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**Research Article**

# EFFECT OF SOIL COMPACTION ON AERIAL AND ROOT GROWTH OF *Tabebuia caraiba* MART. BUR.

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**Abstract-** Soil compaction is one of the main factors affecting forest productivity, hence research is necessary in order to identify species that are capable of breaking compacted layers. This study aimed to evaluate the initial aerial and root growth of *Tabebuia caraiba* in a soil sampleput through different levels of compaction. The experiment was carried out in a green house at the Federal University of Rio Grande do Norte (UFRN), Brazil. A sample of yellow Latosol with sandy texture was collected from the Agricultural School of Jundiaí and set in columns by using three overlapping 10-cm diameter and 25-cm height PVC rings, and the amount of soil in the central ring was compacted. A randomized complete block design with six replicates was used and four levels of soil compaction (1.35, 1.45, 1.60, and 1.80 $kg.dm^{-3}$) were tested. The following variables were evaluated: diameter, height, number of leaves, and dry mass of aerial and root system in each layer of the columns. The physical impediment in subsurface did not alter the aerial growth of the seedlings. Compaction changed root system growth more significantly at soil densities greater than 1.60 $kg.dm^{-3}$.

**Keywords**- Root system, soil density, soil management.

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## Introduction

Soil is a natural resource that can have its quality assessed with the analysis of physical, chemical and biological factors that regulate its processes [1]. The physical and structural quality of a soil influences root growth and development [2]. Soil compaction is directly related to soil physical and mechanical properties, especially the properties related to mass/volume, since compaction can be understood as an increase in soil mass (density) or decrease in pore spaces in a given volume of soil [3]. Resistance increases and soil porosity decreases with soil compaction. As an effect, there is a restraint in root growth and consequently in aerial growth. Root system may be the first component affected by compaction, as the development of fine roots, where the highest rate of nutrient absorption occurs, is impaired [3]. Soil compaction is a usual problem in agricultural soils because of its inadequate management, either with the use of machines and implements in an excessive way or the intensive trampling of animals in the area, causing drastic effects on plant development. However, the effects of compaction are not always easy to identify, especially when compaction does not reach a drastic level, which makes it an even more serious problem [4]. According to Camargo and Alleoni, 1997 [4], soil compaction in sandy-loam soils is one of the main factors that influence plant root growth. Limited root development in sandy and sandy-loam soils with field capacity is considered critical for soils with densities of 1.85 kg.dm-3 or greater, leading to productivity losses [5]. *Tabebuia caraiba* (Mart.) Bur. is a species popularly known in Brazil as "craibeira", a plant of arboreal character and wide geographic distribution. Its wood is used to produce furniture, keels, knees and boards for boats, tool handles, yokes, beams, poles and groundsills. In addition, this tree is also useful for mixed coating of degraded areas for replanting [6,7], but little is known about its development in compacted soils. Pereira Junior et al. (2012) [8], evaluating the aerial and root growth of *Moringa oleifera* in compacted soil, observed that, although there was a decrease of variables with the increase of soil compaction, such reduction did not affect significantly aerial and root growth. Silva et al. (2012) [9], studying the effect of soil compaction on aerial and root development of *Crambe abyssinica* and *Jatropha curcas*, found that the former is sensitive to increased soil compaction, which modifies its root distribution in and belowthe compacted soil layer, but no significant changes were observed in *Jatropha curcas* plants. There is a lack of information regarding the effects of soil compaction on the growth of forest species, especially in species of the Caatinga Biome. These studies are important because they allow the identification of species capable of breaking compacted layers and alter soil physical properties that make it unviable for agricultural production, enhancing the sustainable exploitation of these species and contributing to the economic and social development of the Northeast Region in Brazil. The overall aim of this work was to evaluate the initial aerial and root growth of *Tabebuia caraiba* in a soil sample put through different levels of compaction.

## Materials and Methods

For the experiment, a sample of yellow Latosol with sandy texture was collected in the forest experimentation area of the Jundiaí Agricultural School (EAJ) in the city of Macaíba, Brazil. In order to obtain a higher soil homogeneity, soil portions of the subsurface layer (B horizon) were collected at a depth between 20.0 and 40.0 cm. Afterwards, the soil was dewormed, air-dried, sieved with a 2.0 mm mesh, and homogenized. Then, subsamples were removed for chemical and physical analysis [Table-1].

With respect to chemical analysis, soil correction was not performed because of the high value of base saturation and the absence of aluminum. Just basic fertilization was carried out by using urea, simple superphosphate and potassium

**Table-1** *Chemical and physical characterization of the yellow Latosol used in the experiment.*

| Characteristic | |
|---|---|
| **Chemical** | |
| pH in water (1:2.5) | 5.78 |
| P ($mg.dm^{-3}$)(1) | 2.00 |
| $K^+$ ($mg.dm^{-3}$)(1) | 268.00 |
| $Na^+$ ($mg.dm^{-3}$) | 132.00 |
| $Ca^{2+}$ ($cmol_c.dm^{-3}$)(2) | 1.18 |
| $Mg^{2+}$ ($cmol_c.dm^{-3}$)(2) | 0.40 |
| $Al^{3+}$ ($cmol_c.dm^{-3}$)(2) | 0.00 |
| H+ Al ($cmol_c.dm^{-3}$)(3) | 0.75 |
| SB ($cmol_c.dm^{-3}$) | 2.83 |
| CEC (T) ($cmol_c.dm^{-3}$) | 3.58 |
| V (%) | 79.05 |
| **Physical** | |
| Sand ($g.kg^{-1}$) | 688 |
| Clay ($g.kg^{-1}$) | 180 |
| Silt ($g.kg^{-1}$) | 132 |
| FC (%) | 9.04 |
| PWP (%) | 7.03 |

(1) Mehlich$^{-1}$ extractor; (2) KCl 1 $mol.L^{-1}$extractor; (3) 0.5 mol L-1 at pH 7.0 calcium acetate extractor. SB = Sum of bases; CEC = Cation exchange capacity at pH 7.0; V = Base Saturation; FC = Field capacity; PWP = Permanent wilting point

chloride in the amounts of 150, 300 and 100 $mg.dm^{-3}$, respectively. The experiment was carried out in a greenhouse located at the Agricultural Sciences Academic Unit (UECIA), Federal University of Rio Grande do Norte, Macaíba, Brazil. The greenhouse was coated with 1.0 mm nylon mesh and a transparent fiberglass roof (minimum temperature of 24ºC and maximum temperature of 38ºC).The experimental design was a randomized complete block with six replicates containing five seeds per unit, and the effect of soil compaction on the initial growth of *Tabebuia caraiba* was tested at densities of 1.35 $kg.dm^{-3}$ (non-compacted soil), 1.45 $kg.dm^{-3}$, 1.60 $kg.dm^{-3}$, and 1.80 $kg.dm^{-3}$.The experimental unit was a 10-cm diameter and 25-cm height PVC column with three layers (upper, central and lower). The height of the upper and lower layers was 10 cm, and the central layer was 5 cm high. The layers were kept together with duct tape. To close the base of the column bottom layer, a multipurpose cloth fixed with rubber alloys was used [Fig-1].

The upper and lower layers of the PVC column were filled with non-compacted soil; whereas the soil in the central layer underwent four different densities of compaction. The compaction was done at every 2.5 cm soil layer with a metal plunger, and the soil was pressed in the PVC column until the volume corresponded to the desired density inside the central layer. To avoid root development in the PVC-compacted soil interface (spots with less resistance to penetration), the methodology described by Müller, Ceccon and Rosolem, 2001 [10] was used. Adhesive plastic strips about 2.0 cm wide were used, folded from the periphery to the center of the upper surface of the central ring, avoiding the development of roots in the areas contiguous with the wall [Fig-1]. Fifteen days after emergence, the seedlings were pruned, and only one plant per experimental unit was left until the end of data collection, performed 90 days after seedling emergence. The soil was irrigated daily with a graduated cylinder by applying the volume of water corresponding to field capacity of the soil. After 90 days of seedling emergence, their height, collar diameter at the soil level, number of leaves, and aerial and root dry mass were analyzed at each layer of the experimental unit. The layers of each column were separated with the help of a stiletto at the three corresponding parts. Then, the roots were separated from the soil in each layer with running water and 1.0 mm sieves to avoid root loss. The shoots and roots were placed in a greenhouse at 65° C for 72 hours to determine dry mass by using an analytical scale. The data were compared by using variance analysis and Tukey's test at 5% of probability. A regression study was conducted with the equation that best fit the untransformed data by using the Assist at 7.7 statistical program.

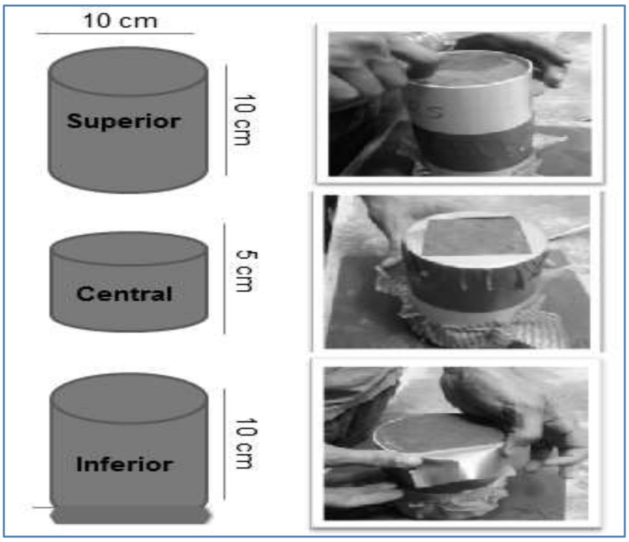


**Fig-1 Schematic illustration of the experimental unit used in the experiment**.

### Results and Discussion

Soil compaction at the subsurface layer did not significantly influence the initial growth of *Tabebuia caraiba* seedlings when considering the variables collar diameter, number of leaves, height and dry mass of shoots, and the data did not fit any regression model, which shows that soil compaction is not a limiting factor to the initial aerial growth of *Tabebuia caraiba* at the compaction levels evaluated [Table-2].

**Table-2** *Variance analysis and mean values of collar diameter (RCD), number of leaves (NL), height (H), shoot dry mass (SDM), and root dry mass in the upper (RDM.U), central (RDM.C) and lower (RDM.L) column of Tabebuia caraiba seedlings undergoing different levels of compaction*.

| FV | GL | Mean squares | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | RCD | NL | H | SDM | RDM.U | RDM.C | RDM.L |
| Treatments | 3 | $0.96^{ns}$ | $1.37^{ns}$ | $8.26^{ns}$ | $3.54^{ns}$ | $8.96^{*}$ | $2.18^{**}$ | $3.12^{**}$ |
| Linear | 1 | $0.20^{ns}$ | $0.20^{ns}$ | $0.64^{ns}$ | $0.10^{ns}$ | $18.56^{*}$ | $5.20^{**}$ | $8.80^{**}$ |
| Quadratic | 1 | $2.66^{ns}$ | $2.04^{ns}$ | $0.20^{ns}$ | $0.37^{ns}$ | $5.80^{ns}$ | $1.21^{*}$ | $0.51^{ns}$ |
| CV (%) | | 23.13 | 11.21 | 38.15 | 17.62 | 18.41 | 29.03 | 26.65 |
| **Treatments** | | **Mean values** | | | | | | |
| | | **RCD (mm)** | **NL** | **H (cm)** | **SDM (g)** | **RDM.U (g)** | **RDM.C (g)** | **RDM.L (g)** |
| T1- 1.35 kg/dm³ (non-compacted) | | 8.66 a | 11.00 a | 6.70 a | 5.82 a | 7.20 b | 1.90 a | 3.00 a |
| T2 – 1.45 kg/dm³ | | 7.95 a | 11.00 a | 9.30 a | 7.18 a | 7.60 ab | 1.80 a | 2.60 a |
| T3 – 1.60 kg/dm³ | | 7.81 a | 10.30 a | 6.80 a | 5.38 a | 7.50 ab | 1.60 a | 2.20 ab |
| T4 – 1.80 kg/dm³ | | 8.43 a | 11.50 a | 8.90 a | 6.23 a | 9.90 a | 0.60 b | 1.30 b |

Pereira Junior et al. (2012) [8], analyzing the effect of soil compaction on the initial growth of *Moringa oleifera*, found similar results, showing that the increase in soil density did not affect the variables related to aerial growth. The same happened to Silva and Rosolem (2001) [11], who reported a non-significant effect of soil compaction on dry matter production in soybean shoots. This result can be explained as a strategy of the plant to translate photo assimilates to aerial part in function of the physical restriction to root growth imposed by compaction, favoring the allocation of aerial biomass that was not affected in the compaction levels studied [12]. For Reichardt, 1990 [13], the effects caused by soil compaction are more apparent in clayey than in sandy soils. The physical limitation imposed on root growth significantly affected the development of root system in *Tabebuia caraiba*. The treatment with soil at the greatest level of compaction (T4 - 1.80 kg.dm-³), which presented the highest means, was superior to the treatment without any compacted layer; however, it did not differ from the others. From the regression analysis, it was possible to observe that, for the greatest level of compaction tested, the plant had a linear increase of 37.5% in root dry mass in the upper layer of the experimental units compared to the treatment with non-compacted soil, and that greater densities would continue to favor root accumulation in the upper layer of the column.

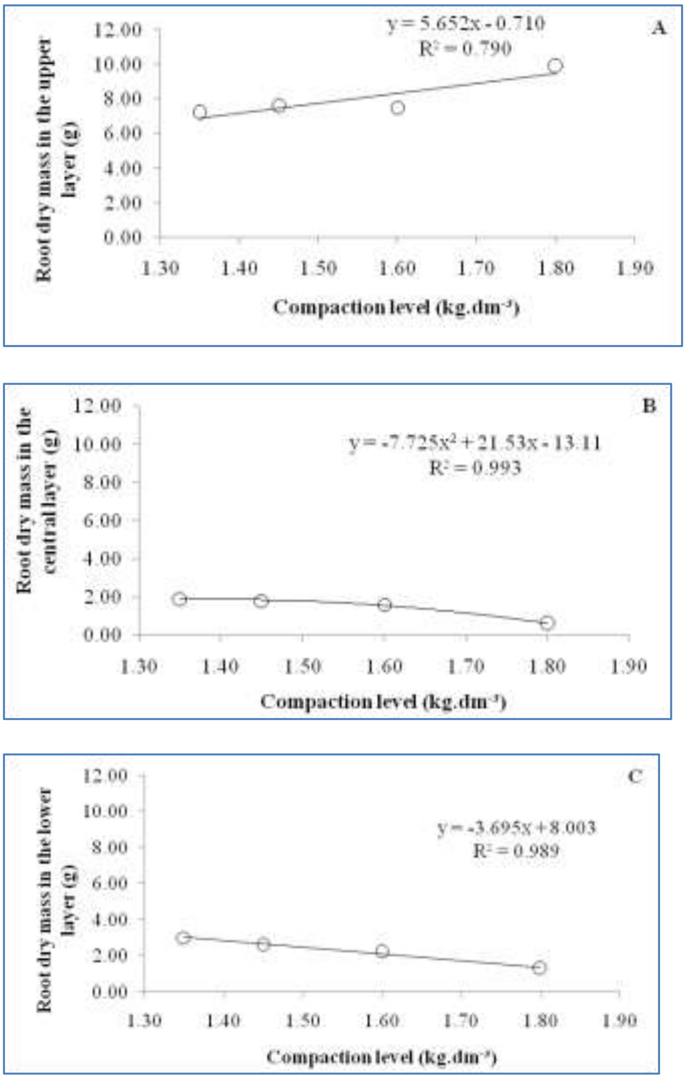


**Fig-2 Root dry mass of *Tabebuia caraiba* in the upper (A), central (B) and lower (C) layers as a function of different levels of soil compaction**

The linear increase of roots in the upper layer of the PVC columns was probably due to the physical impediment caused by the compacted central layer, partially restraining the expansion of root system along the PVC column, thus promoting the accumulation and the folding of roots in the upper layer [Fig-3].

The accumulation of roots in the soil surface layer due to the physical constraint imposed on root development forms a very dense and shallow root system, which, under field conditions, would probably make difficult for a plant to survive a drought period. A shallow root system would impede the search for water and nutrients, which become more scarce during the dry season [4]. According to Borges et al. (1999) [14], high soil densities affect the development of plants by restraining root penetration.

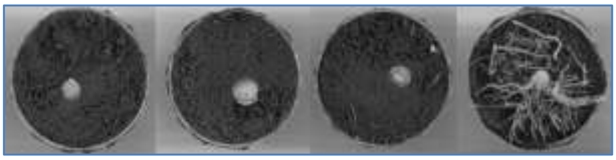

**Fig-3 Internal view of the upper layer of the PVC column after sectioning of the experimental units by using a stiletto. Distribution of the apparently unchanged root system in soil without any compacted layer (A), with a compacted layer at a density of 1.45 kg.dm-³ (B) and 1.60 kg.dm-³ (C), and apparent accumulation of roots in the surface layer due to subsurface soil compaction at a density of 1.8 kg.dm-³ (D).**

With respect to production of root dry mass in the central layer (the layer where the compaction was applied), the results showed that the soil with the greatest level of compaction had the lowest means and was significantly inferior to the other treatments, which, in turn, did not statistically differ from one another. The variable presented a quadratic behavior of data, showing that the greatest plant performance would be reached at a soil density estimated in 1.39 kg.dm-³ and that densities greater than this value would promote a decrease in the highlighted variable [Fig-2]. One of the main effects of soil compaction, considering the external pressure that it suffers, is the decrease in soil porosity and the increase in density. Macropores, which allow the movement of water and air rapidly and consistently, are the main route to root system development. They are naturally the most affected structures by compaction, and can inhibit the root development of plants when deformed or poorly structured [4]. The decrease in soil macroporosity, along with the lower oxygen concentration due to the increase in compaction, was probably a limiting factor to pivotal root expansion, as this restraint to development was observed in the compacted layer at the density of 1.80 kg.dm-³.This shows that a compacted soil layer with density equal to or greater than 1.8 kg.dm-³ stops the pivoting root of *Tabebuia caraiba* from crossing this layer and developing in depth [Fig-4]. According to Silva et al. (2012) [9], resistance of soil to penetration due to porosity reduction is one of the soil characteristics that are more sensitive to the effects of compaction. The root distribution of *Tabebuia caraiba* seedlings in the lower layer of the column was affected by the soil compaction in the layer above it. A linear decrease in root dry mass was observed, and the layer that underwent compaction had the best means. This treatment was superior to the one with compacted soil at the density of 1.80 kg.dm-³, but did not differ from the other treatments evaluated. From the regression analysis, it was verified that soil compaction at subsurface layer at the greatest compaction level favored a linear decrease of 56.7% in root dry mass in the lower layer and that greater compaction levels would continue to promote the decrease in the variable [Fig-2].

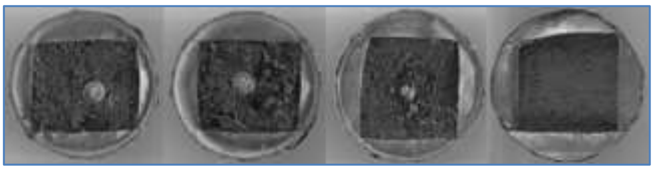

**Fig-4 Presence of pivoting root in the non-compacted central layer (A), in the compacted layer at a density of 1.45 kg.dm-³ (B), in the compacted layer at a density of 1.60 kg.dm-³ (C), and negative effect of compaction under the restricting pivot root its growth in the column with the central layer the density of 1.80 kg.dm-³ (D).**

The reduction of 56.7% in root dry mass occurred probably because it was difficult for the plant to expand its roots due to the compacted subsurface layer, thus preventing an adequate soil volumetric exploitation and causing losses in water and nutrient absorption. According to Marschner (1995) [15], the accumulation of phytotoxins and ethylene in moist soils, combined with oxygen deficiency, inhibits root system expansion. Silva (2000) [16], evaluating the growth of eucalyptus influenced by soil compaction along with phosphorus and potassium doses, observed that compaction limits root system growth, interfering with the absorption of water and nutrients. According to the same author, compaction is a more relevant problem than is soil nutrient availability, since compaction considerably reduces the responses of the plant to increasing doses of phosphorus and affects the efficiency of phosphate and potassium fertilization. The reduction in root system expansion might also be associated with the accumulation of carbon dioxide and the low diffusion of oxygen due to compaction. When soil oxygen levels are low, it is possible that there is a decrease in turgescence pressure in the cell or a greater resistance of cell wall to elongation [17].

## Conclusions

The physical impediment in subsurface did not alter the aerial growth of *Tabebuia caraiba* plants at the compaction levels tested. On the other hand, it affected the root system growth of *Tabebuia caraiba* plants, and such change was most significant at soil densities greater than 1.60 kg.dm-³. Compaction limited the expansion of root system and favored the accumulation of roots above the compacted layer. The root dry mass of *Tabebuia caraiba* plants in and below the compacted layer decreased with the increase in soil density. Compacted soil layers with density greater than or equal to 1.8 kg.dm-³ prevented the pivoting root of *Tabebuia caraiba* from crossing these layers and developing in depth.

**Research Category:** Soil Science

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**Conflict of Interest: None declared**

**Ethical approval:** This article does not contain any studies with human participants or animals performed by any of the authors.

## References

[1] Melloni R., Melloni E. G. P., Alvarenga M. I. N. and Vieira F. B. M. (2008) *Revista Brasileira de Ciência do Solo*, 32, 2461-2470.

[2] Silva A.P., Tormena C.A., Fidalski J. and Imhoff S. (2008) *Revista Brasileira de Ciência do Solo*, 32, 1-10.

[3] Reichert J. M., Suzuki L. E. A. S. and Reinert D. J. (2007) *Tópicos Ci. Solo*, 5, 49-134.

[4] Camargo O. A. and Alleoni L. R. F. (1997) *Compactação do solo e o* desenvolvimento *das plantas*. USP/ESALQ,Piracicaba.

[5] Bowen H. D. Alleviating mechanical impedance. In: Camargo, O. A. de, Alleoni, L.R.F. (2006) *Reconhecimento e medida da compactação do solo*. Available on: <http://www.infobibos.com/Artigos/2006_2/C6/Index.htm>. Accessed on 27 nov 2017.

[6] Ferreira R.A. and Cunha M.D.C. (2000) *Revista Brasileira de Sementes*, 22, 1, 134–143.

[7] Lorenzi H. (2002) *Árvores brasileiras*: Manual de identificação e cultivo de plantas arbóreas do Brasil. Instituto Plantarum,Nova Odessa.

[8] Pereira Junior E.B., Nunes E. M., Souto J. S., Aguiar Neto P. and Rolim H. O. (2012) *Revista Verde de Agroecologia e Desenvolvimento Sustentável*, 7, 2, 96-101.

[9] Silva S. D., Alves J. M., Mesquita G. M. and Leandro W. M. (2012) *Global Science and Technology*, 5, 2, 87-97.

[10] Müller M. M. L., Ceccon G. and Rosolem C. A. (2001) *Revista Brasileira de Ciência do Solo*, 25, 3, 531-538.

[11] Silva H.R. and Rosolem, C.A. (2001) *Revista Brasileira de Ciência do Solo*, 25, 2, 253-260.

[12] Bonelli E. A., Bonfim-Silva E. M., Cabral C. E., Campos J. J., Scaramuzza W. L. M. P. and Polizel A. C.(2011) *Revista Brasileira de Engenharia Agrícola e Ambiental*, 15, 264-269.

[13] Reichardt K. (1990) *A água em sistemas agrícolas*. Manole,São Paulo.

[14] Borges E. N., Lombardi Neto F., Corrêa G. F. and Borges E. V. S. (1999) *Pesquisa Agropecuária Brasileira*, 34, 663-1667.

[15] Marschner H. (1995) *Mineral nutrition of higher plants*. Academic Press, San Diego.

[16] Silva S. R. (2000) *Crescimento do eucalipto influenciado pela compactação de solos e doses de fósforo e de potássio*.

[17] Borges E. N., Lombardi Neto F., Corrêa G.F. and Costa L.M. (1997) *Revista Brasileira de Ciência do Solo*, 21, 125-130.