Ciência Florestal, Santa Maria, v. 28, n. 3, p. 1217-1229, jul.- set., 2018
ISSN 1980-5098 DOI: http://dx.doi.org/10.5902/1980509833351

Trema micrantha (L.) Blume. IN PLANTATIONS FOR ECOLOGICAL RESTORATION: EARLY DEVELOPMENT IN THE BRAZILIAN SUBTROPICAL FOREST

Trema micrantha (L.) Blume. EM PLANTAÇÕES PARA RESTAURAÇÃO ECOLÓGICA: DESENVOLVIMENTO INICIAL NA FLORESTA SUBTROPICAL BRASILEIRA

Oiliam Carlos Stolarski[1] Mauricio Romero Gorenstein[2] Marcos Lubke[3] Lucas Lubke[4] Paula Helena Pereira O'Connor[5] Fernando Campanhã Bechara[6]

ABSTRACT

The understanding of silviculture of native species in a determined region is fundamental for the selection of more appropriate species for using in ecological restoration. *Trema micrantha* (Cannabaceae), a pioneer species which is widely distributed, shading and attractive to birds, is intensively planted in restoration projects of the southeastern Brazilian Atlantic Forest. In order to get information regarding to the performance of this species in subtropical forests (subject to the yearly frosts), we analyzed its early growth in a planting carried out with 70 native tree species in 3 x 2 m spacing in four plots of 40 x 54 m. Semiannually, we collected data of 72 individuals of *Trema micrantha*. These data were statistically analyzed using the Statistical Software Assistat-beta submitted to Tukey test ($p<0.05$) and graphically described by R. *Trema micrantha* showed excellent performance at 3.5 years of age in root collar diameter (12.01 ± 5.24 cm), total height (5.95 ± 1.44 m), crown projection area (22.56 ± 11.26 m²) and crown volume (61.34 ± 37.46 m³), enduring severe frosts with a yearly survival rate of 78%. Based on the results obtained, and considering that this species has broad natural distribution, we recommend its extensive use also in forestry restoration projects in the subtropical regions of Brazil.

Keywords: tropical forestry; early growth; reforestation; pioneer species.

RESUMO

O conhecimento da silvicultura de espécies nativas em determinada região é fundamental para a escolha de espécies mais adequadas à utilização em plantios de restauração ecológica. *Trema micrantha* (Cannabaceae), espécie pioneira de ampla distribuição geográfica, sombreadora e atrativa de avifauna, é intensivamente plantada em projetos de restauração da Mata Atlântica na região sudeste brasileira. A fim de se obter informações referentes à atuação desta espécie em florestas subtropicais sujeitas às geadas anuais, analisou-se o seu crescimento inicial na região sudoeste do estado do Paraná, sul do Brasil. Em um plantio realizado com 70 espécies arbóreas nativas sob espaçamento 3 x 2 m em quatro parcelas de 40 x 54 m, coletaram-se dados semestrais de 72 indivíduos de *Trema micrantha*. Os dados foram analisados estatisticamente utilizando o *software* Assistat-beta, submetido ao teste de Tukey ($p<0.05$) e descritos graficamente através do *software* R. *Trema micrantha* apresentou excelente desempenho aos 3,5 anos de idade com diâmetro de

1 Engenheiro Florestal, Analista de Pesquisa da empresa Casa da Floresta Ambiental SS, Av. Joaninha Morganti, 289, Monte Alegre, CEP 13415-030, Piracicaba (SP), Brasil. oiliam@casadafloresta.com.br
2 Engenheiro Florestal, Dr., Professor efetivo da Universidade Tecnológica Federal do Paraná, Estrada para Boa Esperança, km 04, CEP 85660-000, Dois Vizinhos (PR), Brasil. mauriciorg@utfpr.edu.br
3 Engenheiro Florestal, Pós-graduando MBA em Manejo Florestal de Precisão, Universidade Federal do Paraná, Rua dos Funcionários, 1540, CEP 80035-050, Curitiba (PR), Brasil. marcoslubke@hotmail.com
4 Engenheiro Florestal, Consultor na empresa Utflorestal, Universidade Tecnológica Federal do Paraná, Estrada para Boa Esperança, km 04, CEP 85660-000, Dois Vizinhos (PR), Brasil. lucas_lubke@hotmail.com
5 Engenheira Florestal, Consultora na empresa Big Tex Tree Nurseries, Highway 6 South, 9755, Sugar Land, CEP 77498-000, Houston (TX), USA. paula8@hawaii.edu
6 Engenheiro Florestal, Pós-doutor, Professor efetivo da Universidade Tecnológica Federal do Paraná, Estrada para Boa Esperança, km 04, CEP 85660-000, Dois Vizinhos (PR), Brasil. bechara@utfpr.edu.br

Recebido para publicação em 29/11/2015 e aceito em 10/08/2017

colo (12,01± 5,24 cm), altura total (5,95±1,44 m), área de projeção de copa (22,56 ±11,26 m²) e volume de copa (61,34 ± 37,46 m³), suportando severas geadas anuais com sobrevivência de 78%. Baseando-se nos resultados obtidos e considerando que se trata de uma espécie de ampla distribuição natural, seu uso extensivo é também recomendado em projetos de restauração florestal em regiões subtropicais do Brasil.
Palavras-chave: silvicultura tropical; crescimento inicial; reflorestamento; espécies pioneiras.

INTRODUCTION

Forestry information on native species at the regional level is essential to the planning of forest restoration projects and it may prescribe the use of pioneer species adapted to local soil and climate conditions that initiate the establishment of the future forest canopy (KRAMER, 1986). The initial performance in size and crown covers are important factors to consider when choosing tree species for restoration work in a particular region (PARROTTA, 1992; GUARIGUATA; RHEINGANS; MONTAGNINI, 1995; HOLL et al., 2000); especially in subtropical forests subject to the influence of annual frosts that cause the burning of seedlings and young samplings. However, the dendometric data during the initial development phase of native tree species in natural and planted forests are scarce in most Brazilian ecosystems (CHAMBERS; HIGUCHI; SCHIMEL, 1998; CHAGAS et al., 2004), which complicates the planning of restoration based on the choice of the species to be planted.

Trema micrantha (Cannabaceae) is a pioneer tree, shading and attractive to fauna. It occurs widely in various types of environments (except in highly humid ones), which explains its vast natural distribution throughout the region stretching from Mexico and South Florida, through Central America and Brazilian states, especially in the Atlantic Forest Biome (RIBAS; KAGEYAMA, 2006; SPLINK, 2015). *Trema micrantha* is one of the first species to colonize gaps and degraded areas, usually in aggregated populations. Its flowers are pollinated primarily by bees and other insects (VILLANUEVA, 2002; YAMAMOTO; KINOSHITA; MARTINS, 2007), and occasionally the wind (KINOSHITA et al., 2006). The seeds dispersion is zoochoric and the fruits are greatly appreciated by a wide variety of animals, such as birds, bats and primates (WHEELWRIGHT et al., 1984; KINOSHITA et al., 2006; RIBAS; KAGEYAMA, 2006; ANDREANI et al., 2014). When into the soil, its seeds can remain viable for a long period of time in the seed bank (GROMBONE-GUARATINI; RODRIGUES, 2002).

Trema micrantha is strongly recommended to accelerate the colonization of large open areas in the restoration of Brazilian Tropical Atlantic forest programs in the southeastern Brazil, such as forest edges and large clearings (MARTINS; RODRIGUES, 2002; RODRIGUES; MARTINS; BARROS, 2004). It is a pioneer species that usually presents abundance (SÁ, 2002; RODRIGUES; MARTINS; BARROS, 2004). But there is a lack of studies of its performance in subtropical forests, which hampers the recommendation of the species and its implication of use, especially in areas where frosts are common. Our study aimed to analyze the performance of this species up to 3.5 years old on an ecological restoration plantation in the southern Brazil, aiming to identify the pace and the initial growth rate, as well as understand the possible kind of behavioral changes along its establishment phase.

MATERIAL AND METHODS

The experimental area is located at UTFPR (Federal Technological University of Paraná), in a farm in the municipality of Dois Vizinhos, state of Paraná, southern Brazil, on the geographical coordinates 25°41’37”S and 53°06’07”W; altitude ranging from 495 to 504 m. The region predominant soil type is Dystroferric Red Latosol (EMBRAPA, 2006). The climate is subtropical, Cfa (Köppen), with no dry season, four distinct seasons, an average temperature of the coldest month less than 18°C and an average temperature of the warmest month greater than 22°C (ALVARES et al., 2014). There is occurrence of at least one frost each two years (CARAMORI et al., 2001), typically in the month of July, and at early times in the months from May to June, or late from August to early September. The average annual rainfall is 1.953 mm (MACHADO et al., 2013). The region was originally occupied by *Araucaria* forests with the influence of a Semideciduous Seasonal Forest.

After the soil preparation through mechanized opening planting furrows in December 2010, the establishment of seedlings of 70 native tree species in rows of filling and diversity species was carried out, as proposed by Rodrigues et al. (2009; 2011), under spacing 3 x 2 m, in four plots of 40 x 54 m. We planted 18 seedlings of *Trema micrantha* (30-50 cm tall) in each plot. A total of 72 individuals were evaluated. Semianually, the plots were kept clean by mechanical mowing followed by herbicide applications (glyphosate) and ants control by formicide. The planting was carried by using 360 g of NPK (5-20-10) plus 2.5 L of hydrogel seal in the pits. Seedlings were protected by cardboard mulching and received annual topdressing with 40 g of urea per plant. Replanting (of dead seedlings) was made at 3, 5, 12 and 24 months after the implementation date of the experiment.

Data collection was carried out every six months, considering the following parameters: survival (%), total height (m), root collar diameter (cm), crown length (m) and canopy projection area (m^2). There were two cross-cutting measures of crown diameter that were transformed into crown projection area by the ellipse area formula: $sc\ (m^2) = x.y.\pi/4$, in which x and y are the diameter of the canopy (m). The crown volume was estimated as an elliptical cylinder, multiplying the area by length of the crown: $vc\ (m^3) = sc.cc$. According to Montgomery and Chazdon (2001) this method overestimates the volume of the real crown, but has an informational potential of the estimate of the quantity of vegetation in the canopy.

The occurrence of frost was characterized by minimal temperature data obtained from the university Climatological Station belonging to the network INMET (National Institute of Meteorology), located about 800 m from the experimental area under coordinates 25°41’38”S and 53°6’8”W. The effects of frost in the development of the species have been verified through dendrometric variables, including the assessment of regrowth formation held 52 months after planting (April 2015), which was the number of individuals who issued shoots of adventitious buds below 1.3 m high.

Data was analyzed statistically using the Statistical Software 7.7 Assistat-beta (2015) and described graphically using the R software (2015). The ANOVA and Tukey tests, with 5% of probability, was held for the dendrometric variables.

Three regression equations presented in Table 1 were used to study the growth rate in root collar diameter, total height and crown area. Adjustments were made through the R software (2009), in which the initial values of the algorithm parameters, nonlinear regressions of mathematical models, were obtained from the minimum and maximum values considered possible. The best equation was selected by examining the coefficient of determination, standard error of estimate (percentage) and waste distribution analysis.

TABLE 1: Mathematical models tested for adjustment of growth data of *Trema micrantha,* 3.5 years old, Dois Vizinhos – PR state, Brazil.
TABELA 1: Modelos matemáticos testados para ajuste dos dados de crescimento de *Trema micrantha* aos 3,5 anos de idade no município de Dois Vizinhos - PR, Brasil.

Model	Mathematical function	Growth rate
Chapman-Richards	$W = A\,(1 - b\,e^{-kt})$	$\partial W/\partial t = k\,(A - W)$
Logistic	$W = \dfrac{A}{1 + b\,e^{-kt}}$	$\partial W/\partial t = \dfrac{k\,W\,(A - W)}{A}$
Gompertz	$\mathrm{W} = \mathrm{A}\,\mathrm{e}^{-be^{-kt}}$	$\partial W/\partial t = k\,W\,ln\left(\dfrac{A}{W}\right)$

Where in: *W* = organism size at time t; *A* = asymptotic value that the organism can achieve; *K* = relative measure of the growth rate of the organism; *B* = usually without biological significance, reflecting only the choice of time zero; *t* = age.

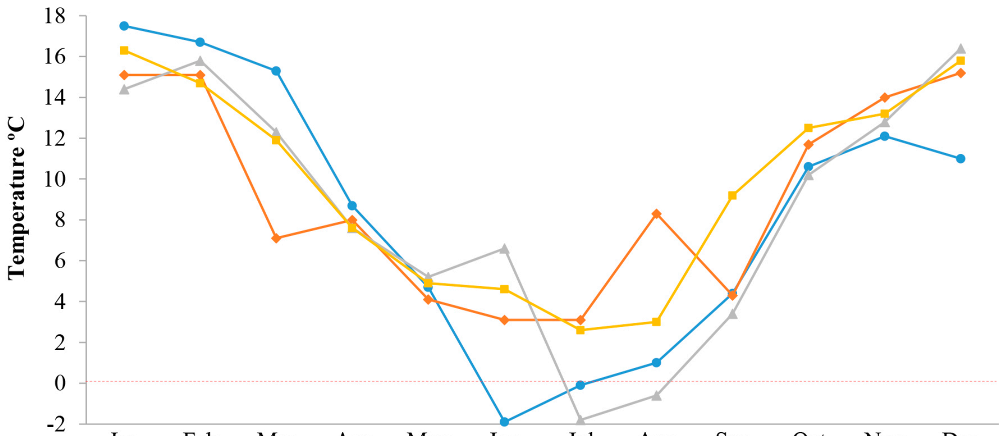
RESULTS AND DISCUSSION

Including the four replantings, the survival rate was 78.26%. It is noteworthy that the first replanting (three months) was due to the entry of cattle trampling and breaking off some seedlings, causing the death of only 1.38%. Max, Melo and Faria (2004) evaluated the behavior of native species in different spacing in a Semideciduous Seasonal Forest, and found a decrease in survival for *Trema micrantha* at the end of three years: 2 x 1 m = 68,57%; 2 x 2 m = 57,43%; 2 x 3 m = 51,43%. The authors assumed that for the study conditions, the species presented a short life cycle, initiating mortality from three years of age. Associated with this, competition with other pioneering species for canopy space may also have corroborated to this result.

Moraes et al. (2005) monitored the adaptation (survival rate) of native species one year after their planting, in Lowlands Atlantic Forest, and observed a survival rate from 61% to 97%. According to these authors, the lowest survival values found for the species are justified due to an exceptional period of flooding in the planted area, resulting from precipitation above the monthly average. The survival found by Alvarenga et al. (2016) for *Trema micrantha* ranged from 40% to 100% at 11 months of age. This variation was attributed to the soil, since the characteristics between the sites were different.

Elliott et al. (2003) suggested that the minimum acceptable rate of survival for any species in seasonal dry tropical forests should be 50% and considered excellent performers if their survival rate is 70% or greater. Knowles and Parrotta (1995) suggested that species with a survival rate of 75% should be selected for restoration plantings.

To categorize the mortality rate of trees in their initial establishment phase in the Brazilian subtropical region with frosts occurrence, Carvalho (1982) proposed the following levels of survival at seven years of age: high (≥ 70%), regular (≥ 50% ≤ 69%) and low (≤ 49%). Accordingly, our *Trema micrantha* survival rate (78.26%) was rated as high, denoting that it adapted well to the local restrictions. The species showed rusticity and the ability to survive the climate stress conditions (i.e. frosts); important features of colonizing species in degraded environments. It is assumed that the low temperatures and frosts recorded during the study period of winter (June-July 2011 and July-August 2013) have influenced the mortality rate and the development of *Trema micrantha* individuals (Figure 1).Weather events can cause a reduction in plant resistance and susceptibility to pathogen attacks (HIGA et al., 2000), acting indirectly in the death of some plants.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011	17,5	16,7	15,3	8,7	4,7	-1,9	-0,1	1,0	4,4	10,6	12,1	11,0
2012	15,1	15,1	7,1	8,0	4,1	3,1	3,1	8,3	4,3	11,7	14,0	15,2
2013	14,4	15,8	12,3	7,6	5,2	6,6	-1,8	-0,6	3,4	10,2	12,8	16,4
2014	16,3	14,7	11,9	7,6	4,9	4,6	2,6	3,0	9,2	12,5	13,2	15,8

FIGURE 1: Minimum temperatures (°C) recorded at the study site between the years 2011 to 2014. Data from the Meteorological Federal Technological University of Paraná station - Campus Dois Vizinhos.

FIGURA 1: Temperaturas mínimas (ºC) registradas no local de estudo entre os anos de 2011 a 2014. Dados provenientes da Estação Meteorológica da Universidade Tecnológica Federal do Paraná - Campus Dois Vizinhos.

Trema micrantha showed great performance in the early development: even with seven days of frost during the 2011 period, we recorded a significant increase in dimensional growth (Table 2). However, it is clear that the lower average growth values were obtained at 12 months, mainly for the variables root collar diameters and total heights. Note that reducing the rate of growth has strong relationship with the period of the lowest temperatures of the year, which certainly hampered the development of the species at this stage (KRAMER, 1986; TONINI; FINGER; SCHNEIDER, 2003).

TABLE 2: Trema micrantha dendrometric data at 3.5 years old in a plantation, Dois Vizinhos – PR state, southern Brazil.

TABELA 2: Dados dendrométricos de Trema micrantha aos 3,5 anos de idade de plantio no município de Dois Vizinhos - PR, sul do Brasil.

Variables	Time (months)													
	6		12		18		24		30		36		42	
dc (cm)	3.31	e	1.33	f	5.49	d	7.91	c	9.12	bc	10.54	ab	12.01	a
CV(%)	44.11		98.16		32.62		40.19		41.56		48.31		43.60	
ht (m)	1.53	e	0.82	f	3.08	d	3.91	c	4.65	b	4.21	bc	5.95	a
CV(%)	39.20		31.12		27.39		36.32		31.90		40.52		24.15	
sc (m^2)	1.12	e	0.21	e	6.03	d	12.08	c	17.61	b	10.05	c	22.56	a
CV(%)	89.68		82.91		54.98		59.56		60.75		68.16		49.92	
vc (m^3)	1.08	e	0.11	e	14.96	d	33.53	c	46.67	b	25.41	cb	61.34	a
CV(%)	123.82		111.51		71.17		77.45		68.54		77.45		61.07	
N	63		58		61		66		71		71		71	

Where in: dc = root collar diameter; CV (%) = coefficient of variation; ht = total height; sc = crown projection area; vc = canopy volume; N = number of individuals. Significant test at 5% probability ($p < 0.05$). The averages followed by the same letter within each variable are not statistically different from each other.

The frost may have damaged the apex of some plants, decreasing their heights, and also their average growth (VIEIRA; FEISTAUER; SILVA, 2003). Along with the loss of apical dominance, vegetative growth that is taken below the height where the damage occurs often promotes the development of more than one apical bud (HIGA et al., 2000). This phenomenon was evidenced in 77.46% of the total of 71 plants of *Trema micrantha*, reinforcing the idea that the species is not itself resistant, but resilient to frost due to its sprouting potential.

The emission of shoots modified the silvicultural behavior of the species that came to shade a larger area, showing that the shoots may even be considered beneficial, since the ability to cover and shade the soil are important factors to consider when choosing species to promote forest early succession (WISHNIE et al., 2007). It was statistically noted that *Trema micrantha* trees obtained their highest values of all the variables at 3.5 years of age. At this age, *Trema micrantha* trees can be regarded as established in the region. The height found six months after planting was already 1.53 m, but decreased to 0.82 m at 12 months of age, which is much lower than that one found by Nogueira (2015) for the same period (ht = 2.66 m), which was planted in a warmer and wetter rainforest. Alvarenga et al. (2016) obtained at 11 months of age, average height of just 0.32 m for *Trema micrantha* in plantations established in the highlands of Minas Gerais state. In our study, the height of the species at 36 months after planting was already 4.21 m (Table 2). In the same period, Moraes et al. (2005) evaluated the development of native tree species of a plantation conducted in lowland Atlantic rainforest, and observed that the height of *Trema micrantha* ranged from 6.81 to 7.53 m, surpassing other fast growing native species, such as *Alchornea triplinervia, Schinus terebenthifolius* and *Inga affinis*. It should be noted that in the year 2011 and 2013 of our study, frosts caused physiological damage to the individuals of *Trema micrantha*, which certainly inhibited the maximum expression of growth, both at 12 and 36 months after planting, justifying this difference with the values found in literature. Max, Melo and Faria (2004) under 2 x 1 m spacing, found an average height of 2.64 m for *Trema micrantha* at 36 months. These authors observed that the decrease in spacing tends to promote an increase in the height growth of *Trema micrantha*, since it is a pioneer species with high demand for light.

Regarding the root collar diameter, Sgarbi et al. (2012) found a diameter of 3.8 cm for *Trema micrantha* at six months of age, close to that registered in this study for the same period (dc = 3.31 cm). At 12 months of age the species presented a diameter of 1.33 cm, surpassing that found by Alvarenga et al. (2016), which ranged from 0.26 to 0.88 cm at 11 months. However, it remained lower than that found by Nogueira (2015) for the same period (dc = 8.48 cm). The diameter obtained at 42 months (dc = 12.01 cm) was close to the values mentioned by Moraes et al. (2005) at 36 months after planting, which varied between 13.2 and 15.7 cm. Pereira, Botelho and David (1999) evaluated the development of fast growing forest species at different site conditions and found distinct values for height, diameter and crown area for *Trema micrantha* at 39 months (ht = 1.7 to 6.3 m; dc = 4 to 16.2 cm; sc = 0.63 to 31.3 m²). The worst results were recorded in the sites with the highest water deficit and Litolic soil.

Nascimento et al. (2012) tested the influence of spacing on the growth of six native forest species at 22 months of age, in plantations of forest restoration in the Guandu River Basin. As a result, they also found that wider spacings resulted in higher growth rates. Among the evaluated species, *Schizolobium parahyba* showed higher growth in height (ht = 5.2 m) under 2 x 2 m spacing, and *Cordia* sp. under 3 x 2 m spacing presented diameter (dc = 16.26 cm) and crown area (sc = 18.34 m²) best values. Both species had better performance when compared to that obtained for *Trema micrantha* in this study at 24 months of age.

Ferreira et al. (2007) analyzed the growth of native tree species 155 months after planting, and found that *Trema micrantha* had a higher height growth than that registered for many other pioneer native species such as *Mimosa bimucronata*, *Senna multijuga*, *Myrsine ferruginea*, *Alchornea triplinervia*, *Myrsine umbellata, Croton urucurana* and *Schinus terebinthifolia*. According to the authors, the existence of compacted soils with higher resistance to penetration may have influenced the decrease in height growth for some species.

The average crown area projected at 3.5 years was 22.56 m² (Table 2), very similar to the 22.50 m² obtained by Leles et al. (2011) for a group of pioneer species. At 48 months after planting, the average crown area was three times higher than the planting spacing used, which was 6 m², thus resulting in a high efficiency at the intersection of crown and canopy formation. The canopy coverage provides the base for forest structure in the horizontal profile and protection against invasive grasses, and it is important for the establishment of the understory species (CHAZDON, 2003; CUSACK; MONTAGNINI, 2004; LAMB; ERSKINE; PARROTTA, 2005; ELLIOT; BLAKESLEY; HARDWICK, 2013). Therefore an average canopy volume of 61.34 m^3 indirectly indicates a probably better light quality in the soil (even it was not measured).

In general, our values of area and volume of the crown gradually increased over time (Figure 2). The amplitude of data has increased due to the different levels of development. Box charts at 12 months showed less dispersion; however, during this period there was a reduction of growth, as the median is also under other periods (Figure 2). We believe that the physiological damage to the plants susceptible to cold weather during the period from June to September, reduced the development and resulted in the death of the aerial part of some, but it also induced to new sprouts due to anatomical changes in the cambium region (SOUZA et al., 1991).

As there was no harsh winter in the year 2012, the plants grew up normally until the age of 30 months. After this period, a rigorous winter occurred again before the evaluation performed at 36 months of age, which resulted in a further reduction of height and crown growth. However, the plants returned to normal growth patterns at 42 months of age, becoming gradually more resistant. Some individuals managed to overcome the competition of the vegetation and began to occupy the upper stratum.

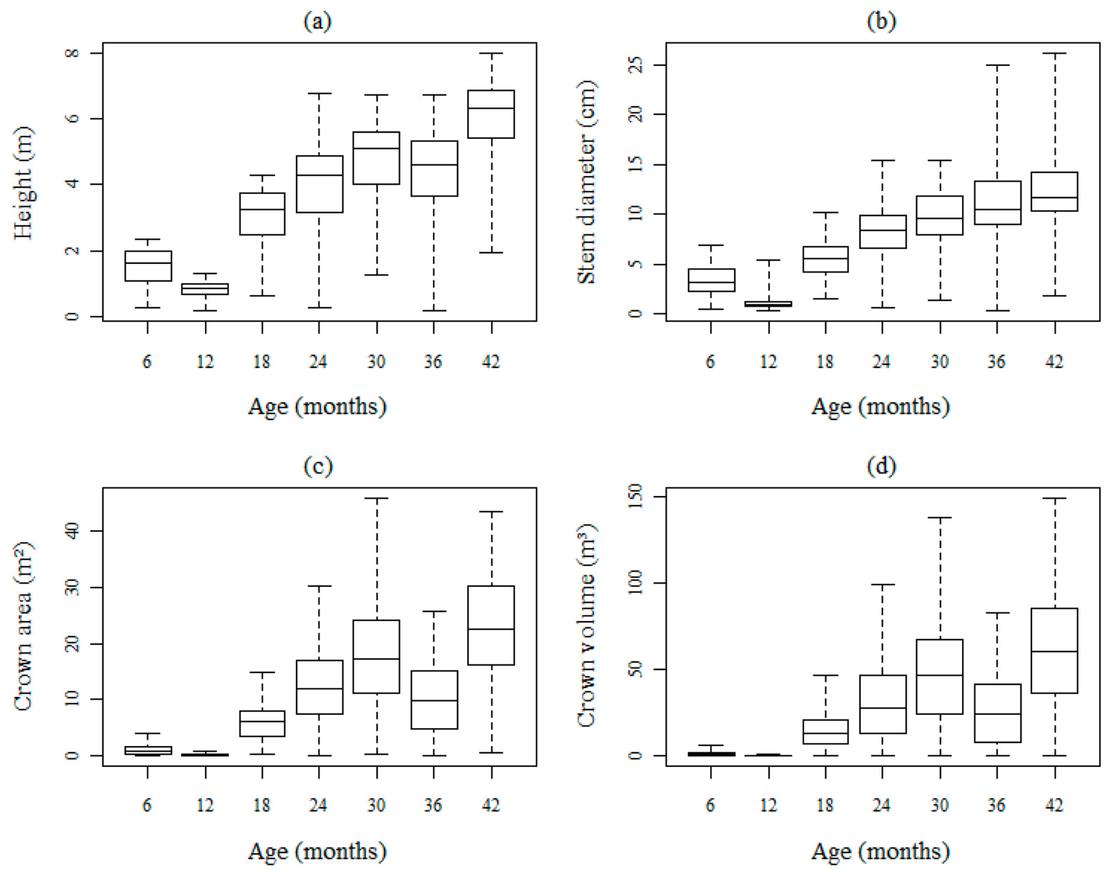


FIGURE 2: Box charts with root collar diameter values (a), total height (b), crown projection area (c) and crown volume (d) of individuals of Trema micrantha evaluated over 42 months. The dark lines inside the boxes represent the median. The boundary lines of the cases are the quantiles 25 and 75%. The fins represent ± 1.5 times the interquartile distance.

FIGURA 2: Gráficos de caixa com valores do diâmetro do colo (a), altura total (b), área de projeção de copa (c) e volume de copa (d) dos indivíduos de Trema micrantha avaliados ao longo de 42 meses. As linhas escuras no interior das caixas representam a mediana. As linhas limites das caixas são os quantis de 25 e 75%. As aletas representam ± 1,5 vezes a distância interquartil.

The largest data dispersions were recorded in the variables: a) crown projection area and b) crown volume. It is suggested that the natural dynamics of the canopy structure of each individual contributed to increase the heterogeneity of the data set. According to Thorpe et al. (2010), competition for canopy space is a fundamental structuring feature of forest ecosystems, and the result of this competition determines the size of the canopy of each tree, which reflects in interception of light, photosynthetic capacity, growth and even survival. Costa et al. (2012) observed that increasing the density of tree vegetation contributed to increase competition of the canopy for light. Siqueira (2006), verified that competition of the crown by light favors the development of the higher branches in detriment of the lower ones. On the other hand, Costa et al. (2012) observed that the decrease of the density of the tree vegetation facilitated the penetration of light, making possible the existence of lower live branches. Costa and Finger (2016), found that in a natural subtropical forest, the decrease of the competition favors the increase of the crown length of *Araucaria angustifolia*.

For the growth estimates, Chapman-Richards' model (Figure 2) showed a better adjustment to determine the growth of root collar diameter, total height and crown area. The Chapman-Richards function has been widely used in modeling biological phenomena due to its accuracy and flexibility, and the most used in studies of growth in forest areas (ZEIDE, 1993).

The growth rate for *Trema micrantha* in root collar diameter (0.25 cm/month), height (0.12 m/month) and crown area (0.56 m²/month) was high, with a satisfactory standard for pioneer species which main function is the coverage and incorporation of organic matter in the soil. Some coefficients adjusted for the function were not significant (p >0.1), implying a decrease in the degree of the certainty in the adjusted value. The adjusted functions adjusted showed high levels of standard error of the estimate (Table 3). It is therefore suggested that the heterogeneity of the presented data set has a strong influence on the estimation of the parameters which resulted in lowering the accuracy of the adjusted function (VANCLAY, 1994). This phenomenon can be explained by the different variations of growth that may have occurred because of the genetic influence and of edaphoclimatic conditions. Therefore, the coefficients obtained for the *Trema micrantha* in the Chapman-Richards model, only provided the current growth rate of the species. The estimates of future growth through the application of the model would be inefficient. It is suggested that the analysis of the dimensions and the competition from neighboring trees would likely help to better explain this growth variation recorded between *Trema micrantha* individuals.

TABLE 3: Statistical parameters of the model adjusted to estimate the growth in rootcollar diameter (cm) total height (m) and crown area for *Trema micrantha,* 3.5 years old, Dois Vizinhos – PR state, Brazil.
TABELA 3: Parâmetros estatísticos da equação ajustada para estimar o crescimento em diâmetro do colo (cm), altura total (m) e área de copa para *Trema micrantha* aos 3,5 anos de idade no município de Dois Vizinhos - PR, Brasil.

Variables	a	t value	B	t value	k	t value	N	Syx	Syx (%)	rate / month
Root collar diameter	84.22	0,409 ns	0.9979	212,729 ***	0.0035	0,376 ns	454	33.66	48.09	0.25 cm
Height	19.32	1,225 ns	0.994314	88,741 ***	0.008099	1,006 ns	454	1.376	39.48	0.12 m
Crown area	513.6	0,109 ns	1.007	14,601 ***	0.001123	0,107 ns	466	8.059	78.17	0.56 m²

Where in: a, b, k = coefficients; t value = ANOVA (*** p = 0.001; ** p<0.01, * p<0.05, "p<0.1, ns: not significant p>0.1); N = number of observations; Syx = standard error of the absolute estimate; Syx (%) = standard error of the relative estimate.

Observing the asymptotic values obtained for root collar diameter (84.22 cm) and for total height (19.32 m), we can note that they are overestimated. According to Lorenzi (1992), *Trema micrantha* can reach height of 5 to 12 m and DAP of 20 to 40 cm. The asymptotic crown area was also highly overestimated, since the value of 513.6 m² would correspond to an average crown diameter of 25.57 m, much higher than what is observed in the field for individuals of this species. This can be explained by the short period of time used in the modeling, of only 3.5 years. Considering that this species can reach a life cycle of up to 15 years (CARVALHO, 1994), the observation window used was only 23.33%. Asymptotic models are more realistic and appropriate when used for analyzes of the entire plant life cycle, such as annual plants (PAINE et al., 2012). However, this does not prevent the use in arboreal species; we recommend longer monitoring, providing more realistic values.

CONCLUSION

The size of *Trema micrantha* satisfactorily increased over time, reducing its growth only during the occurrence of severe frosts. The growth of this species at 3.5 years of age associated with a high rate of survival and regrowth after cold weather confers its excellent performance in the southern Brazil and can be highly recommended for use as a shading plant for rapid canopy formation in subtropical forest restoration projects, especially those subject to frosts.

REFERENCES

ALVARES, A. A. et al. Köppen's climate classification map for Brazil. **Meteorologische Zeitschrift**, Stuttgart, v. 22, n. 6, p. 711-728, jan. 2014.

ANDREANI, D. V. D. M. et al. Aves como potenciais dispersoras de *Trema micrantha* (L.) Blume (Cannabaceae) em um fragmento florestal no estado de Mato Grosso. **Atualidades Ornitológicas**, Ivaiporã, n. 180, p. 33-37, jul./ago. 2014.

ALVARENGA, A. P. et al. Sobrevivência e crescimento inicial de espécies arbóreas nativas na restauração de nascentes no Sul de Minas Gerais. **Enciclopédia Biosfera, Centro Científico Conhecer**, Goiânia, v. 13, n. 23, p. 1239-1250, jun. 2016.

CARAMORI, P. H. et al. Climatic risk zoning for coffee (*Coffea arabica* L.) in Paraná state, Brazil. **Revista Brasileira de Agrometeorologia**, Passo Fundo, v. 9, n. 3, p. 486-494, 2001.

CARVALHO, P. E. R. Comparação de espécies nativas, em plantio em linhas em capoeira, na região de IRATI-PR – resultados aos sete anos. **Boletim de Pesquisa Florestal**, Curitiba, n. 5, p. 53-68, dez. 1982.

CARVALHO, P. E. R. **Espécies florestais brasileiras**: recomendações silviculturais, potencialidades e uso da madeira. Colombo: Embrapa; CNPF; SPI, 1994. 640 p.

CHAGAS, R. K. et al. Crescimento diametral de espécies arbóreas em Floresta Estacional Semidecidual ao longo de seis anos. In: DURIGAN, G.; VILAS-BOAS, O. **Pesquisas em conservação e recuperação ambiental no oeste paulista**. São Paulo: Páginas e Letras, 2004. p. 265-290.

CHAZDON, R. L. Tropical forest recovery: legacies of human impact and natural disturbances. **Perspectives in Plant Ecology, Evolution and Systematics**, Zurich, v. 6, p. 51-71, mar. 2003.

COSTA, E. A.; FINGER, C. A. G. Efeito da Competição nas Relações Dimensionais de Araucária. **Floresta e Ambiente**, Seropédica, v. 24, p. 1-11, abr. 2016.

COSTA, M. P. et al. Alometria e arquitetura de *Copaifera langsdorffii* (Desf.) Kuntze (Fabaceae) em fitofisionomias neotropicais no sul de Minas Gerais. **Ciência Florestal**, Santa Maria, v. 22, n. 2, p. 223-240, abr./jun. 2012.
CHAMBERS, J. Q.; HIGUCHI, N.; SCHIMEL, J. P. Ancienttree in Amazonia. **Nature**, London, v. 391, p. 135-136, jan. 1998.
CUSACK, D.; MONTAGNINI, F. The role of native species plantations in recovery of understory woody diversity in degraded pasturelands of Costa Rica. **Forest Ecology and Management**, Amsterdam, v. 188, p. 1-15, feb. 2004.
ELLIOTT, S. et al. Selecting framework tree species for restoring seasonally dry tropical forests in northern Thailand based on field performance. **Forest Ecology and Management**, Amsterdam, v. 184, p. 177-191, mar. 2003.
ELLIOTT, S.; BLAKESLEY, D.; HARDWICK, K. Restoring Tropical Forests: a practical guide. **Royal Botanical Garden**, Kew, p. 118-123, 2013.
EMBRAPA. **Sistema brasileiro de classificação de solos**. Rio de Janeiro: Empresa Brasileira de Pesquisa Agropecuária, 2006. 306 p.
FERREIRA, W. C. et al. Avaliação do crescimento do estrato arbóreo de área degradada revegetada à margem do Rio Grande, na Usina Hidrelétrica de Camargos, MG. **Revista** Árvore, Viçosa, MG, v. 31, n. 1, p. 177-185, 2007.
GUARIGUATA, M. R.; RHEINGANS, R.; MONTAGNINI, F. Early woody invasion under tree plantations in Costa Rica: implications for forest restoration. **Restoration Ecology**, Malden, v. 3, p. 252-261, dec. 1995.
GROMBONE-GUARATINI, M. T.; RODRIGUES, R. R. Seed bank and seed rain in a seasonal semideciduous
forest in south-eastern Brazil. **Journal of Tropical Ecology**, Cambridge, v. 18, n. 5, p. 759-774, set. 2002.
HIGA, R. C. V. et al. Resistência e resiliência a geadas em *Eucalyptus dunnii* Maiden plantados em Campo do Tenente. **Boletim de Pesquisas Florestais**, Colombo, v. 40, p. 67-76, jan./jun. 2000.
HOLL, K. D. et al. Tropical montane forest restoration in Costa Rica: overcoming barriers to dispersal and establishment. **Restoration Ecology**, Malden, v. 8, p. 339-349, dec. 2000.
KINOSHITA, L. S. et al. Composição florística e síndromes de polinização e de dispersão da mata do Sítio São Francisco, Campinas, SP, Brasil. **Acta Botanica Brasilica**, São Paulo, v. 20, n. 2, p. 313-327, set. 2006.
KNOWLES, O. H.; PARROTTA, J. A. Amazon forest restoration: an innovative system for native species selection based on phenological data and field performance indices. **Commonwealth Forestry Review**, Oxford, v. 74, n. 3, p. 230-243, 1995.
KRAMER, P. J. The role of physiology in forestry. **Tree Physiology**, Oxford, v. 2, n. 1, p. 1-16, 1986.
LAMB, D.; ERSKINE, P. D.; PARROTTA, J. A. Restoration of degraded tropical forest landscapes. **Science**, Washington, v. 310, p. 1628-1632, dec. 2005.
LELES, P. S. S. et al. Grownth of tree species in different planting spacing for forest recovery. **Scientia Forestalis**, Piracicaba, v. 39, n. 90, p. 231-239, jun. 2011.
LORENZI, H. Árvores brasileiras: manual de identificação e cultivo de plantas arbóreas nativas do Brasil. Nova Odessa: Editora Plantarum, 1992. 352 p.
MACHADO, J. M. C. et al. Precipitação pluvial no município de Dois Vizinhos (PR): estudo da distribuição probabilística mensal de chuvas (19732013). In: SEMINÁRIO DE INICIAÇÃO CIENTÍFICA E TECNOLÓGICA DA UTFPR, 17., 2013, Dois Vizinhos. **Anais...** Dois Vizinhos: UTFPR, 2013.
MARTINS, S. V.; RODRIGUES, R. R. Gap-phase regeneration in a semideciduous mesophytic forest, south-eastern Brazil. **Plant Ecology**, Dordrecht, v. 163, p. 51-62, 2002.
MAX, J. C. M.; MELO, A. C. G.; FARIA, H. H. Comportamento de seis espécies nativas de dois grupos ecológicos plantadas em diferentes espaçamentos em reflorestamento ciliar. In: VILAS BOAS, O.; DURIGAN, G. (Org.). **Pesquisas em conservação e recuperação ambiental no oeste paulista.** São Paulo: Páginas e Letras, 2004. p. 385-396.
MONTGOMERY, R. A.; CHAZDON, R. L. Forest structure, canopy architecture, and light transmittance in Tropical Wet Forests. **Ecology**, Washington, v. 82, n. 10, p. 2707-2718, oct. 2001.
MORAES, L. F. D. et al. Plantio de espécies arbóreas nativas para a restauração ecológica na reserva biológica de poço das antas, rio de janeiro, Brasil. **Rodriguésia**, Rio de Janeiro, v. 57, n. 3, p. 477-489, nov.

2005.
NASCIMENTO, D. F. et al. Crescimento inicial de seis espécies florestais em diferentes espaçamentos. **Cerne**, Lavras, v. 18, n. 1, p. 159-165, jan./mar. 2012.
NOGUEIRA, F. F. **Avaliação do crescimento inicial de espécies nativas para restauração florestal**. 2015. 24 f. Monografia (Graduação em Engenharia Florestal) - Departamento de Ciências Florestais e da Madeira da Universidade Federal do Espírito Santo, Jerônimo Monteiro, 2015.
PAINE, C. E. et al. How to fit nonlinear plant growth models and calculate growth rates: an update for ecologists. **Methods in Ecologyand Evolution**, v. 3, n. 2, p. 245-256, apr. 2012.
PARROTTA, J. A. The role of plantation forests in rehabilitating degraded tropical ecosystems. **Agriculture, Ecosystems and Environment**, Amsterdam, v. 41, n. 2, p. 115-133, jul. 1992.
PEREIRA, J. A. A.; BOTELHO, S. A.; DAVIDE, A. C. Desenvolvimento de espécies florestais de rápido crescimento em diferentes condições de sítio visando a recomposição de matas ciliares. **Cerne**, Lavras, v. 5, n. 1, p. 36-51, 1999.
RODRIGUES, R. R. et al. Large-scale ecological restoration of high-diversity tropical forests in SE Brazil. **Forest Ecology and Management**, Amsterdam, v. 261, p. 1605-1613, may 2011.
RODRIGUES, R. R. et al. On the restoration of high diversity forests: 30 years of experience in the Brazilian Atlantic Forest. **Biological Conservation**, Essex, v. 142, n. 6, p. 1242-1251, jan. 2009.
RODRIGUES, R. R.; MARTINS, S. V.; BARROS, L. C. Tropical Rain Forest regeneration in an area degraded by mining in Mato Grosso State, Brazil. **Forest Ecologyand Management**, Amsterdam, v. 190, p. 323-333, 2004.
RIBAS L. A.; KAGEYAMA P. Y. Sistema de cruzamento de *Trema micrantha* (L.) B. em fragmentos florestais. **Scientia Forestalis**, Piracicaba, v. 72, p. 29-37, dez. 2006.
SÁ, C. F. C. Regeneração de um trecho de floresta de restinga na Reserva Ecológica Estadual de Jacarepiá, Saquarema, Estado do Rio de Janeiro: II - Estrato arbustivo. **Rodriguésia**, Rio de Janeiro, v. 53, n. 82, p. 5-23, 2002.
SGARBI, A. S. et al. Crescimento inicial de espécies nativas em plantio de grupos de Anderson. In: SEMINÁRIO DE INICIAÇÃO CIENTÍFICA E TECNOLÓGICA DA UTFPR, 17., 2012, Curitiba. **Anais...** Curitiba: UTFPR, 2012. p. 1-8.
SIQUEIRA, A. S. Alometria de *Caryocar brasiliense* (Caryocaraceae) em diferentes fisionomias do Parque Estadual da Serra de Caldas Novas, GO. **Biota Neotropica**, Campinas, v. 6, p. 1-6, set. 2006.
SOUZA, A. J. et al. **Observações preliminares de alguns fatores que afetam a brotação do eucalipto**. Piracicaba: IPEF, 1991. (Circular técnica, 177).
SPLINK. **S*pecies* Link network**. 2015. Disponível em: <http://www.splink.org.br>. Acesso em: 16 jul. 2015.
THORPE, H. C. et al. Competition and tree crowns: a neighbourhood analysis of three boreal tree species. **Forest Ecology and Management**, Amsterdam, v. 259, n. 8, p. 1586-1596, jan. 2010.
TONINI, H.; FINGER, C. A. G.; SCHNEIDER, P. R. O crescimento da *Nectandra megapotamica* Mez., em floresta nativa na depressão central do Estado do Rio Grande do Sul. **Ciência Rural**, Santa Maria, v. 1, n. 33, p. 85-90, jan./fev. 2003.
VANCLAY, J. K. **Modelling forest growth and yield**: applications to mixed tropical forests. Wallingford: CAB International, 1994. 312 p.
VIEIRA, A. R. R.; FEISTAUER, D.; SILVA, V. P. Adaptação de espécies arbóreas nativas em um sistema agrossilvicultural, submetidas a extremos climáticos de geada na região de Florianópolis. **Revista Árvore**, Viçosa, MG, v. 27, n. 5, p. 627-634, set. 2003.
VILLANUEVA, G. Polliniferous plants and foraging strategies of *Apis mellifera* (Hymenoptera: Apidae) in Yucatan Peninsula, Mexico. **Revista de Biologia Tropical**, San Rosé, v. 50, n. 3-4, p. 1035-1044, ago. 2002.

WHEELWRIGHT, N. T. et al. Tropical fruit-eating birds and their food plants: a survey of a Costa Rican lower montane forest. **Biotropica**, Washington, v. 16, n. 3, p. 173-192, sep. 1984.
WISHNIE, M. H. et al. Initial performance and reforestation potential of 24 tropical tree species planted across a precipitation gradient in the Republic of Panama. **Forest Ecology and Management**, Amsterdam, v. 243, p. 40-47, may 2007.
YAMAMOTO, L. F.; KINOSHITA, L. S.; MARTINS, F. R. Síndromes de polinização e de dispersão em fragmentos da Floresta Estacional Semidecídua Montana, SP, Brasil. **Acta Botanica Brasilica**, São Paulo, v. 21, n. 3, p. 553-573, nov. 2007.
ZEIDE, B. Analysis of Growth Equations. **Forest Science**, Bethesda, v. 39, n. 3, p. 599-600, 1993.