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GROWING SPACE IN A 35-YEAR-OLD *Pinus taeda* STAND

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ABSTRACT - Considering the economic importance of the Pinus species in Brazil, especially in the southern region, this study was carried out to fill some gaps and assist in the production processes of this species. The specific objective was to evaluate the influence of different growing space regimes in experimental plantations of *Pinus taeda* L., aged 35 years, without thinning, located in the state of Santa Catarina. Diameter at breast height (DBH) and total height data were collected, and the Gamma and Weibull (3P) probability density functions (PDF) were used to describe the structure of the diameter and height variables, respectively. Then multivariate analysis and discriminant functions were applied to identify the correlation of these variables. For qualitative variables, tree health was assessed in three classifications: 1 - Healthy, with no apparent damage; 2 - Initial stage of deterioration by pests and/or diseases; and 3 - Advanced stage of deterioration by pests and/or diseases. The trunk quality variable was also evaluated in three classifications: 1 - Trunk without apparent defects; 2 - Slightly crooked trunk, however cylindrical and devoid of considerable ramifications; and 3 - Trunk with strong tortuosity or bifurcation. The results showed that growing space directly affected the average diameter. Stands with greater space per tree maximized the variables when considering height and DBH together. Stands with less growing space, on the other hand, favored better trunk quality, and the dominant individuals in height had superior health and trunk quality compared to the others.
Keywords: Loblolly pine, distribution probability function, MANOVA.

ESPAÇO VITAL EM POVOAMENTOS DE Pinus taeda COM 35 ANOS DE IDADE

RESUMO - Ao considerar a importância econômica que a espécie Pinus apresenta no Brasil, principalmente na região sul, este estudo foi realizado com o intuito de preencher algumas lacunas e auxiliar nos processos de produção desta espécie. Com isso, o objetivo deste trabalho foi avaliar a influência de diferentes espaços vitais sob plantios experimentais de *Pinus taeda* L. com 35 anos, em regime sem desbaste, localizados em Santa Catarina. Foram coletados os dados de diâmetro à altura do peito (dap), altura total e utilizadas as funções de densidade de probabilidade (FDP) Gamma e Weibull (3P) para descrever a estrutura das variáveis diâmetro e altura, respectivamente. Em sequência foram aplicadas análise multivariada e função discriminante para identificar a correlação destas variáveis. Para as variáveis qualitativas, a sanidade foi avaliada em três classificações: 1 - Sadia, sem danos aparentes; 2 - Estágio inicial de deterioração por pragas e/ou doenças; 3 - Estágio avançado de deterioração por pragas e/ou doenças. A variável qualidade de fuste também foi avaliada em três classificações: 1 - Fuste sem defeitos aparentes; 2 - Fuste ligeiramente torto, porém cilíndrico e desprovido de ramificações consideráveis; 3 - Fuste com forte tortuosidade ou bifurcação. Após análises, foi possível concluir que o espaço vital afeta diretamente o diâmetro médio. Os plantios com maior espaço vital maximizam as variáveis ao considerar em conjunto altura e dap. Já plantios com menor espaço vital favorecem uma melhor qualidade de fuste, e os indivíduos dominantes em altura apresentam sanidade e qualidade de fuste superiores em relação aos demais.
Palavras-chave: Pinheiro bravo, função de probabilidade de distribuição, manova.

INTRODUCTION

Among the decisions to be made by foresters, planting density or growing space (GS) for the development of each tree is among the variables that directly influences the production and quality of wood (BERGER, 2002). For this decision, important factors such as the characteristics of the species, the form of growth, root development, tolerance to adverse conditions and adaptability should be taken into account. Local characteristics such as soil, climate, market opportunities, forestry techniques, machinery, available labor, among others (SANQUETTA et al., 2003b) should also be considered. Therefore, when considering all these factors, one should opt for a density that provides maximum growth, with high quality and low cost (CHIES, 2005).

Of the factors influenced by GS to produce high-quality wood, the diameter at breast height (DBH) and tree height are usually the most common to evaluate the results of planting and to serve as a basis for decisions for new plantings. Many studies have evaluated the average values of these variables in relation to GS. However, there is a lack of studies assessing not only the mean, but also the distribution of these data in relation to GS at older ages, such as by application of

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probability density functions (PDF), which provide more detailed information regarding the structure of the forest, to enable more efficient planning of existing resources (DEBASTIANI et al., 2019).

Another way to address this theme is to consider the correlation of DBH with height in plantations with advanced age and analyze them through multivariate statistics. This enables observations that often do not occur when using univariate analysis, since an analysis with coexistence of these variables can provide more answers about the total effect of treatments. Based on these gaps, the objective of this work was to evaluate the influence of growing spaces of 4, 8 and 16 m^2 in relation to DBH, height, health and trunk quality in *Pinus taeda* plantations at 35 years of age.

MATERIAL AND METHODS

The study was carried out in an experimental area planted with *Pinus taeda* located in the municipality of Campo Belo do Sul (Santa Catarina), in the southern plateau region of the state, at approximate altitude of 900 m. According to the Köppen classification, the climate is *Cfb* type, mesothermal, humid subtropical, with cool summers, without a distinct dry season and with frequent frosts (ALVARES et al., 2013). The average annual rainfall is 1,555 mm, and the average monthly temperatures range from 11.5ºC to 21.0ºC (WREGE et al., 2012). The region predominantly has nitosols and cambisols (DORTZBACH et al., 2016).

The stands were planted in 1984, with control plots having different densities, to evaluate development without interference. For the preparation, the original forest vegetation was burned, and soil grading was performed. Bare root seedlings were transplanted at 6 months of age. Cultural treatment and ant control were performed in the first three years after planting. No pruning was performed.

The experiment was implemented in two replications, in which the treatments were three planting densities, defined as 2500, 1250 and 625 ha^{-1} (Table 1). Each plot has an area of 2000 m². Measurements were performed in the central part of the plot, with a useful area of 1000 m². The present work is based on data collected in 2019, when the trees were 35 years old, disregarding the development since planting. In this year, plot 2, with the lowest planting density, had already been submitted to shallow cutting, so only one repetition was performed for this planting density. The diameters at breast height (DBH, 1.3 m) were determined with a tape measure, and the total height (Ht) was measured with a vertex clinometer. Tree health (TH) was classified with values from 1 to 3 (TH) and trunk quality (TQ) was ranked according to the recommendations of the Brazilian Forest Service, disregarding standing dead trees (Table 2).

TABLE 1 - Distribution of the planting densities of the experiment.

Planting density (trees ha^{-1})	Starting density (trees ha^{-1})	Spacing (m)	Number of trees measured
625	625	5.0 x 3.2 m	52 (1 repetition)
1250	1250	2.5 x 3.2 m	117 (2 repetitions)
2500	2500	2.5 x 1.6 m	131 (2 repetitions)

TABLE 2 - Classification of tree health and trunk quality.

Tree health (TH)	Trunk quality (TQ)
1 - Healthy, without apparent defects or asymptomatic	1 - Trunk without apparent defects
2 - Initial stage of deterioration by pests and/or diseases	2 - Slightly cooked, but cylindrical and devoid of considerable ramifications up to 30%
3 - Advanced stage of deterioration by pests and/or diseases in the commercial trunk	3 – Trunk with pronounced tortuosity or bifurcation

The criteria for tree health were 1 – no apparent defects of asymptomatic; 2 – initial stage of deterioration, with up to 30% of the trunk and/or crown affected; and 3 – advanced stage of deterioration. The trunk quality also had three classifications: 1 – trunk without defects, and branches only near the crown; 2 – branches composing 10 to 30% of the tree; and 3 – trunk with pronounced tortuosity or bifurcation.

To determine the dominant diameter (Ddom) and dominant height (Hdom), we used the interval between 100 trees with the largest diameter and greatest height, respectively, per hectare of each planting density. Since the planting densities were evaluated in an area of 1000 m^2, the 10 tallest trees and the 10 thickest trees were used. Analysis of variance was performed for DBH and height and significance were verified. The Tukey test was performed to compare the means of planting densities. For a more detailed analysis of the data distribution, the variables DBH and total height (Ht) were tested separately in the following probability density functions (PDF): Gamma (three parameters); Normal; and Weibull (three parameters).

The ability of the PDFs to describe the evaluated characteristics of the planting was evaluated. The probabilistic function that presented the best performance according to the Kolmogorov-Smirnov test was selected, with a probability level of 99% for each variable, using the R Core Team software (2021). Then simple linear regression analysis was performed between the planting densities to establish the coefficient of determination between the means. After the correlation was verified, the multivariate analysis of variance (MANOVA) and discriminant analysis were performed considering the correlations between the variables, using the SPSS software (2009). The data were used to compute descriptive statistics of the distribution of DBH and Ht frequencies, into high, medium and low density. For tree health (TH) and trunk quality (TQ), the occurrence of each characteristic was compared through percentages in Excel spreadsheets for the mean data and for dominant height.

RESULTS AND DISCUSSION

Due mainly to competition between individuals, but also other natural factors that commonly occur in plantations, such as lightning strikes, animal action and strong winds, among others, self-thinning occurred, and the initial planting density was lower at the end of the experiment (Table 3). Although mortality is not accurate regarding its individual location, the mean growing space (GS) was considered at 35 years of age to better understand the area available to each individual. The planting density of 625, which started with ¼ of the individuals, compared to the planting density of 2500, presented survival approximately 2.7 times higher. When comparing the initial GS with that found at 35 years of age, there was an increase of 282% for 2500 density per hectare, 127% for the 1250 density and 39% for the 625 one. These increases occurred due to mortality, which indicates that survival was directly related to the density in this experiment.

TABLE 3 - Comparison of density and growing space (GS) of *Pinus taeda* at early stage and at 35 years of age, and tree survival.

Planting density (trees ha^{-1})	Initial GS (m^2)	Final density (trees ha^{-1})	Average GS 35 years old (m^2)	Surv (%)
2500	4	655	15.3	26
1250	8	550	18.2	44
625	16	450	22.2	72

Surv = survival.

Harms et al. (2000), in a study of 34-year-old trees of the same species, without thinning located in Hawaii, identified 53%, 81%, 85% and 97% survival for stands with 3.2 m^2, 5.8 m^2, 9.0 m^2 and 13.7 m^2 of GS respectively. The authors also observed that canopy closure occurred in the 4th year for the trees with lower GS, and only in the 11th year for trees with higher GS, which resulted in a lower number of suppressed individuals and less competition for light as the GS increased. These results are similar to those found in this study and help explain the other characteristics studied for *P. taeda* at 35 years of age planted southern Santa Catarina.

The trees had increasing DBH values as the GS increased (Table 4). The mean planting densities differed from each other at 5% significance. For the analysis of variance of the variable DBH, the planting densities differed at 5% significance.

TABLE 4 - Descriptive statistics of DBH of *Pinus taeda* trees aged 35 years with three planting densities.

DBH (cm)	Planting density		
	2500	1250	625
Average	35.5[a]*	8.6[b]	5.6[c]
Standard error	0.6	0.6	1.0
Median	34.3	37.5	46.3
Mode	28.0	38.2	47.0
Standard deviation	6.9	6.4	7.4
Sample variance	47.1	40.5	54.2
Kurtosis	0.3	0.2	0.8
Asymmetry	0.7	0.6	0.1
Minimum	21.6	26.4	31.2
Maximum	57.0	56.5	65.0

*Averages followed by the same letter do not differ statistically from each other at 5% probability.

TABLE 5 - Analysis of variance for the variable DBH of *Pinus taeda* trees aged 35years with three planting densities.

Sources of variation	d.f.	MS
Treatments	2	1876.359**
Waste	297	45.71**
Total	299	

d.f.= degrees of freedom, MS = mean square.

These results indicated higher frequency in classes with higher values. The highest planting density was associated with diameters between 20 and 60 cm, while the density of 1250 was associated with diameters of 25 to 60 cm, and the density of 625 trees per hectare was associated with diameters of 30 to 65 cm (Figure 1). Samuelson et al.

(2010), in a study with *P. taeda* at 47 years of age in Hawaii, also found higher frequency in the classes with higher DBH values according to the increase in GS, which ranged from 1.8 m^2 to 3.7 m^2.

The initial GS values (4 m^2, 8 m^2 and 16 m^2) influenced the average DBH, with 28.3% more growth of the trees with the greatest GS when compared with the smallest space. This differs from the findings of Inoue et al. (2011), in an experiment located in the Brazilian state of Paraná with *P. taeda* at 7 years of age, in which growing space greater than 12 m^2 had no influence on the average DBH. This difference is due to the age of the trees in the two studies, because at 7 years the demand for growing space is still small. In comparison with the results of this study, Cardoso et al. (2013), analyzing *P. taeda* trees with age of 24 years, identified an 18% greater DBH with GS of 11 m^2 compared to the treatment with 3 m^2 in an experiment located in Paraná. Harms et al. (2000), analyzing 34-year-old trees, found 32.6% greater DBH for GS of 13.7 m^2 compared to the treatment with 3.2 m^2. Several studies have shown similar results, with greater growing space associated with larger DBH (ASSMANN, 1970; LEITE et al., 2006).

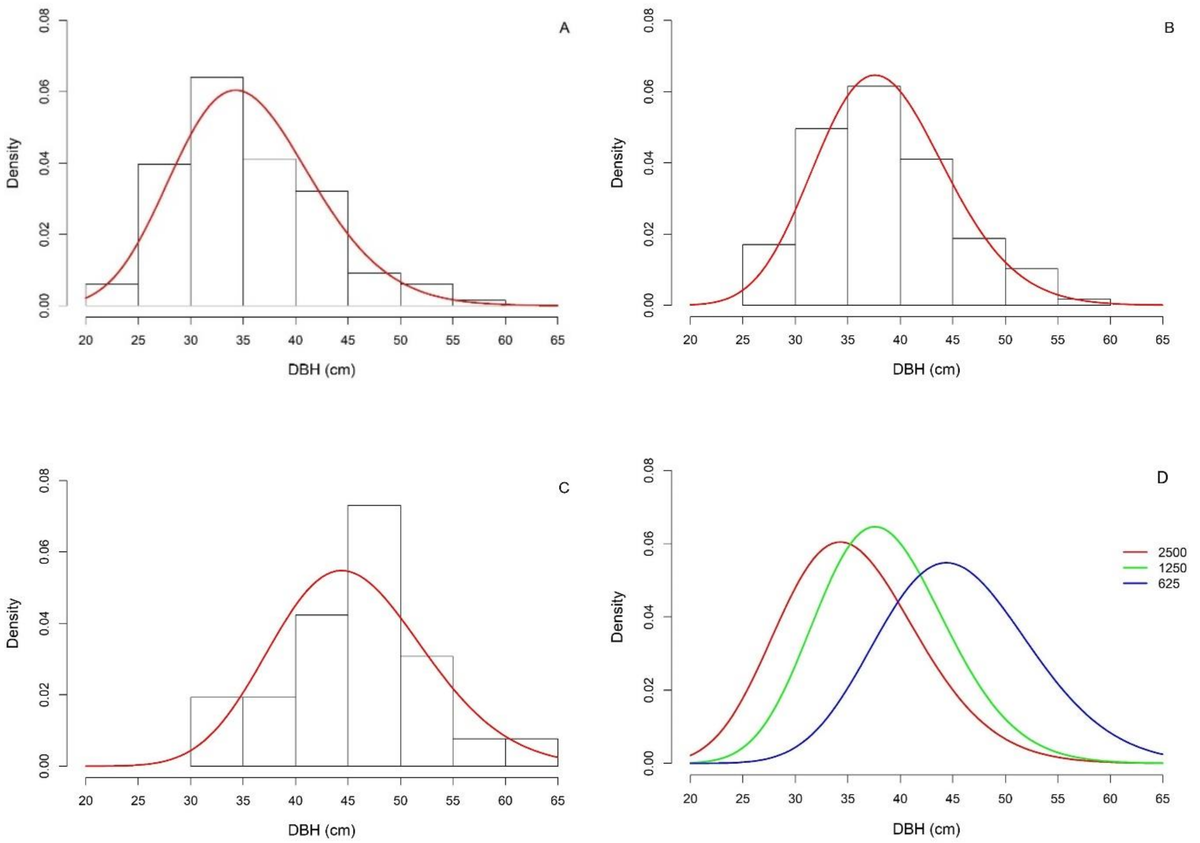

FIGURE 1 - Distribution and histogram of DBH frequency of a *P. taeda* plantation at 35 years of age. Where: A: planting density 2500, B: planting density 1250; C: planting density 625; D: probability distribution curves of planting densities 2500, 1250 and 625.

The probability distribution that presented the best fit to the DBH data set was the Gamma (Table 6). The three planting densities showed positive asymmetry for the DBH data, but as the GS increased, the asymmetry value decreased, with planting density 625 approaching symmetry. The three planting densities presented leptokurtic curves, with high peak values.

TABLE 6 - Distribution functions used and adhesion test for DBH of *P. Taeda* trees at 35 years, with three planting densities.

Planting density	Distribution	Parameters	Kolmogorov Smirnov
2500	Gamma	α=28.1735001 β=0.7927675	0.0644
1250	Gamma	α=38.2795913 β=0.9919629	0.0512
625	Gamma	α=38.3480528 β=0.8414325	0.1036

According to the results presented in Table 7, planting densities 2500 and 1250 had higher numbers of individuals (75% and 61%, respectively) in the range of 20 to 40 cm of DBH, a range that is located at the mean of the two planting densities. For 625, which had an average DBH of 45.6 cm, the planting density resulted in 74% of the curve area being located between 40-60 cm for DBH. An inverted trend was observed as a function of density, which increased in frequency in the upper classes for low density and decreased to high density, with intermediate values for medium density. This was repeated when comparing the dominant diameters (Ddom), obtained through the range of 100 trees with the largest diameter per hectare, in which the planting density of 625 presented a higher frequency (19.6%) of individuals with the dominant diameters, followed by the planting density of 1250 with 17% and finally the planting density of 2500, which presented 13% of individuals with dominant height.

TABLE 7 - Frequency by diameter class for *Pinus taeda* at 35 years of age, in three planting densities.

DBH (cm)	Frequency per diameter class (%)		
	2500	1250	625
[0-20)	0.4	0	0
[20-40)	75	60.7	23
[40-60)	24.4	39	73.6
Ddom 2500 (42.4-57)	12.8	-	-
Ddom 1250 (44.3-56.5)	-	17.5	-
Ddom 625 (51.5-65)	-	-	19.6

The three planting densities did not appear to be influenced by growing space (Table 8). Although the mean height increased as the GS increased, the means of planting densities 2500 and 625 showed no statistical difference at 5% significance by the Tukey test. For the analysis of variance of the variable DBH, the planting densities differed from each other, also at 5% probability of error (Table 9).

TABLE 8 - Descriptive statistics of height of *Pinus taeda* trees with 35 years of age, with three planting densities.

Height (m)	Density		
	2500	1250	625
Average	35.7^{a}	34.1^{b}	36.4^{a}
Standard error	0.3	0.3	0.4
Median	35.5	34.5	37.0
Mode	35.4	36.8	38.0
Standard deviation	3.3	3.4	2.7
Sample variance	10.6	11.7	7.5
Kurtosis	0.7	0.1	0.9
Asymmetry	-0.3	-0.5	-0.9
Minimum	19.0	17.7	13.0
Maximum	24.7	24.5	28.5
Average	43.7	42.2	41.5

*Averages followed by the same letter do not differ statistically from each other at 5% probability.

TABLE 9 - Analysis of variance for height of *Pinus taeda* trees with age of 35 years, with three planting densities.

Source of variation	d.f.	MS
Treatments	2	120.17**
Residual	297	10.48
Total	299	

d.f.= degrees of freedom, MS= mean square.

The most frequent height range in meters was close for the three planting densities (Figure 2). However, when considering the total amplitude, the planting density of 625 presented the lowest value, which resulted in greater homogeneity of the individuals.

A different result was found by Inoue et al. (2011) with 7-year-old *Pinus taeda* trees, in which smaller growing spaces resulted in greater average height. This fact can be explained by the theory, developed by Binkley (2004), by which dominance declines after a certain age of a stand. It should also be taken into account that the tree age was high for Brazilian production patterns, so the peak of self-thinning by competition had already occurred, with mortality mainly of the trees from the lower strata, with stagnation of height growth. Leite et al. (2006), in a study with different densities of *P. taeda*, located in Santa Catarina, concluded that the GS had little effect on the height at 14 years, and larger spaces tended to present growth stagnation at 11 years. Cardoso et al. (2013) and Harms et al. (2000) also found no statistical difference in the mean height for treatments with different growing spaces at 24 and 34 years of age, respectively, in line with the results of this study.

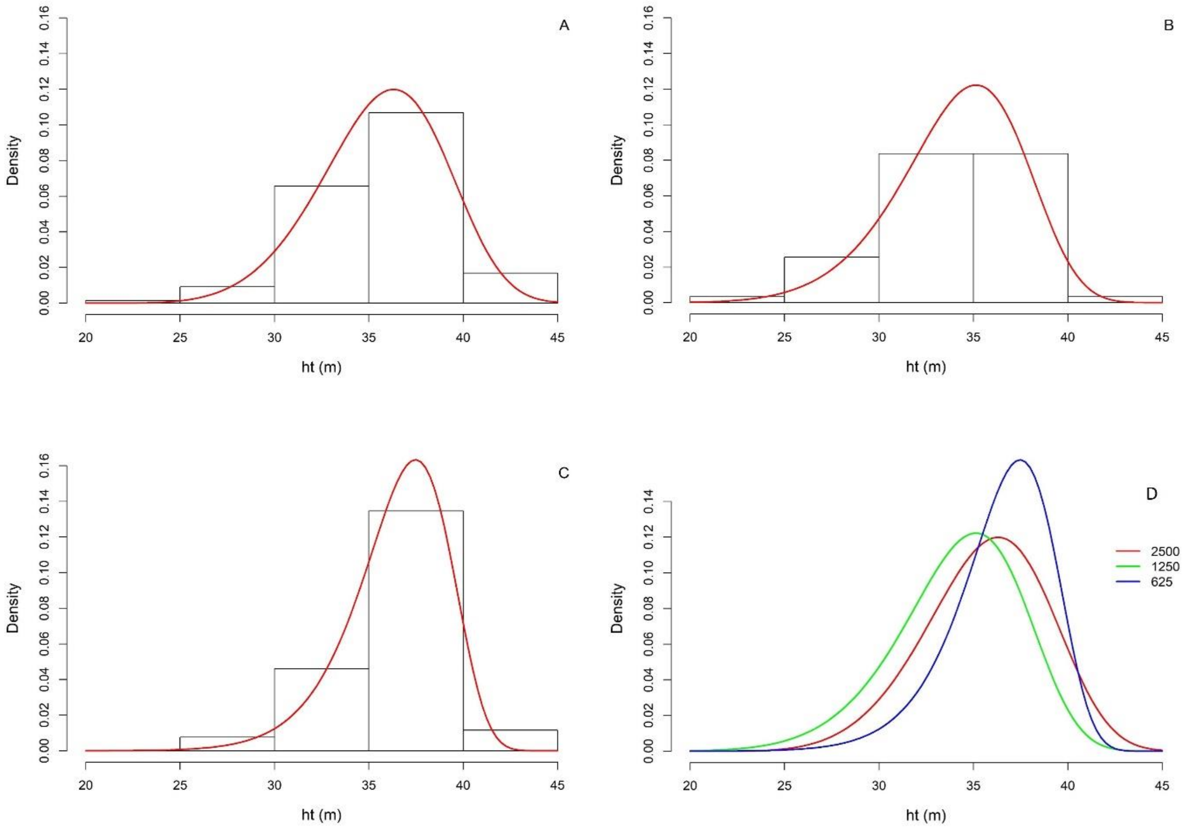

FIGURE 2 - Distribution and histogram of frequency of the height of *Pinus taeda* trees at 35 years of age with three densities. Where: A: planting density 2500, B: planting density 1250, C: planting density 625, D: probability distribution curves of planting densities 2500, 1250 and 625.

The probability distribution that presented the best fit to the height dataset was the Weibull (3P) (Table 10). With respect for the distribution of heights, there were differences between the three planting densities. There was an increase of asymmetry with the increase of GS, with asymmetry values of -0.3, -0.5, and -0.9 for planting densities 2500, 1250 and 625, respectively. The increase of growing space enabled a greater number of individuals to reach height above average, in which 625 stood out by presenting the strongest asymmetry. Among the three planting densities, that of 1250 was associated with the highest percentage (11%) of individuals located in the lowest height classes (24-30 m and 30-35 m) (45%) (Table 11).

TABLE 10 - Distribution functions used and adhesion test for *Pinus taeda* tree height at 35 years, with three planting densities.

Planting density	Distribution	Parameters	Kolmogorov-Smirnov
2500	Weibull (3P)	α= 5.261395 β= 16.449387 γ= 20.506708	0.0304
1250	Weibull (3P)	α= 7.626977 β= 23.146856 γ= 12.407796	0.0454
625	Weibull (3P)	α= 16.3716580 β= 36.9298458 γ =0.6873907	0.0966

TABLE 11 - Frequency by height class of *Pinus taeda* trees at age 35, with three planting densities.

Height (m)	Frequency by height class (%)		
	2500	1250	625
[24-30)	5.3	11	2.2
[30-35)	34.7	45	25.6
[35-40)	51.1	42	67.8
[40-50]	8.7	2	6.2
Hdom 2500 (39-43.7)	15.5	-	-
Hdom 1250 (37.3-42.2)	-	17.4	-

When considering the two intervals of [35 - 50 m], the planting density of 2500 presented 60% of the individuals within these intervals, while for the density of 625, 74% were within these intervals. When comparing the frequencies for the dominant height class (Hdom) obtained from the 100 tallest trees per hectare, the planting densities showed increasing values, with planting density of 625 having the greatest percentage (21%) of individuals located in the dominant height class (38.6 m to 41.5 m). These results may be related to the higher GS available at this planting density, which provided more light to the trees, thus reducing suppression and resulting in individuals with more uniform heights.

When analyzing the relationship between the variables height and DBH, planting densities 2500 and 1250 presented moderate Pearson correlation coefficients (0.54 and 0.57). The planting density of 625 showed weak correlation (0.33) (Figure 3). The results of the correlations between moderate and weak may be related to the age of the trees. Dias et al. (2016) and Lima (2010), also studying *P. taeda*, identified a reduction in the correlation between height and DBH and increasing tree age. The weak correlation presented by planting density 625 can be explained by the greater availability of light to individuals, which favors greater girth increment, and a lesser need to grow tall to seek light in the first years after planting (Inoue et al., 2011).

Although not presenting high correlations, the results confirmed correlation between height and DBH, making it appropriate to apply multivariate analysis. Since these variables have a relationship, it is important to take this correlation into account when discriminating the planting densities. One way to do this is to apply discriminant analysis. When analyzing the data using MANOVA, a significant difference was identified between the groups (Table 12). The four applied tests indicated that the null hypothesis was false, that is, growing space had an effect on the means of the variables DBH and height. The most important variable in discriminant function 1 was DBH and in function 2 it was height (Table 13). Therefore, the variable that most discriminated the growing space was DBH. This result is associated with intraspecific competition, which increases as the space available for the development of trees declines, something that occurs more intensely in the first years after planting. According to Inoue et al. (2011), the average values of DBH at 7 years for *P. taeda* increasing directly with rising growing space. Conversely, smaller growing space limits the average and individual growth of trunk diameter.

According to Figure 4, planting density of 625 presented the highest values for DBH (x-axis) and height (y-axis) when considering the correlation between them. The planting density that presented the lowest values for the two variables together was 1250.

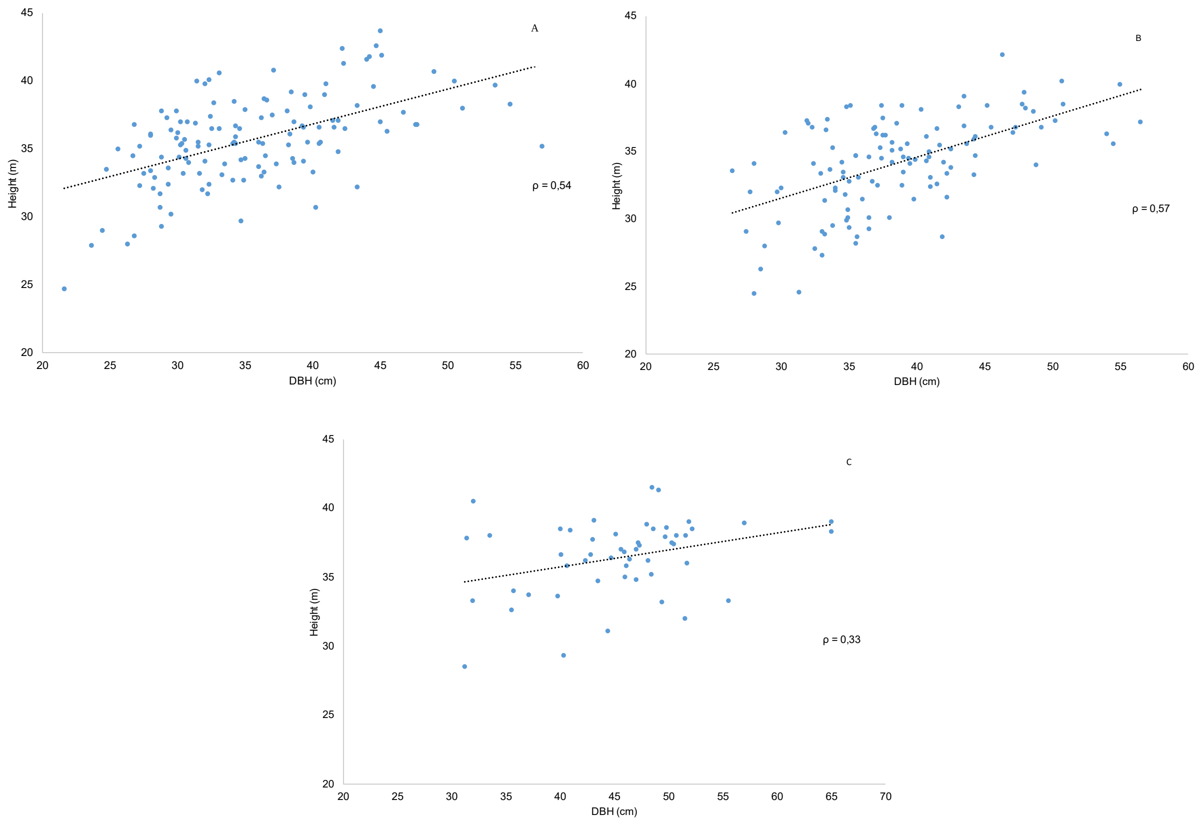

FIGURE 3 - Height, trend curves and correlations as a function of *pinus taeda* DBH at age 35, with three planting densities.

TABLE 12 - Results of multivariate analysis for planting densities of 2500, 1250 and 625 with the variables DBH and height, of *Pinus taeda* at 35 years.

Effect		Value	F	d.f hypothesis	Error d.f.	Sig.
Spacing	Pillai's Trace	0.330	29.320	4	594	<0.001
	Wilks' Lambda	0.689	30.335	4	592	<0.001
	Hotelling's Trace	0.425	31.349	4	590	<0.001
	Roy's Largest Root	0.348	51.652	2	297	<0.001

F = Factor, d.f. = degrees of freedom, Sig. = significance level.

TABLE 13 - Correlations between groups in the set between discriminant variables and standardized canonical discriminant functions.

Array of structures		
Discriminating function	1	2
Dbh	0.858*	0.514
Height	0.001	1.000*

*Greatest absolute correlation between each variable and any discriminant function.

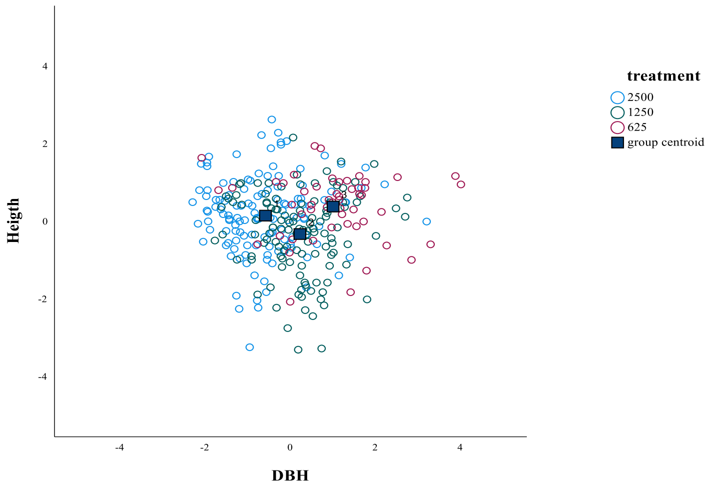

FIGURE 4 - Canonical discriminant functions of different densities of *Pinus taeda* at age of 35 years, with three planting densities.

With respect to phytosanitary quality (Figure 5), planting densities of 2500 and 625 presented close values, of 88% and 83%, respectively, classified as healthy and without apparent damage. With planting density of 1250, 42% of the individuals were in the initial stage of deterioration, which we believe was an isolated fact caused by insect attack in the growing area. The presence of wood wasps, whose action results in exudation and damage to the bark, was identified only in a repetition of this density, which appears not to be related to spacing.

The trees classified as having dominant height presented the best health, with emphasis on planting density 1250, in which the incidence of individuals in the initial stage of deterioration was only 15% and there were no trees with advanced stage of deterioration. According to Gaiad et al. (2003), attacks of *Sirex noctilio* (wood wasp) occur more intensely in denser pine-like stands, with attack starting in trunks with smaller diameters. Thus, at the lowest planting density, the incidence of the wasp attack was lower than that reported by Gaiad et al. (2003).

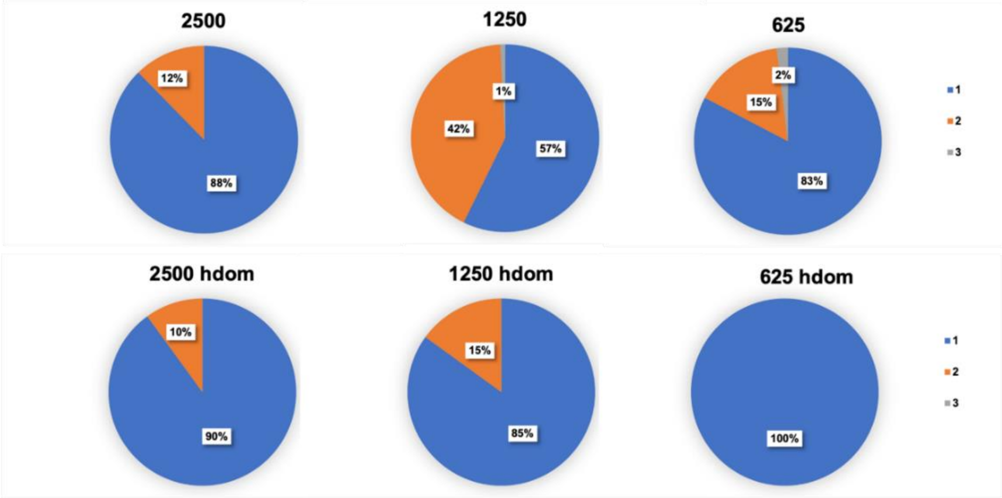

FIGURE 5 - Classification of health of *Pinus taeda* trees with three planting densities at 35 years of age located in the south of Santa Catarina. Where: 1 - healthy, without apparent defects, 2 - initial stage of deterioration by pests and/or diseases, 3 - advanced stage of deterioration by pests and/or diseases.

With regard to trunk quality (Figure 6), the planting densities showed increasing values of classification 2 and 3 with increasing GS. Of the trees with planting density of 2500, 45% had healthy and straight trunks, while the percentages for planting densities 1250 and 625 were 28% and 17%, respectively, of individuals in classification 1. Pelissari et al. (2013) observed that with advancing age and consequent canopy closure, there was improvement in the straightness of trunks and reduction of branches of *Tectona grandis* aged from 3 to 10 years. Comparison of those results with our findings indicates the effect of competition. According to Pelissari et al. (2013), the reason is that with more growing space, trees receive greater light incidence and for a longer period before the canopy closes, allowing greater insolation on the bark, generating greater production of branches and bifurcations, and consequently reducing the stimulus for rectilinear growth.

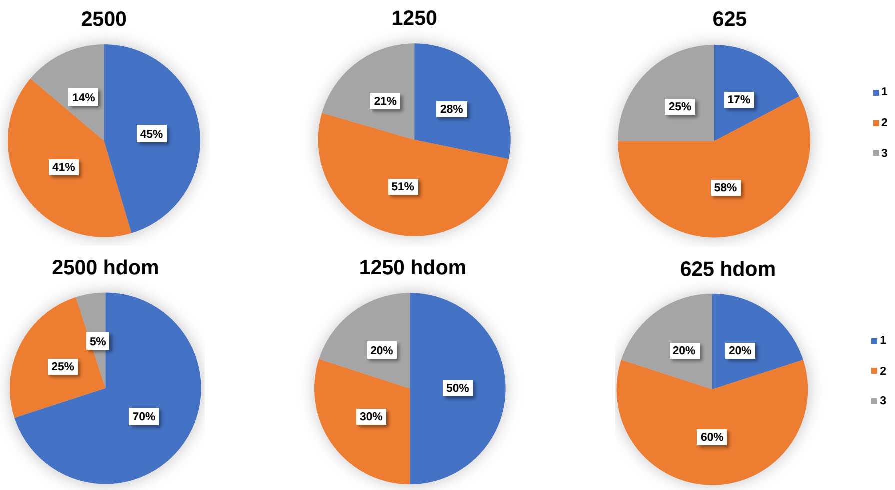

FIGURE 6 - Trunk quality classification of *Pinus taeda* at age of 35 years under three densities located in southern Santa Catarina. Where: 1 - trunk without apparent defects, 2 - trunk slightly crooked, but cylindrical and devoid of considerable ramifications, 3 - trunk with strong tortuosity or bifurcation.

Regarding trunk quality (Figure 6), the planting densities showed increasing values for classification 2 and 3 with increasing GS. Among the trees planted with density of 2500, 45% were healthy with straight trunks (classification 1), while these values were 28% and 17%, respectively, for planting densities of 1250 and 625. Sanquetta et al. (2003a), in a study of 12-year-old *P. taeda* trees in growing spaces ranging from 3 m^2 to 11 m^2, identified greater presence of branches and lower insertion height of first branches in stands with lower density.

As mentioned before, according to Pelissari et al. (2013), the reason is that with more growing space, trees receive greater light incidence and for a longer period before the canopy closes, allowing greater insolation on the bark, generating greater production of branches and bifurcations, and consequently reducing the stimulus for rectilinear growth.

Among individuals with dominant heights (Hdom), they also presented superior quality in relation to total individuals, mainly for planting densities of 2500 and 1250, which presented superior results, with 70% and 50% of trees having straight trunks without apparent defects. However, when comparing the planting density of 625, several factors impaired the shape or caused damage or other alterations, resulting in low trunk quality in relation to the other planting densities, with incidence of 60% of individuals with mild tortuosity, and 20% incidence of bifurcations and branches greater than 30% of the length of the trunk.

Future research can apply economic analysis to trees with various growing spaces for better commercial comparison.

CONCLUSIONS

The growing space directly affected the average diameter at breast height.

Gamma and Weibull functions were adequate to discriminate the variables.

Greater growing space maximized the variables when considering height and DBH together.

Smaller growing space favored better trunk quality.

The dominant individuals in height had superior health and trunk quality compared to the others.

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