ISSN 0104-7760

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DIOECY EFFECT ON GROWTH OF PLANTED *Araucaria angustifolia* Bert. O. Kuntze TREES

Keyworks:
Paraná Pine
growth and yield models
weighted models
heteroscedasticity

ABSTRACT: The aim of the study was to evaluate the influence of dioecy on the growth in diameter at breast height (DBH), individual basal area, total height and individual volume of planted *Araucaria angustifolia* trees. The data came from 60 trees (30 male trees and 30 female trees) sampled from a 30-year-old plantation in Paraná State. Complete stem analysis was used to recover historical tree growth. The Chapman-Richards model was fitted in order to represent the growth and yield of the dendrometric variables for female and male Araucaria trees. Weighted non-linear least squared method was used in the fitting process and the inverse variance was used as weight to solve the problem of heteroscedasticity. The test to verify the equality of parameters and the identity of non-linear regression models proposed by Regazzi (2003) was used to test the influence of dioecy on growth. Dioecy significantly influenced the growth of Araucaria, and female trees have higher growth in diameter, individual basal area and individual volume, while male trees showed better height development. The asymptotic coefficient of the Chapman-Richards model showed that male trees have a higher asymptotic height than female trees.

Histórico:
Recebido 08/07/2014
Aceito 10/09/2015

EFEITO DA DIOICIA NO CRESCIMENTO DE *Araucaria angustifolia* Bert. O. Kuntze PLANTADA

Palavras chave:
Pinheiro-do-Paraná
modelos de crescimento
produção
modelos ponderados
heterocedasticidade

RESUMO: O objetivo da pesquisa foi avaliar a influência da dioicia no crescimento do diâmetro a 1,3 (DAP), área transversal (g), altura total (h) e volume individual (v) de *Araucaria angustifolia* plantada. Os dados utilizados são provenientes de 60 árvores de *Araucaria angustifolia* (30 árvores masculinas e 30 femininas) amostradas em um plantio com idade de 30 anos em Laranjeiras do Sul, Estado do Paraná. A análise de tronco completa foi utilizada para recuperar o crescimento passado das árvores. O modelo de Chapman-Richards foi ajustado para estimar o crescimento e a produção das variáveis dendrométricas para as araucárias femininas e masculinas. O ajuste foi realizado pelo método dos mínimos quadrados não lineares ponderados e o inverso da variância foi utilizado como peso para resolver o problema da heterocedasticidade. O teste de igualdade de parâmetros e identidade de modelos de regressão não lineares proposto por Regazzi (2003) foi aplicado para testar a influência da dioicia no crescimento. A dioicia influenciou significativamente o crescimento de *Araucaria angustifolia*, sendo que as araucárias femininas têm um crescimento maior em diâmetro, área transversal e volume individual, enquanto as araucárias masculinas apresentam maior desenvolvimento em altura. O coeficiente assintótico do modelo de Chapman-Richards indicou que árvores masculinas possuem uma maior altura assintótica que as femininas.

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DOI:
10.1590/01047760201521031756

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INTRODUCTION

Araucaria angustifolia (Bertol.) O. Kuntze belongs to the Araucariaceae family, known popularly as the "pinheiro-do-paraná", or "Parana pine". The tree grows 20 to 50 m tall, attains 1 to 2 m or more in diameter, generally has a cylindrical stem, which is straight and rarely branched (REITZ; KLEIN, 1966).

Araucaria is a dioecious species, i.e., has male and female individuals (ZANON, 2007). The female plants have rounded strobili, popularly known as the cone and in the male plants strobili are cylindrical, elongated and leathery with scales, between 10 and 22 cm long and a with a diameter between 2 and 5 cm (ANGELI, 2003).

The most common uses of the *Araucaria angustifolia* are lumber, beams, plywood, furniture, pulp, paper, musical instruments and adornment, fence posts, among others. The branches and slash, and especially the "pine node" make good firewood and boiler fuel. The resin is a base for making varnishes, turpentine, pyroligneous acid and other chemicals (REITZ; KLEIN, 1966).

The growth or increment of an individual refers to the increase in the dimensions of height, diameter, basal area, volume, while the yield is related to its final size after a defined period of observation. Thus, it can be said that the term growth is used to denote the absolute growth rate and the yield to denote total growth or cumulative growth (SPATHELF; NUTTO, 2000).

According to Husch et al. (2003), the growth of any organism follows a sigmoidal pattern: juvenile phase which ends in the maximum current annual increment; maturity which begins at the point of maximum current increment and ends in the maximum mean annual increment; and senescence which begins at the point of maximum mean annual increment.

A logical way to express the growth or increase of forest production is by means of a model. This can take the form of graphs, tables, or both graphs and tables, of an equation or set of equations, or a group of sub-models each having one or more equations (VANCLAY, 1994).

The Chapman-Richards model is valuable because of its precision and is used more than any other function in tree growth studies (ZEIDE, 1993). This model was introduced in forestry by Turnbull (1963).

Pinto (1990) studied the influence of dioecy on diameter (DBH) and height growth of *Araucaria angustifolia* and its effects on application of thinning in a 26-year old seed orchard, located in Iguazu Falls, Paraná. No statistical difference was found in DBH and height growth between male and female Araucaria trees in the studied forest.

Zanon (2007) studied the periodicity of male and female tree growth, dominant and dominated, in 40- and 60-year old stands of *Araucaria angustifolia*, in the São Francisco de Paula National Forest, Rio Grande do Sul state and correlated this growth with meteorological, morphometric and environmental variations. The author concluded that the beginning of the annual tree growth occurs in September, peaking in January, and beginning to decline by March. This pattern is influenced by competition, vitality and canopy area conditions. There was no statistical difference in growth between male and female trees.

Araucaria angustifolia is one of the most important native species from southern Brazil, especially from an economic standpoint. It has a good growth rate and produces a high quality wood. Differentiating the growth pattern between male and female trees is important for the forest management, considering that the production of pine seeds is an important food and income source. It is necessary to know if the seeds production affects the growth rate of the species. Therefore, discovering if the difference between timber production of female and male trees, constitutes an important tool in making intervention decisions in the stand.

In this context, the objective of this research was to study the growth of *Araucaria angustifolia*, and to test whether the dioecy factor had any influence over the growth in diameter inside bark (DBH), individual basal area inside bark (g), height (h), and individual volume inside bark (v).

MATERIALS AND METHODS

Data Collection

The data used in this study came from 60 *Araucaria angustifolia* trees (30 male and 30 female trees) sampled from a 30-year-old plantation in Nova Colonia (25°22'46.55" S, 52°29'16.98" W), in the municipality of Laranjeiras do Sul, state of Paraná, Brazil. The initial spacing was 2 x 2 m with three thinning applications.

The 60 trees were randomly selected in all classes, proportionally to the diameter distribution, to take into account the variability in diameter with respect to sex. After the selected trees were felled, disks were collected at absolute heights of 0.1 and 1.3 m and at the relative heights of 15%, plus one disk at every 10% increase up to a final disk at 95% of total height (totaling 11 disks per tree). After cutting, the disks were dried in an industrial timber oven at 60°C for 4 days and sanded after drying. In Table 1 are shown the features of the Araucaria male and female samples.

Complete stem analysis technique (ANATRO) was used to recover historical growth at ages between 1 and 30 years of the inside bark diameter at 1.3 m (DBH), total height and individual inside bark volume. On each disk 4 rays were traced where the annual growth rings were measured to give the diameters (inside bark) at each age. The final portion of the heights of each age was estimated based on similar triangles. The supplement FlorExcel (ARCE, 2002) was used to determine the dendrometric parameters of the sampled trees.

Growth Modeling

The Chapman-Richards (1) model was used to describe the growth of *Araucaria angustifolia*. The model [1] was fitted using nonlinear regression (Marquardt algorithm) separately for male and female Araucaria and for the different dendrometric parameters in order to compare the average growth between male and female individuals, where: f(x) = size of the organism in time t; a = asymptotic value that the organism can reach; b = relative measure of the growth-rate; c = expresses the inflection point.

$$f(x) = a\left[1 - e^{-bt}\right]^{c} \qquad [1]$$

Due to the presence of heterogeneity in the variances of the residuals (heteroscedasticity), we used the method of weighted nonlinear least squares which placed less weight on observations where the error variance was higher, while the method of ordinary least squares places equal weight on all observations. To accomplish this, the Weight [2] function of the Statgraphics Centurion software was used, and the assigned weight (W) was the inverse variance (σ^2) of each age.

$$W = \frac{1}{\sigma^2} \qquad [2]$$

For the analysis of the fitted model the Akaike Information Criterion (AIC), residual standard error as a percentage (Syx%) and graphical analysis of the residuals were employed.

The presence of outliers in the residual graphical distribution was detected after model fitting. These values appeared to be measurement errors. To solve this problem we used an existing option in the statistical software used to fit the model, which informs the outliers. After excluding outliers, the model was fitted again.

Outliers are sample values that are located far from the vast majority of other sample values (TRIOLA, 2011). According to Scolforo (1997) outliers are not normal values observed in the residuals analysis, and these should only be removed if and only if the detected problem cannot be corrected.

Influence of Dioecy on Growth

The test to verify the equality of parameters and the identity of non-linear regression models proposed by Regazzi (2003) was used to test the hypotheses: (a) H01, H02 and H03: a given coefficient is equal for both sets of data; H1: a given coefficient is different for both sets of data; (b) H04, H03 and H06: at least two coefficients are equal for both sets of data; H1: at least one equality is an inequality, that is, at least one coefficient is different. (c) H07: the growth functions are identical for both male and female trees, that is, a single function can be used to estimate both sets of data (this hypothesis tests whether the coefficients of the two growth equations are equal for the two groups, female and male); H1: at least one equality is an inequality, that is, at least one coefficient is different. The three groups of hypotheses (a, b and c) have an H1 hypotheses that rejects the H0.

TABLE 1 Summary of the utilized data in the study.
TABELA 1 Caracterização dos dados utilizados no estudo.

Variable	Male Araucaria sample				Female Araucaria sample			
	Mean	Max	Min	CV (%)	Mean	Max	Min	CV (%)
DBH (cm)	28.99	36.40	22.95	12.59	30.12	38.50	22.30	14.14
h (m)	19.05	22.70	16.00	10.19	18.75	22.30	15.00	9.86
v (m^3)	0.73	1.17	0.44	27.93	0.81	1.42	0.35	32.76

For the test, the Chapman-Richards model was adjusted for male and female trees with "dummy" variables, where a complete model (omega) and a reduced model (w) were fitted. The full model was adjusted with different coefficients for the two sets of data and in the reduced model a constraint is imposed such that the model coefficients for the two groups must be equal, i.e., a single equation can be used for both sets of data (female and male). A more detailed description of the test can be found in Regazzi (2003). The test statistic is as follows [3], where: SSRΩ = Sum of Squares of the residuals of the full model (Ω); SSRw = Sum of Squares of the reduced model (w); n = total number of observations.

$$\chi^2_{calculated} = -n \ln\left(\frac{SSR_\Omega}{SSR_w}\right) \quad [3]$$

The decision rule is, If χ^2calculated $\geq \chi^2$tabled, H0 is rejected, otherwise not. The tabled value is a function of α level of probability and the degree of freedom v (pΩ-pw), where: v = number of degrees of freedom; pΩ = number of coefficients in the full model (for the fitted growth function in this study = 6); pw = number of coefficients in the reduced models (for the fitted growth function in this study = 5, 5, 5, and 3).

RESULTS AND DISCUSSION

Growth Equation

The fits of the Chapman-Richards biological model showed good fit statistics, residual standard error (Syx%) ranging from 11.46 to 38.82% (Table 2). The growth equation for the variable total height showed the best statistical fit, precision and had homogeneous distribution of residuals (Figure 1). Moreover, the errors were greater for estimating individual volume inside bark.

Figure 1 shows the percentage residual distribution of the fitted model for each variable, showing a homogeneous residual distribution, except at early ages, where overestimation can be observed for all variables considered in this study.

It is important to note that the sample used in the study was 30 years old. The estimate of the parameter "a" of the Chapman-Richards model (Table2) is a consequence of the range of the data used and therefore does not yet represent the maximum value (asymptotic values) of the variables evaluated in this research. It should also be mentioned that the values of this coefficient are average and inside bark (except for the height). Table 3 shows that the parameters of the model are highly significant.

Growth Analysis

The Chapman-Richards model was used to generate growth curves for mean inside bark diameter growth, total height and individual inside bark volume as a function of age, for male and female Araucaria trees (Figure 2).

TABLE 2 Coefficients and statistics for the growth equations to estimate diameter inside bark (DBH), total height (h) and individual inside bark volume (v) as a function of age (years).

TABELA 2 Coeficientes e estatísticas para as equações de crescimento ajustadas para estimar diâmetro sem casca (DAP), altura total (h) e volume individual sem casca (v) em função da idade (anos).

Variable	Coefficient a	Coefficient b	Coefficient c	AIC	Syx(%)
Male Araucaria trees					
DBH	34.5452	0.0691	1.3895	2179.58	14.82
Height	21.2273	0.0944	1.5730	2169.71	12.10
Volume	1.4902	0.0593	3.7734	2178.38	31.58
Female Araucaria trees					
DBH	35.1510	0.0757	1.4732	2183.48	16.65
Height	20.0162	0.1114	1.8250	2189.12	11.46
Volume	1.4665	0.0659	3.9814	2164.45	38.82

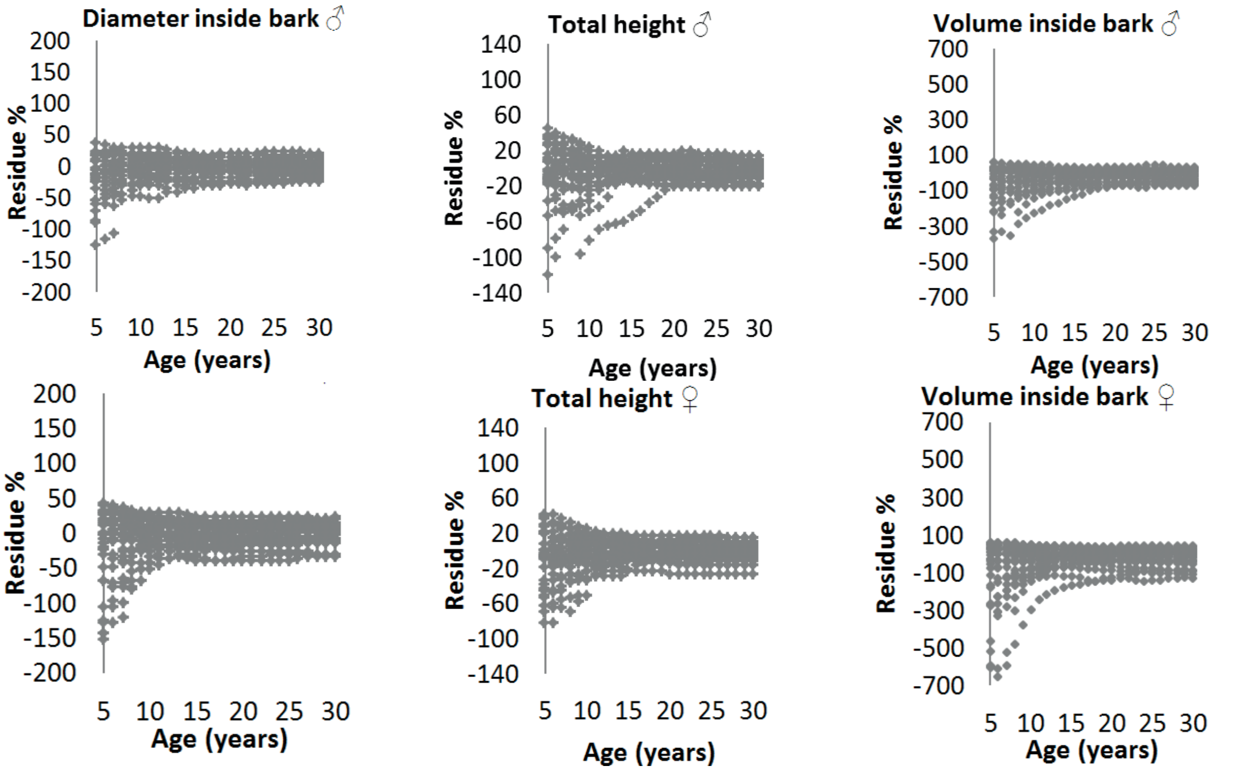

FIGURE 1 Residual distribution (%) of the Chapman-Richards model for estimating diameter inside bark, total height and individual inside bark volume for male (♂) and female(♀) Araucaria trees.

FIGURA 1 Distribuição gráfica de resíduos do modelo de Chapman-Richards para estimar o diâmetro sem casca, altura total e volume individual sem casca para araucárias masculinas (♂) e femininas (♀).

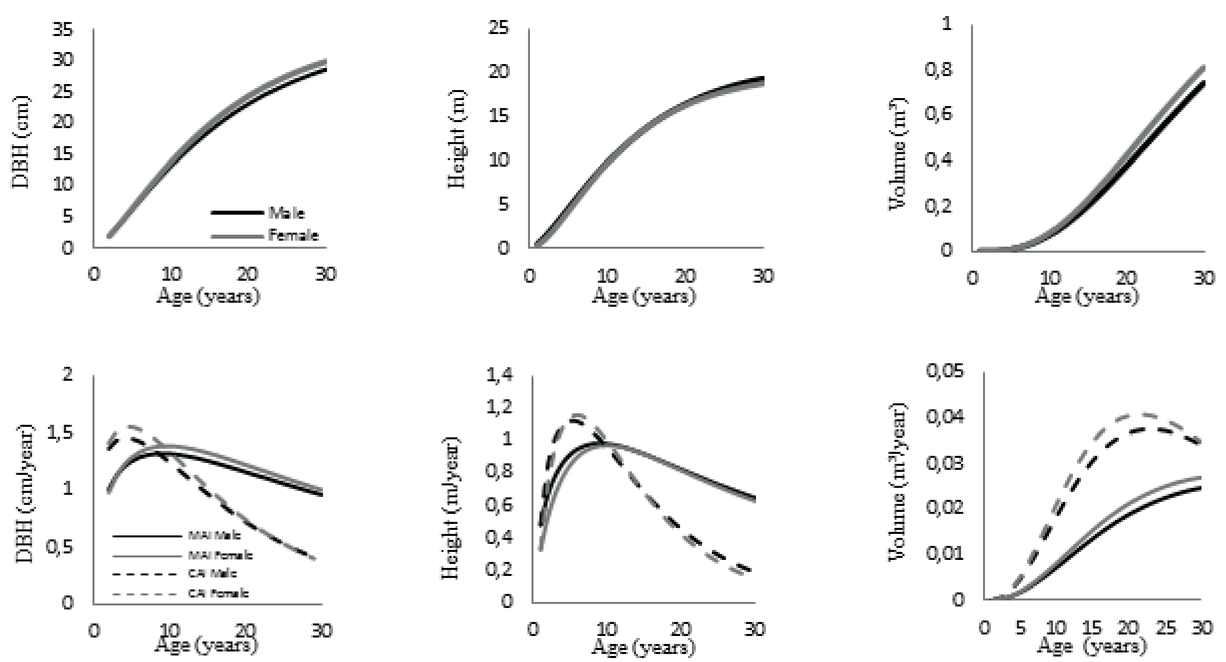

FIGURE 2 Mean annual increment (MAI) and current annual increment (CAI) yield curves of male and female Araucaria trees generated by the biological model.

FIGURA 2 Curvas médias de produção, incremento médio e corrente anual (IMA e ICA) de araucárias masculinas e femininas geradas pelo modelo biológico.

TABLE 3 Significance of the parameters of the model for the different variables.
TABELA 3 Significância dos parâmetros do modelo para as diferentes variáveis.

Variables	Parameter	Value	Standard deviation	t-value	p-value
DBH	**a (*male*)**	34.5452	1.4300	24.1573	<000.1
	a (*female*)	35.1510	1.4433	24.3546	<000.1
	b (*male*)	0.0691	0.0075	9.1829	<000.1
	b (*female*)	0.0757	0.0086	8.7469	<000.1
	c (*male*)	1.3895	0.0950	1.6307	<000.1
	c (*female*)	1.4732	0.1185	12.4280	<000.1
Height	**a (*male*)**	21.2273	0.4460	47.5994	<000.1
	a (*female*)	20.0162	0.3180	62.9482	<000.1
	b (*male*)	0.0944	0.0070	13.5631	<000.1
	b (*female*)	0.1114	0.0066	16.9540	<000.1
	c (*male*)	1.5730	0.1051	14.9632	<000.1
	c (*female*)	1.8250	0.1123	16.2543	<000.1
Volume	**a (*male*)**	1.4902	0.1651	9.0244	<000.5
	a (*female*)	1.4665	0.1736	8.4454	<000.5
	b (*male*)	0.0593	0.0055	10,8587	<000.5
	b (*female*)	0.0659	0.0069	9.6079	<000.5
	c (*male*)	3.7734	0.1908	19.7735	<000.5
	c (*female*)	3.9814	0.2574	15.4707	<000.5

Mean annual increment (MAI) and current annual increment (CAI) curves crossed earlier for male rather than female Araucaria trees for all variables except volume, considering that the intersection for this variable has not yet occurred for both sexes.

For diameter and height, the maximum MAI occurred early, around 9 and 10 years old, respectively, for male and female trees. In the case of individual volume, the age at which the MAI and CAI curves cross can be projected as occurring over 35 years old.

The curves show that increment values for female trees were slightly higher than for male trees, except for height, where the female trees was surpassed by male near the asymptote. Zanon (2007) found a tendency for female trees to develop faster than male ones, but the analysis of variance showed no statistical difference between the growth of male and female trees.

Influence of Dioecy on Growth

The results for the Regazzi (2003) test are shown in Table 4 and indicate that hypothesis H04, H05, H06, and H07 were rejected ($\alpha \leq 0{,}05$) for all the dendrometric parameters considered in this study. Thus, the growth functions should be adjusted separately to represent male and female *Araucaria angustifolia* trees. It was concluded, therefore, that the dioecy, significantly influences *Araucaria angustifolia* growth.

Araucaria female trees have higher growth in diameter and volume, while male trees show better development in height. This can be observed in the growth and production curves shown in Figure 2. The number of observations for each variable was different, because for each one a different number of outliers was detected and excluded from the regression fits.

The coefficients of the Chapman-Richards model were tested separately, however, only the coefficient "a" (related to the asymptotic value) for the height fit was distinguished by the equality test, i.e., the asymptotic values for the variable height are different for female and male trees. For the DBH and individual volume the rejection of the hypotheses H04 indicates that at least one of the parameters "a" or "b" are different. It should be noted that the test is very sensitive and it was able to capture slight differences in the male and female curves. This can be verified by analyzing the

TABLE 4 Equality test parameters and identity of nonlinear regression models proposed by the Regazzi (2003) applied to the biological model fitted to the dendrometric variables evaluated.

TABELA 4 Teste de igualdade de parâmetros e identidade de modelos de regressão não linear proposto por de Regazzi (2003) aplicado para o modelo biológico ajustado para as variáveis dendrométricas avaliadas.

Variable	Test	H1	H01	H02	H03	H04	H05	H06	H07
	Parameters		**a**	**b**	**c**	**a, b**	**a, c**	**b, c**	**a, b, c**
DBH	**a (*male*)**	34.545	34.867	34.027	34.085	35.431	35.130	34.033	34.816
	a (*female*)	35.152	34.867	35.798	35.736	35.431	35.130	35.788	34.816
	b (*male*)	0.069	0.067	0.072	0.072	0.068	0.068	0.072	0.072
	b (*female*)	0.076	0.077	0.072	0.072	0.068	0.073	0.072	0.072
	c (*male*)	1.389	1.372	1.424	1.424	1.428	1.403	1.425	1.427
	c (*female*)	1.473	1.494	1.425	1.424	1.324	1.403	1.425	1.427
	SS res	1497.8	1497.9	1498.1	1498.1	1509.3	1500.8	1498.1	1538.0
	N	1553	1553	1553	1553	1553	1553	1553	1553
	X^2 calc	-	0.08	0.33	0.32	**11.89***	2.99	0.33	**41.15***
	GL	6	1	1	1	2	2	2	3
	X^2 tab	-	3.841	3.841	3.841	5.991	5.991	5.991	7.815
Height	**a (*male*)**	21.227	20.579	20.723	20.807	20.578	20.580	20.707	20.559
	a (*female*)	20.016	20.579	20.413	20.331	20.578	20.580	20.431	20.559
	b (*male*)	0.094	0.104	0.103	0.102	0.103	0.104	0.103	0.103
	b (*female*)	0.111	0.102	0.103	0.104	0.103	0.102	0.103	0.103
	c (*male*)	1.573	1.711	1.707	1.703	1.671	1.695	1.701	1.701
	c (*female*)	1.825	1.683	1.697	1.703	1.715	1.695	1.701	1.701
	SS res	1493.8	1498.9	1497.0	1496.6	1499.6	1499.0	1497.1	1502.3
	N	1556	1556	1556	1556	1556	1556	1556	1556
	X^2 calc	-	**5.26***	3.34	2.86	**6.02***	5.37	3.39	**8.79***
	GL	6	1	1	1	2	2	2	3
	X^2 tab	-	3.841	3.841	3.841	5.991	5.991	5.991	7.815
Volume	**a (*male*)**	1.490	1.479	1.418	1.430	1.527	1.499	1.413	1.504
	a (*female*)	1.466	1.479	1.576	1.557	1.527	1.499	1.581	1.504
	b (*male*)	0.059	0.060	0.062	0.061	0.060	0.060	0.062	0.061
	b (*female*)	0.066	0.065	0.062	0.062	0.060	0.063	0.062	0.061
	c (*male*)	3.774	3.784	3.857	3.850	3.882	3.830	3.851	3.831
	c (*female*)	3.981	3.965	3.841	3.850	3.673	3.830	3.851	3.831
	SS res	1478.5	1478.5	1479.1	1479.0	1487.5	1480.2	1479.1	1517.2
	N	1553	1553	1553	1553	1553	1553	1553	1553
	X^2 calc	-	0.01	0.59	0.48	**9.34***	1.77	0.63	**40.11***
	GL	6	1	1	1	2	2	2	3
	X^2 tab	-	3.841	3.841	3.841	5.991	5.991	5.991	7.815

ns: not significant at the 5% probability level; *significant at the 5% probability level; SS res: sum of squares of the residuals; n: number of observations; X^2 calc: calculated qui-square; DF: degrees of freedom; X^2 tabled: Chi-square from table. Note: marked cells refer to coefficients that were estimated as being equal for both groups of data.

graph of growth in height in Figure 2 where it is noted that the curves begin to distance themselves above the age of 20 years, near the asymptotic value, where the curve of the male is superior to female one. The test was able to capture this slight difference.

The fact that male Araucaria trees are higher than female ones may be related to their reproductive cycle, since until about 20 years the height curves are very similar, after which the males become higher in height. According to Carvalho (2003), seed production in isolated Araucaria trees begins between 10 and 15 years of age, while in forest plantation, reproduction begins at around 20 years, emphasizing that these ages may vary widely with growing conditions. As stated by Pinto (1979, 1990), at 26 years of age, 54.7% of Araucaria trees in thinned plantation had not yet flowered. In a study conducted an Araucaria provenance test in Colombo, Paraná state, Brazil, Sousa and Hattemer (2003) report that at 17 years old only 27.4% of trees were reproducing, of which 17.2% were male. The authors stated that the stand was too young to draw conclusions about the reproduction age.

One of the three hypotheses tested by Pinto (1979) was that the height and diameter growth of female trees would be significantly lower than male trees, only after the beginning of the sexual reproduction, when energy reserves would be reallocated to the formation of catkins and cones. This author commented that this hypothesis is based on the theory of reproductive effort in dioecious species, that the production of ovules and seeds requires more energy than the production of pollen, i.e., the reproductive effort would be greater for females than for males (LLOYD; WEBB, 1977).

To test this hypothesis, Pinto (1979) used the t test for paired and unpaired plots. In the paired plots test, the trees were grouped in pairs, eliminating the possible spacing and soil variations. No significant difference in the growth in diameter (DBH) and height between the sexes in Araucaria in the studied area was found. Although differences for DBH and height were not significant, the mean values obtained by the author were higher for female Araucaria trees for both DBH and height (30.3 (♀) and 29.2 cm (♂) for DBH and 19.4 (♀) and 18.8 m (♂) for height for unpaired data). For paired data, the mean was 30.1 (♀) and 29.3 cm (♂) for DBH and 19.2 (♀) and 19.0 m (♂) for height. For the results obtained in the present study, all variables (DBH, h and v) showed significant differences between male and female individuals. Only the height variable would agree with the theory of reproductive effort in dioecious species.

Paludo et al. (2009) studied a natural population in the Caçador Forest Genetics Reserve in the Santa Catarina state, with the goal of generating information about the population structure of the species. The populations studied by the authors was divided into 4 classes: regrowth, juvenile, male and female. They analyzed the diameter and height structure, sex ratio and spatial pattern. The authors observed an average diameter for adult plants of 63.5 cm. Average DBH and heights between male and female individuals were tested using the t test for unpaired data. Male individuals had mean diameter significantly smaller than the female individuals (♂56.8 cm and $n = 79$; ♀71.0 cm and $n = 71$; $t = -2.9$; $p < 0.005$). The medium height of the adult plants was 21.9 m, also showing significative diference between the male and female medium (♂ 21.1 m and $n = 79$; ♀ 22.7 m and $n = 71$; $t = -22$; $p = 0.026$).

The results of Paludo et al. (2009) were similar to those of this study for the variable DBH. However, the authors also observed that female trees were higher than male trees, which differed from the findings of this study where male trees were higher than female trees. The results obtained by these authors also contradict the assumption that female plants have reduced growth because of reproductive effort.

According to Pinto (1979) several studies have been conducted in order to establish whether or not there is a relationship between sex and DBH and height growth in dioecious species. Cited for example Farmer (1964), who related sex with growth in height, DBH and other variables in natural stands of *Populus deltoides* and verified that for male trees height was significantly higher (♂ 29.6 and ♀ 28.6 m), while there was no significant difference with respect to DBH (♂ 35.8 and ♀ 34.3 cm).

Populus tremula female trees had higher increment in height and DBH than male trees (BORSER, 1957 cited by PINTO, 1979). Some research shows that not all dioecious species exhibit height and DBH growth differences between sexes.For example, Einspahr (1960, cited by Pinto, 1979), found no statistically significant difference in height and DBH growth between the sexes of *Populus treftiuloides* trees. Khosla et al. (1979), studying *Populus ciliata*, report that analysis of variance showed no difference between male and female trees with respect to height and DBH. However, the female trees had higher mean values than the male ones for the three variables (♀ 26.0 m and ♂ 25.6 m for height; ♀ 37.5 to 52.6 and ♂ 33.0 to 48.2 cm for DBH; ♀ 0.39 to 0.5 and ♂ 0.4 to 0.5 for the specific gravity). According to these authors, the higher values presented by female trees with respect to the characteristics studied can be attributed to the occurrence of males in competition with dominant species, whereas females prefer open and exposed places. Another related study was conducted by Zanon et al. (2009) who found no significant difference in the mean diameter between female and male *Araucaria* trees, but found that female trees had greater DBH than male ones (42 cm for females and 38.5 cm for males).

CONCLUSIONS

Dioecy significantly influenced the growth of *Araucaria angustifolia*, and female Araucaria trees have higher growth in diameter, and individual volume, while male Araucaria trees showed better development in height.The equality test parameters and identity for nonlinear regression models proposed by Regazzi (2003) indicated that the coefficient "a" of the Chapman-Richards model was different for height of male and female Araucaria trees. This coefficient is related to the asymptotic value and indicates that adult male Araucaria trees tend to be higher than female Araucaria trees.

REFERENCES

ANGELI, A. *Araucaria angustifolia* (Araucaria). Piracicaba: **IPEF**, 2003. Disponível em: http://www.ipef.br/identificacao/araucaria.angustifolia.asp. Acesso em: 25/03/2012.

ARCE, J.E., Florexcel – Funções florestais desenvolvidas para o Microsoft Excel©. Curitiba: CCFM, UFPR, 2002 (Software/Suplemento).

CARVALHO, P. E. R. Espécies arbóreas brasileiras. Brasília, DF. Colombo, PR: **Embrapa Informações Tecnológicas Embrapa Florestas**, 2003. 1035 p.

HUSCH, B., BEERS, T. W. AND KERSHAW, J. A. **Forest Mensuration.** John Wiley e Sons, 2003, 443 p.

KHOSLA, P. K.; DHALL, S.P.; KHURANA, D.R. Studies in Populus ciliate Wall. ex. Royle. I. Correlation of phenotypic observation with sex of trees.**Silvae genetica**, 28 (1), 1979.

LLOYD, D.G.; WEBB, C.J. Secondary sex characters in plants. **The botanical review**, 43 (2): april-june, 1977.

PALUDO, G. F.; MANTOVANI, A.; KLAUBERG, C.; REIS, M. S. Estrutura demográfica e padrão espacial de uma população natural de *Araucaria angustifolia* (Bertol.) Kuntze (Araucariaceae), na Reserva Genética Florestal de Caçador, Estado de Santa Catarina. **Árvore**, Viçosa-MG, v.33, n.6, p.1109-1121, 2009.

PINTO, S. A. A. Influência da dioicia no diâmetro e na altura de *Araucaria angustifolia* (Bert.) O. Ktze. e suas implicações na formação de áreas de produção de sementes na região de Quedas do Iguaçu – Estado do Paraná. 1979. 40f. **Dissertação**. UFPR, Setor de Ciências Agrárias, Curitiba.

PINTO, S. A. A. Influência da dioicia no diâmetro e na altura de *Araucaria angustifolia* (Bert.) O. Ktze. e suas implicações na formação de áreas de produção de sementes na região de Quedas do Iguaçu – Estado do Paraná. **Floresta**, v. 20, n. 1 e 2, p. 1, 1990.

REGAZZI, A.J. Teste para verificar a igualdade de parâmetros e a identidade de modelos de regressão não linear. **Ceres**, v.50, p.9-26, 2003.

REITZ, P.R.; KLEIN, R.M. **Araucariaceas**. Itajaí, HBR, 1966, 62 p.

SCOLFORO, J. R. S. **Biometria florestal 2: Técnica de regressão aplicada para estimar: volume, biomassa, relação hipsométrica e múltiplos produtos de madeira**. 292 p. Lavras: UFLA/FAEPE, 1997.

SOUSA, V. A.; HATTEMER, H. H. Fenologia reprodutiva da *Araucaria angustifolia* no Brasil. **Boletim de Pesquisa Florestal**, Colombo, n. 47, p. 19-32, jul./dez. 2003.

SPATHELF, P.; NUTTO, L. **Modelagem aplicada ao crescimento e produção florestal**. Santa Maria: Universidade Federal de Santa Maria. 71p. 2000.

TRIOLA, M. F. **Introdução à estatística**. 10 ed. Rio de Janeiro: LTC, 2011.

TURNBULL, K. J. Population dynamics in mixed forest stands: A system of mathematical models of mixed stand growth and structure. 1963. 186f. **Dissertação**. University of Washington, W.A., Washington.

VANCLAY, J. K. **Modelling Forest Growth and Yield: Applications to Mixed Tropical Forests.** Wallingford: CAB International. 1994.

ZANON, M. L. B. Crescimento da Araucaria angustifolia (Bertol.) Kuntze diferenciado por dioicia. 2007. **Tese** (Doutorado em Engenharia Florestal) – Universidade Federal de Santa Maria, Centro de Ciências Rurais, Programa de Pós-Graduação em Engenharia Florestal, RS.

ZANON, M. L. B.; FINGER, C. A. G. SCHNEIDER, P. R. Proporção da dioicia e distribuição diamétrica de árvores masculinas e femininas de *Araucaria angustifolia* (Bertol.) Kuntze, em povoamentos implantados. **Ciência Florestal**, Santa Maria, v. 19, n. 4, p. 425-431, out.-dez., 2009.

ZEIDE, B. Analysis of growth equations. **Forest Science**, Bethesda, v. 30, n. 3, p. 594-616, 1993.