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# GROWTH OF FOUR MULTIPURPOSE TREES

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**ABSTRACT** – The mesquite (*Prosopis juliflora*), jucá (*Caesalpinia ferrea*), white popinac (*Leucaena leucocephala*) and tamarind (*Tamarindus indica*) are useful species for the Brazilian semi-arid region because are sources of wood, firewood, fruits, forage and others products. Measuring plant height (y) in trees may not be an easy task, but canopy (x) and stem diameter (z) can be more easily evaluated. This work's objective was two-fold: evaluate the growth of related species, in the first two years of age, and obtain linear equations to estimate y from x or z, and x from z, in those species. A randomized complete block design with four treatments (trees) and eight replications was used. The values for x, z, and y were measured biannually from October/2003 to March/2005. The species had different growth in terms of plant height and stem and canopy diameters. Twenty-four months after the transplantation, the highest growth regarding these traits was observed in the mesquite (as well as jucá, as the plant height). The best equations (based on the $R^2$ value) to estimate y in mesquite, jucá, white popinac and tamarind are: y = 0,33 + 0,05 z, y = 0,70 + 0,06 z, y = 0,64 + 0,04 z and y = 0,06 z, respectively. The equations to estimate x from z are: x = 1,47 + 0,03 z, x = 0,55 + 0,05 z, x = 0,04 z e x = 0,05 z, respectively, for the same species.

**Keywords:** Caatinga, plant height, stem diameter, canopy diameter

# CRESCIMENTO DE QUATRO ÁRVORES UTILIZADAS PARA MÚLTIPLOS PROPÓSITOS

**RESUMO –** A algaroba (*Prosopis juliflora*), jucá (*Caesalpinia ferrea*), leucena (*Leucaena leucocephala*) e a tamarindo (*Tamarindus indica*) são espécies úteis para o semi-árido brasileiro porque são fontes de madeira, lenha, frutos, forragem e outros produtos. A mensuração da altura da planta (y) em árvores pode não ser tarefa fácil, mas os diâmetros da copa (x) e do caule (z) podem ser avaliados mais facilmente. Este trabalho teve como objetivos: avaliar o crescimento das referidas espécies e obter equações lineares para estimar y, a partir de x ou z e do x a partir de z. Utilizou-se o delineamento de blocos ao acaso com oito repetições. Os valores de x, z e y foram medidos semestralmente de outubro de 2003 a março de 2005. As espécies cresceram diferentemente em termos de altura da planta e diâmetros do caule e da copa. Aos 24 meses após o transplantio o maior crescimento quanto a essas características foi apresentado pela algaroba (e também pela jucá, quanto à altura da planta). As melhores equações de regressão (com base no valor de $R^2$) para estimar y, para algaroba, jucá, leucena e tamarindo são, respectivamente: y = 0,33 + 0,05 z, y = 0,70 + 0,06 z, y = 0,64 + 0,04 z e y = 0,06 z. A partir de z, as equações respectivas para estimar x são: x = 1,47 + 0,03 z, x = 0,55 + 0,05 z, x = 0,04 z e x = 0,05 z.

**Palavras-chave:** Caatinga, altura da planta, diâmetro do caule, diâmetro da copa

## INTRODUCTION

The mesquite (*Prosopis juliflora* D.C.), white popinac (*Leucaena leucocephala* (Lam.) de Wit.) and tamarind (*Tamarindus indica* L.), although introduced in the semi-arid region of Brazil, are species well adapted to this region. Such species can keep contributing to the solution of some problems in the semi-arid region, for instance, reducing problems of Caatinga desertification as source of firewood. Firewood is today the main power source for household consumption in arid and semiarid regions of third-world countries. The increased population in these areas in the last decades has resulted in a demand for firewood, which in turn inevitably provoked uncontrolled deforestation. At least, some of the referred species can still be used also for animal feeding, for advantageous associations with annual or perennial crops (CHAMSHAMA et al., 1998; OKOGUN et al., 2000), or used in the weed control, such as the white popinac (PIRES et al., 2001; PRATES et al., 2003). In addition, exotic perennial species can be more promising than semiarid native species to the same objectives (DEANS et al., 2003). Therefore, evaluating the behavior of the referred species is a subject of interest. Similar evaluations have been done by other authors (ABEBE, 1994; CERVANTES et al., 1998; DEANS et al., 2003; KUMAR et al., 1998).

Plant height is an important trait of forest species under several aspects, including species succession (larger trees can disperse their propagules more easily and enjoy a reproductive advantage), forest measurements (height is used as a spacing indicator) and environmental suitability (relations such as height/age can be used as quality indicators for the area) (LEARLY et al.,1997). The canopy of trees is much less frequently evaluated than their respective stems, probably due to their smaller economic value. Notwithstanding, due to the fact that canopy size is closely related to its photosynthetic capacity, it is an important parameter in individual tree growth studies. It is also important in studies on the growth of plant groups due to the close correlations between canopy size and stem diameter and between canopy size and planting density (HEMERY et al., 2005). In addition there is interest on canopy firewood.

Measuring plant height in trees may not be an easy task, but canopy diameter can be more easily evaluated. Thus, one idea would be to estimate plant height based on canopy measurements. The first studies on the relation between canopy diameter and stem diameter were conducted more than 100 years ago, and since then a number of papers have been carried out involving several species (HEMERY et al., 2005; SANTOS et al., 2001). Among the species adapted to the Caatinga, the only study found in the literature has dealt with cashew trees (SILVA et al., 2004). Additionally, another idea would be to evaluate stem diameter, a trait that is more easily evaluated than canopy diameter, and also to estimate plant height from that diameter.

The work's objectives were to evaluate the growth of four species adapted to the Brazilian semi-arid region, and to obtain linear regression equations for those species to estimate plant height (y) from canopy diameter (x) or the corresponding stem diameter (z), and to estimate canopy diameter from the stem diameter.

## MATERIAL AND METHODS

The experiment was carried out at the "Rafael Fernandes" Experimental Farm (latitude 5$^o$ 11'S, longitude 37$^o$ 20'W and altitude 18 m), Mossoró county, Rio Grande do Norte State, Brazil. The mean maximum temperature in the region is between 32.1 and 34.5° C and the minimum is between 21.3 and 23.7° C, with June and July as the coolest months. In view of the low latitude, the mean temperature does not present great annual variations. Since the region is located between the 500 and 700 mm isohyets, the climate, according to W. Köppen's classification, is classified as type BSwh', that is, very hot with a summer rainy season that extends through the fall. The mean annual evapotranspiration is around 2,000 mm and the mean insolation is 236 hours/month, with the driest months also being the months with the least insolation. The relative humidity is between 60.5 and 79.1 % and the mean monthly wind speed ranges between 2.6 and 5.6 m/s (CARMO FILHO and OLIVEIRA, 1989).

Four seed-propagated species (mesquite – *Prosopis juliflora*, jucá – *Caesalpinia* *ferrea*, white popinac – *Leucaena leucocephala*, and tamarind – *Tamarindus indica*) were planted in January, 2003. The seeds were sown in black plastic bags, 32 cm tall and 25 cm in diameter, perforated in their bottom third. The bags were filled with substrate consisting of 1/3 manure and 2/3 soil. The soil was classified as a Red-Yellow Argisol, according to the Brazilian Soil Classification System (EMBRAPA, 1999) and as a Ferric Lixisol, according to the Soil Map of the World (FAO, 1988). The soil analysis indicated: pH = 6.8; Ca = 1.80 $cmol_c^{-1}.dm^{-3}$; Mg = 0.40 $cmol_c$ $dm^{-3}$; K = 0.10 $cmol_c$ $dm^{-3}$; Na = 0.01 $cmol_c$ $dm^{-3}$; Al = 0.00 $cmol_c$ $dm^{-3}$; P = 25mg $dm^{-3}$; Org. Matt. = 1.90 g $kg^{-1}$. The manure analysis gave: pH (water) = 8.1; Ca = 4.0 $cmol_c$ $dm^{-3}$; Mg = 5.5 $cmol_c$ $dm^{-3}$; K = 1.72 $cmol_c$ $dm^{-3}$; Na = 1.84 $cmol_c$ $dm^{-3}$; Al = 0.00 $cmol_c$ $dm^{-3}$; P = 76.7 mg $dm^{-3}$.

Transplanting was performed in March, 2003, to a soil of the same type previously referred. The seedlings were transplanted to holes measuring 60 cm × 60 cm × 60 cm. The species were evaluated in a randomized complete block design with eight replications and nine plants per plot. Plant height and crown and stem diameters were evaluated in all plants of each plot, biannually from October/2003 to March/2005. The distance from ground level to the highest point of the crown was considered as plant height. The mean diameter values for the crown or stem, measured in two perpendicular directions, were considered the crown and stem diameters, respectively. Stem diameter was measured at 10 cm above the ground with a digital caliper rule.

In the analysis of variance for the growth data, species were considered plots and age of the pants were considered subplots. This type of analysis was made in the SAEG, *software* developed by Universidade Federal de Viçosa (RIBEIRO JÚNIOR, 2001). For the regression analyses, it was used the tablecurve, software developed by Jandel (1992). In cases where the intercept coefficient value (*a*) was non-significant, a new equation was fitted containing only the slope coefficient value (*b*). A similar procedure was adopted by other authors (SALAM and ABDURAZAK, 2002). The best equations were considered those whose analysis provided the highest coefficient of determination value ($R^2$).

## RESULTS AND DISCUSSION

In terms of plant height, some species grew faster than others (Table 1). At all ages, the tamarind had the lowest growth. In the last measurement, mesquite and jucá had the highest height plant.

The evaluated species also had different growth characteristics regarding the canopy diameter. Six months after the transplantation, the white popinac and tamarind did not differ in this aspect, but in the last measurement, it was observed significant differences in all species, with the mesquite having the largest canopy diameter (Table 2).

Table 1 – Mean plant height (m) of plant species at four ages.

| Species | Age (months after transplanting)[1] | | | | Plant height as a function of plant age[2] |
|---|---|---|---|---|---|
| | 6 | 12 | 18 | 24 | |
| Mesquite | 1.59 a | 1.96 b | 2.91 a | 2.93 a | $y = 4.32 – 6.95/x^{0.5}$, $R^2$ = 0.86 |
| Jucá | 1.73 a | 2.58 a | 2.98 a | 3.11 a | y = 3.56 – 1.09/x, $R^2$ =1.00 |
| White popinac | 1.48 a | 2.02 b | 2.24 b | 2.30 b | y = 2.58 – 6.66/x, $R^2$ = 1.00 |
| Tamarindo | 0.48 b | 0.68 c | 1.03 c | 1.11 c | y = 1.25 – 4.93/x, $R^2$ = 0.87 |
| C.V.a, % | 28.9 | | | | |
| C.V.b, % | 9.0 | | | | |

[1]In each age, means followed by the same letter are not different, at 5 % probability, by Tukey test.

[2] In all equations, the coefficient associated with b was significant, at 5% probability, by the t test.

Table 2 – Mean canopy diameter (m) of plant species at four ages.

| Species | Age (months after transplanting)[1] | | | | Canopy diameter as a function of plant age[2] |
|---|---|---|---|---|---|
| | 6 | 12 | 18 | 24 | |
| Mesquite | 2.33 a | 2.75 a | 2.96 a | 3.17 a | $y = 3.90 - 3.97/x^{0.5}$, $R^2 = 0.99$ |
| Jucá | 1.67 b | 2.16 b | 2.39 b | 2.62 b | $y = 3.49 - 4.50/x^{0.5}$, $R^2 = 0.99$ |
| White popinac | 0.70 c | 1.44 c | 1.54 c | 1.62 c | $y = 2.63 - 4.59/x^{0.5}$, $R^2 = 0.95$ |
| Tamarindo | 0.43 c | 0.60 d | 0.83 d | 0.98 d | $y = 0.24 + 0.03\ x$, $R^2 = 0.99$ |
| C.V. a, % | | | | 35.0 | |
| C.V. b, % | | | | 10.6 | |

[1]In each age, means followed by the same letter are not different, at 5 % probability, by Tukey test.

[2] In all equations, the coefficient associated with b was significant, at 5% probability, by the t test.

The species performance in relation to the measurement date was different regarding the stem diameter (Table 3). The mesquite had, at all ages, the largest stem diameter, and the tamarind, the smallest one.

It is interesting to point out that, equations of the same type were fitted for different species, although the coefficients in such equations were obviously different. Anyway, the coefficients of determination used in all fitted equations were relatively high

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Table 3 – Mean stem diameter (mm), at 10 cm above the ground, of plant species at four ages.

| Species | Age (months after transplanting)[1] | | | | Stem diameter as a function of plant age[2] |
|---|---|---|---|---|---|
| | 6 | 12 | 18 | 24 | |
| Mesquite | 22.2 a | 33.9 a | 48.7 a | 52.2 a | $y = 80.8 - 145.2/x^{0.5}$, $R^2 = 0.94$ |
| Jucá | 21.2 a | 28.2 ab | 38.0 b | 43.0 b | $y^2 = 311.1 + 2.5\ x^2$, $R^2 = 0.94$ |
| White popinac | 20.5 a | 25.0 b | 34.7 b | 41.9 b | $y = -2.0 + 9.2\ x^{0.5}$, $R^2 = 0.99$ |
| Tamarindo | 8.8 b | 11.2 c | 16.9 c | 19.1 c | $y = 80.8 - 145.2/x^{0.5}$, $R^2 = 0.94$ |
| C.V. a, % | | | | 26,8 | |
| C.V. b, % | | | | 10,3 | |

[1]In each age, means followed by the same letter are not different, at 5 % probability, by Tukey test.

[2] In all equations, the coefficient associated with b was significant, at 5% probability, by the t test.

Evaluations involving perennial plant species have demonstrated, as in the present study, differences between themselves in relation to traits intended to evaluate growth, including traits estimated in this work (HEINEMAN et al., 1997; KUMAR et al., 1998; SOUZA et al., 2001). No papers were found in the consulted literature on the joint evaluation of the species herein considered. The results of the present study, however, corroborate papers or observations made for one or more of the species studied here. For example, mesquite is considered to be drought-resistant and to grow fast, but differently opinions about its cultivation are divergent. Some think it is advantageous because it provides firewood and dune fixation, while others think it is a noxious weed (PASIECZNIK et al., 2001). Jucá (Tables 2 and 3) and white popinac (Tables 1 to 3), on the other hand, showed intermediate growth (Tables 2 to 4), in agreement with observations made by other authors (KUMAR et al., 1998; SOUZA et al., 2001). Some authors (REENA and BAGYARAJ, 1990) underlined the slow growth of tamarind, as demonstrated in the present article.

In fitted regression equations, the intercept coefficient was significant only in some cases, but the slope coefficient was significant in all the equations (Table 4). In general, the coefficients of determination were high, but for all species, the value of this coefficient was the same or higher in the plant height estimated value based on the stem diameter than in the plant height estimated value based on the canopy diameter. This information is interesting, as it is much easier to perform the stem diameter measurement, which requires only one person, than to perform the canopy diameter measurement, which requires two persons, especially in the case of higher plants. Besides, the stem diameter can be measured in a very precise and fast manner by using digital caliper rules. Similar considerations can be done to estimate the canopy diameter based on the stem diameter.

Table 4 – Values for parameters a and b, and coefficients of determination of linear regression equations for plant height estimation (PH, m) from canopy (CND, m) and stem diameter (SMD, mm) and for canopy diameter estimation from the stem diameter of seven species adapted to the Brazilian semi-arid region.[1]

| Species | PH = f(CND) | | | PH = f(SMD) | | | CND = f(SMD) | | |
|---|---|---|---|---|---|---|---|---|---|
| | a | b | $R^2$ | a | b | $R^2$ | a | b | $R^2$ |
| Mesquite | 0.00 | 0.84 | 0.63 | 0.33 | 0.05 | 0.91 | 1.47 | 0.03 | 0.74 |
| Jucá | 0.89 | 0.84 | 0.80 | 0.70 | 0.06 | 0.82 | 0.55 | 0.05 | 0.69 |
| White popinac | 0.56 | 0.93 | 0.80 | 0.64 | 0.04 | 0.80 | 0.00 | 0.04 | 0.77 |
| Tamarindo | 0.48 | 0.45 | 0.30 | 0.00 | 0.06 | 0.66 | 0.00 | 0.05 | 0.69 |

[1]All coefficients different from zero were significant at 5% probability by the test t.

The results obtained in the present work agree, in some aspects, with those obtained by other authors for cashew tree (*Anacardium occidentale* L.), also a species adapted to the semi-arid conditions. Regression equations were fitted (SALAM and ABDURAZAK, 2002) considering a two-year period for 18 cultivars, when the crop was 11 and 13 years old. In the first evaluation, only the intercept coefficient was significant, but in the second evaluation both coefficients were significant. According to those authors, the importance of the intercept coefficient decreases, while the importance of the slope coefficient increases as the plant grows. In other words, in young cashew trees, plant height is less related to canopy diameter. Other authors (SILVA et al., 2004) verified that intercept coefficient importance was more dependent on the cultivar studied than on plant age. In the present work, the importance of the intercept coefficient was dependent upon the species evaluated and also on the trait used as dependent variable. For example, the intercept coefficient was not different from zero for jucá, mesquite and tamarind, when plant height was estimated from canopy diameter. When plant height was estimated from the stem diameter, the intercept coefficient was only equal to zero in tamarind. Obviously, using equations of the type y = bx is much simpler than using equations of the type y = a + bx. It is worthwhile to remember that higher coefficient of determination values could have been obtained with other more complex equations, but the aim of the present study was to obtain linear equations to facilitate predictions. Incidentally, the coefficients of determination here obtained had a similar or even higher magnitude than those obtained in similar studies conducted by other authors (PRETZSCH et al., 2002). In their studies, the coefficients of determination ranged from 0.48 to 0.84, depending on the species studied. It is important to highlight that the use of models published for a given species based on data obtained in a region different than the one at which the model was obtained could result in erroneous predictions, as has been warned by other authors (CONDÉS and STERBA, 2005).

## CONCLUSIONS

a) The species showed different growth in terms of plant height and stem and canopy diameters. Twenty-four months after the transplantation, the highest growth regarding these traits was presented by mesquite (as well as jucá, as plant height);
b) The best equations to estimate y in mesquite, jucá, white popinac and tamarind are: y = 0,33 + 0,05 z, y = 0,70 + 0,06 z, y = 0,64 + 0,04 z e y = 0,06 z, respectively. The equations to estimate x from z are: x = 1,47 + 0,03 z, x = 0,55 + 0,05 z, x = 0,04 z e x = 0,05 z, respectively, for the same species.

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