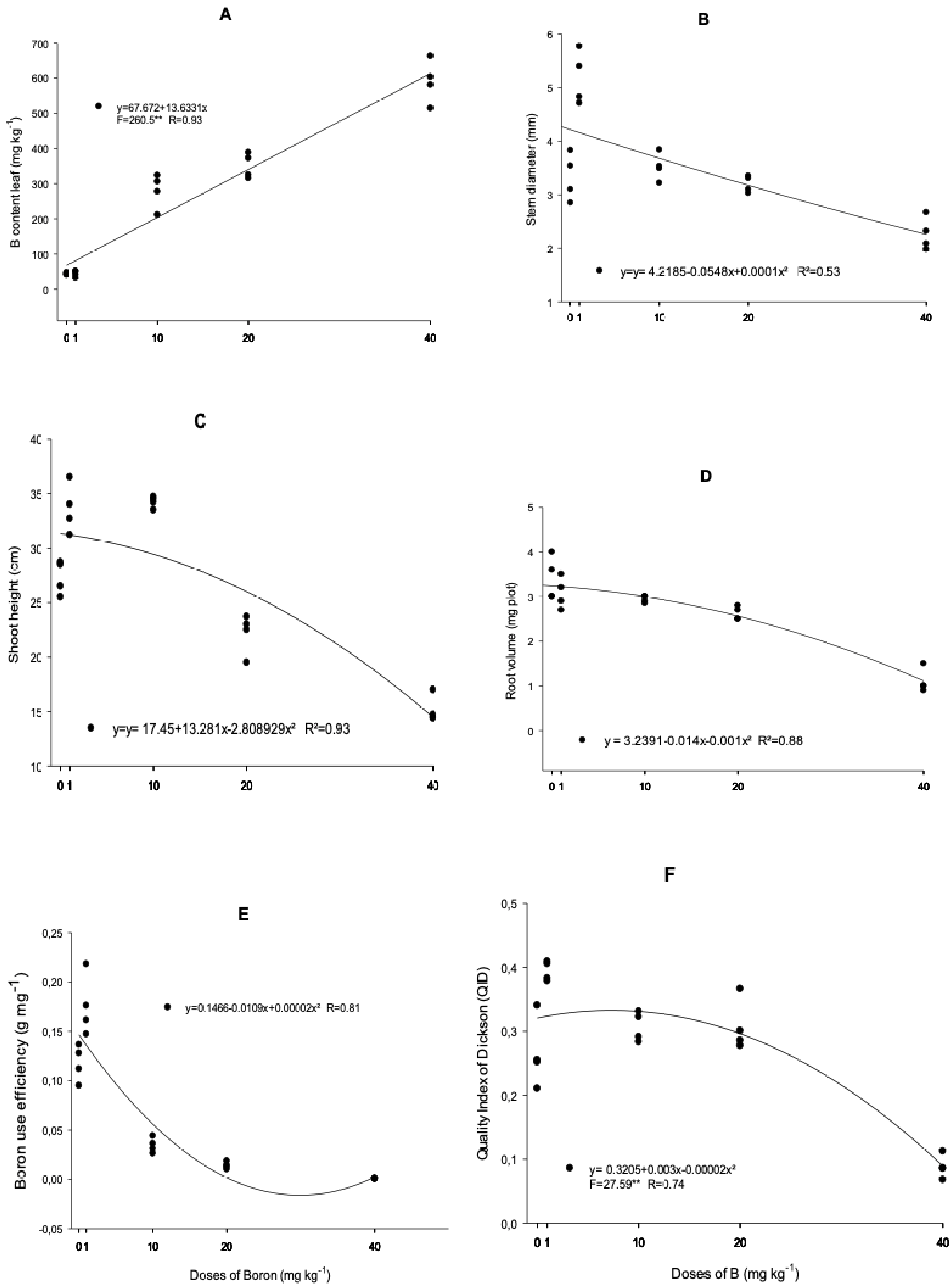

Figure 1

Content leaf of Boron (A), stem diameter (B), shoot height (C), root volume (D), Index Dickson Quality - IDQ (E) and Boron use efficiency - BUE (F) in *Dipteryx odotara* seedlings fertilizers with boron.

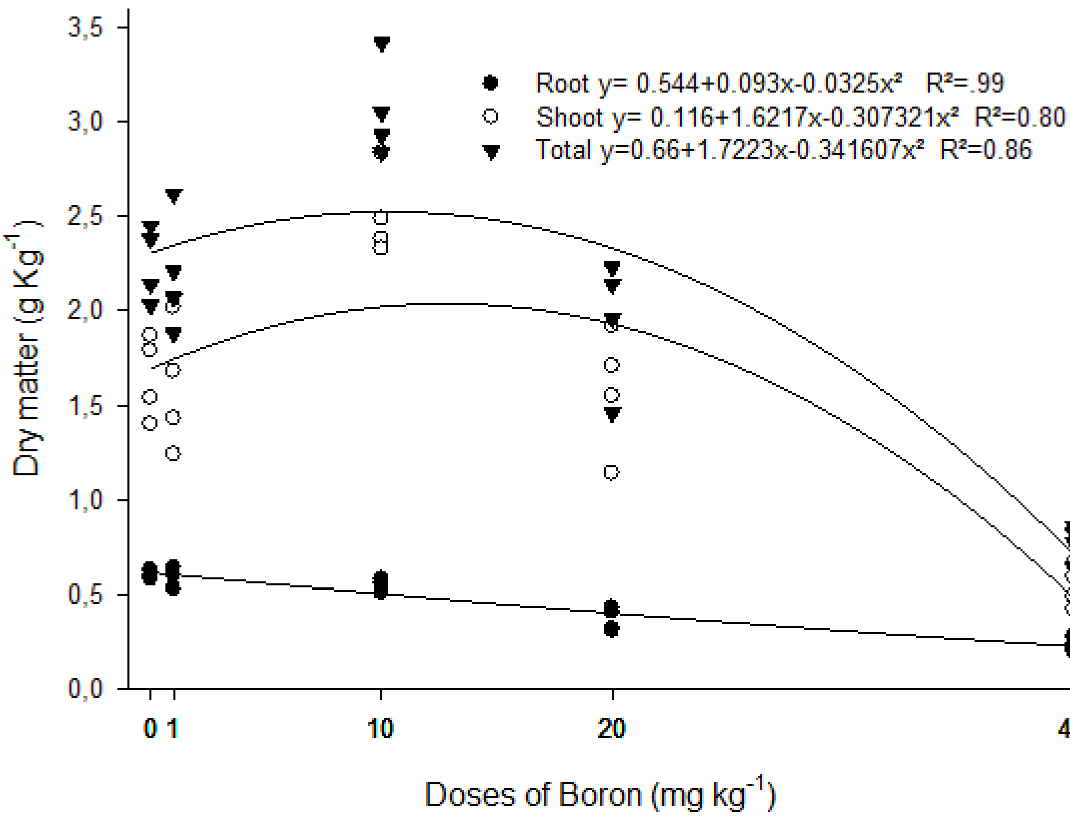

Figure 2

Dry matter of root, shoot and total in *Dipteryx odotara* seedlings fertilizers with boron.

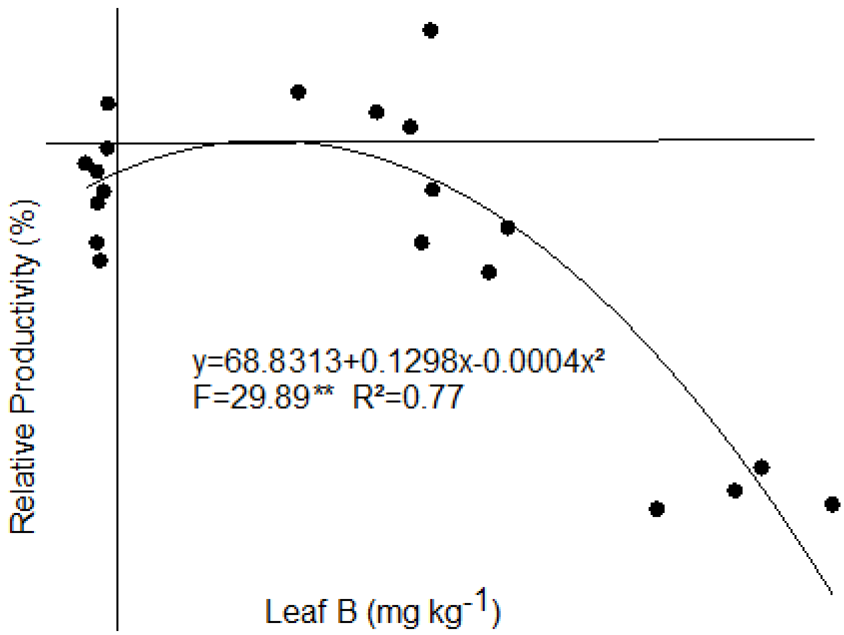

Figure 3

Scatter diagnram and Quadratic Plateau model for critical boron level in *Dipteryx odotara* seedlings.