LUMEN ET VIRTUS
ISSN: 2177-2789

EVALUATION OF THE RESPONSE OF *PINUS TECUNUMANII* IN RELATION TO FIVE TYPES OF SUBSTRATE

https://doi.org/10.56238/levv15n41-009

Submitted on: 01/09/2024 **Publication date:** 01/10/2024

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ABSTRACT

This study was carried out with the aim of evaluating the response of Pinus tecunumanii under the influence of five types of substrates. The study was carried out in the central nursery of the company Florestas do Niassa, which is located in the province of Niassa. The experimental design was Completely Causalized Blocks (DBCC), with 5 treatments (substrates) and 4 replications. The total height of the seedlings was measured on a monthly basis, while the diameter of the seedling base, total biomass were measured at the end of the trial at 120 days. The collected data were submitted to the test of homogeneity of variance and normality of the residuals. The difference between the means of the variances was made to observe the difference between the means of the parameters evaluated by Tukey's test. There were significant differences in the variables analyzed corresponding to the respective substrates. The Dickson quality index was determined for the variables and the correlation analysis between the variables was performed, and the existence of positive correlations was found in most of the variables. The treatments with T1 (80% cocopeat + 20 fine sand) for Pinus tecunumanii, significantly influenced the growth of the seedlings under

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study, the treatment with T4 (60% cocopeat + 40% fine sand) presented low results in most of the parameters evaluated.

Keywords: Seedling production, Morphological and quality variables, Substrate.

INTRODUCTION

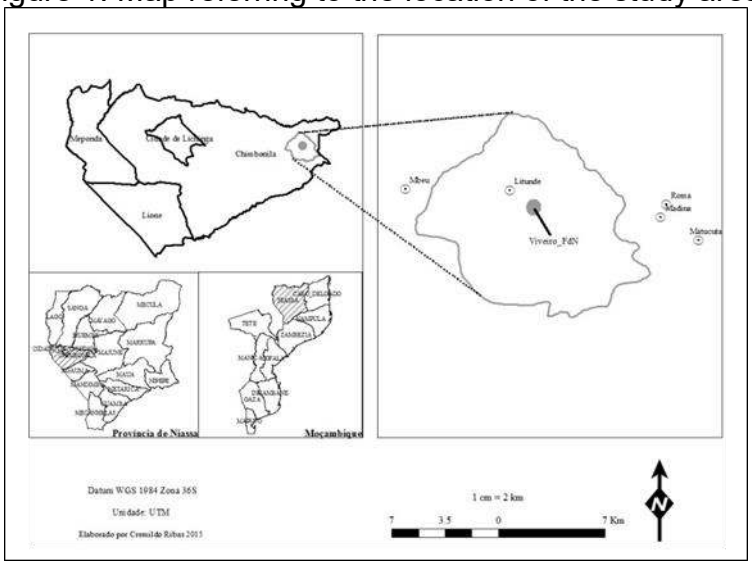
According to Shimizu, (2006), of the approximately 30.6 million hectares considered forest areas in Mozambique, more than 7 million have been mapped as potential for reforestation with fast-growing species and represent a great opportunity for the country's development. For-profit forest stands aim to maximize the return and that this maximization is associated with rapid growth and consequently in the reduction of the cutting cycle, for this, the type of silviculture that is applied plays a very preponderant role. The need to produce seedlings of forest species in large quantities in a short period of time, to meet the needs of commercial plantations, has favored the rapid evolution of different silviculture practices in forest nurseries. The substrate used for the production of seedlings is intended to ensure the development of plants with good quality, since many of the plants are susceptible to attack by microorganisms and little tolerant to water deficit (Cunha et al., 2006).

In Mozambique, particularly in Niassa, research on techniques that favor the production of forest seedlings is still in the incipient phase, not enough, the success in establishing forest stands is indispensable to the success of forestry projects in the province of Niassa, hence the need to intensify research in forest stands, aiming to seek more suitable and acceptable alternatives of substrates for the production of Pinus tecunumaii forest seedlings. The present study was developed with the objective of evaluating the response of Pinus tecunumanii in different substrates at the company Florestas do Niassa in the district of Chimbonila in Niassa.

MATERIALS AND METHODS

The experiment was conducted in the central nursery of the Valley Rifty company, commonly known as Florestas do Niassa, located in the District of Chimbonila. The District of Chimbonila is located in the western part of the province of Niassa with an area of 5,342 km2, lying between latitude 13°23' 48" S and longitude 35°13' 43" E, bordering to the north by the districts of Sanga, Lago and Muembe, to the south by the district of N'gaúma, to the east by the district of Majune and to the west by the Republic of Malawi Ministry of State Administration (MAE, 2012). The experimental area is located about 60 km from the city of Lichinga, (Figure 01).

Figure 1. Map referring to the location of the study area.



Source: The Authors (2024).

For the production of seedlings, five substrate compositions (treatments) were used, namely: 100% cocopeat, 80% cocopeat + 20% fine sand, 80% cocopeat + 20% rasp sand, 60% cocopeat + 40% fine sand, 60% + 40% rasp sand.

Table 1. Proportions in (%) of substrates used for the composition of the treatments

TREATMENTS	Substrate proportions in percentage		
	Cocopeat (%)	Rasp sand (%)	Fine Sand (%)
T1 100% Cocopeat	100	----	----
T2 80% Cocopeat + 20% areia fina	80	20	----
T3 80% Cocopeat + 20% areia grosa	80	----	20
T4 60% Cocopeat + 40% areia fina	60	40	----
T5 60% Cocopeat + 40% areia grosa	60	----	40

Source: The Authors (2024).

The seeds of Pinus tecunumanii were acquired from the company Agrokan S.A. in Guatemala, from a collection in natural forests. With an average of 65,000 seeds/kg, 99% purity, 90% germination power. The sowing was done manually directly in the tubes, in which two seeds were placed, covered with a thin layer of the corresponding substrate. After 30 days, the re-cutting was carried out, leaving only the seedling that had the greatest vigor in the center of each tube. The seedlings remained in the nursery for about six months, still in the nursery the black shade was used as a cover for the control of insolation, with 50% of the sunlight passing over the seedlings.

During the development of Pinus tecunumanii seedlings, water-soluble ammonia fertilizers were used, as follows: NPK cover fertilizer (07-40-17), with a higher amount of phosphorus (P) for a higher emission from the roots, for 3 to 4 weeks; NPK growth fertilizer (07-40-10), for rapid growth of height and diameter in week 5 to 9. The base fertilization

was carried out during the process of preparation and mixing of the substrates in the concrete mixer. Meanwhile, the top dressing fertilization was done one and a half months after the installation of the experiment (sowing), according to the methodology proposed by (Gonçalves et.al, 2000).

After this procedure, data were collected that allowed to characterize the physicochemical aspect of the substrate. Therefore, porosity was calculated with the help of the following expression (equation 1), recommended by (Gonçalves and Poggiani 1996). Substrates in forest seedling production nursery should contain 50 to 80% of total porosity.

$$\text{porosity}(\%) = * 100 \quad \frac{\text{Total pore volume Cavity}}{\text{volume Total}} \qquad \text{Equation 1}$$

To perform the chemical analysis of the substrate, the methodology described by Sodré et al (2005) was used. The procedure consisted of immersing the samples in aqueous solution, the measurements were made in the morning, in five samples for each treatment, where later the average pH of the five samples was considered.

The evaluations of the morphological parameters of the Pinus tecunumanii seedlings were carried out monthly from 30 days after sowing for height and at the end of the trial for diameter, this is because the seedlings at 30 days are still very small and fragile according to the methodology described by (Gomes, 2001). At 120 days, the destructive evaluations of the seedlings were carried out in order to obtain the dry biomass, these parameters were submitted in an oven for drying and then weighed on the electronic scale at the Agronomic Research Institute of Mozambique (IIAM) in Lichinga, to obtain the dry weights of the (biomass) according to the methodology proposed by (Dickson, 1996).

Regarding the determination of the Height to Stem Diameter Ratio (RHD), Gomes and Paiva (2006) found that the stem diameter is easily measurable, however it is considered by many researchers as one of the most important parameters to estimate the survival of forest species seedlings in the field. Thus, seedlings from treatments with larger stem diameters will present a better balance of shoot growth (Carneiro, 1995).

Thus, the diameter measurement was made after 120 days, when the seedlings were taken to the definitive field. The height of the aerial part (H) was determined with the help of a ruler graduated in centimeters (cm), while the diameter of the neck (D) was evaluated at the level of the substrate (at the base of the plant) with the help of a parking meter. Based on the data of the height of the aerial part and diameter of the cervix of each

individual, the ratio of the height of the aerial part/diameter of the corresponding cervix was determined, according to the following formula, used by (Carneiro, 1995),

$$HD = \frac{(H)}{(DC)} \qquad \text{Equation 2}$$

Where:

RHD = height and diameter ratio; H = height in cm; D = diameter in mm

The determination of the dry biomass of the seedlings was obtained from the formula used by (Carneiro, 1995).

$$\frac{BsT(g)}{\frac{H(cm)}{D(mm)} + \frac{BsPA(g)}{BsPR(g)}} \qquad \text{Equation 3}$$

Where:

IQD = Dickson quality index; BsT = weight of total dry biomass in grams; H = height in cm; D = neck diameter in mm; BsPA = weight of the dry biomass of the shoot in grams; BsPR = weight of dry biomass of the radical part in grams.

To determine BsPA and BsPR, they were removed from the respective pots and then washed with water in order to remove grains of sand that were aggregated around the root. Having proceeded with the separation of the root from the aerial part with the help of pruning shears so that each of the parts mentioned above was evaluated separately.

Although the experiment was carried out under the conditions of a forest nursery, in order to minimize possible experimental errors from sources of variations that could influence the performance of the treatment, such as light, water conditions, (sprinklers) temperature variation in the vicinity of the corridors, the experiment was set up according to a completely causalized block design (DBCC), with five treatments (5 substrates) and four replications (blocks).

The data analysis was done using the combination of several procedures, with the help of some statistical tools, the ASSISTAT 7.7 beta software to meet the objectives previously defined in this study. The test chosen to compare the monthly means of the variables was Tukey's, because the same test is more efficient for comparing the means (Muetanene, 2014). The ASSISTAT 7.7 beta software was used both for analysis of variance (ANOVA) as well as to identify different means. It was also used for the tests of

homogeneity of variances and normality of the residuals. For Pearson's correlation analysis, the Microsoft Excel statistical package was used, with the objective of relating morphological and physiological variables (Pocinho, 2010).

RESULTS AND DISCUSSIONS

MORPHOLOGICAL PARAMETERS FOR PINUS TECUNUMANII SEEDLINGS

Height of seedlings (H)

Table 1 shows the results of comparing the means for the different treatments of the Pinus tecunumanii species for the variable seedling height in the different periods studied (30, 60, 90 and 120 days). It is observed that the test of means detected significant differences in all periods studied, at a significance level of 1% at 30 and 120 days and 60 and 90 days. The use of the blocks showed no significant effects. In the table below (table 2) it is also observed that the coefficients of variation are low, varying only at 120 days where the seedlings showed a higher coefficient of variation, even so the coefficients of variation of H30, H60 and H90, show a uniformity.

Table 2. Summary of the analysis of variance of the heights of Pinus tecunumanii seedlings evaluated at 30, 60, 90 and 120 days after sowing.

TREATMENTS		Age (days)		
	H30	H60	H90	H120
	Height			
100% Cocopeat	5.829a	21.078a	26,641from	30,625from
80% Cocopeat + 20% areia fina	5.935a	20.215a	28.878a	33.887a
80% Cocopeat + 20% areia grosa	5.823b	21.523b	25.350b	30.187from
60% Cocopeat + 40% areia fina	5.138b	20.437b	24.178b	29.7750b
60% Cocopeat + 40% areia grosa	5.116a	17.445c	21.850b	30,941from
Overall average	5.568	21.940	26.979	31.078
F-treatment	1.988*	9.3691**	8.0515**	3.2723*
F-block	0.4634ns	1.3724ns	1.4667ns	0.2939ns
CV (%)	13.29	10.04	14.73	28.95

Ns=not significant, *=significant at 0.05 and **=significant at 0.01, F=treatment, F=blocks, CV=coefficient of variation= height. Means followed by the same letter do not differ statistically from each other, by Tukey's test at the level of 1% probability. Source: The Authors (2024).

In general, it was considered the most important evaluation at 120 days. Experiments carried out in forest nurseries, the last evaluation period is considered to be the most important, since it is during this period that the seedlings are taken to the definitive field (Gomes, 2001). The T2 treatment (80% cocopeat + 20% thin) had the highest height, 33,887cm, representing the other treatments, thus there were statistically significant differences with the other treatments. These results were likely associated with higher porosity that contributed to these differences. Thomas (2000) in his study, when evaluating different types of substrates for the production of Pinus taeda seedlings, also found that

higher proportions of coconut fiber provided greater growth in height. Hoppe et al. (2004), evaluating the growth of Pinus tecunumanii seedlings (75% coconut fiber + 25 subsoil sand), found an increase of 22% to 43% at 90 and 120 days. These results found by these two authors are in accordance with the results found in the present study.

The T4 treatment (60% cocopeat + 40% fine sand) with an average height of 29,775cm, presented the lowest growth in height, and was statistically different from the other treatments, but it is not enough to disqualify it since it is within the ideal parameters, although it is different from the results found by Gomes (1978), when he studied the development of Pinus caribaea in the nursery, where he observed that the substrate with (60% coconut fiber and 40% fine fine earth) provided average values in height with 23 cm. The treatment (60% cocopeat + 40% rasp sand), showed the lowest average height at 30 days, According to Mula (2011), the difference in growth is normal, especially in the first months after sowing, as there are several factors that can lead to this behavior, such as the reserves contained in the seed, the base fertilization and the nutrients of the substrate.

The table shows the results of comparison of the means for the different treatments of the Pinus tecunumanii species for the variables Diameter, Height Ratio Diameter (H/D), Dry Biomass and (IQD), from seedlings to (120 days). It is observed that the means test detected significant differences in all the variables studied at 120 days, at a significance level of 1% for the variable Dickson Quality Index (DQI), Diameter height ratio (H/D), Total dry biomass (BsT), and at a significance level of 1% for the variables Diameter, Shoot dry biomass (BsPA), Dry biomass of the root part (BsPR).

Table 3. Summary of the analyses of variance and comparison of the means for height (cm) (IQD), diameter (mm) and height diameter ratio (H/D) for Pinus tecunumanii seedlings, evaluated at 120 days

TREATMENTS		120 Days		
	Height	Diameter	H/D	IQD
100% Cocopeat	30,625from	4.070b	7.524b	0.716b
80% Cocopeat + 20% areia fina	33.887a	4.573a	7.422b	1.325a
80% Cocopeat + 20% areia grosa	30.187from	4,422from	6.826a	0.970from
60% Cocopeat + 40% areia fina	29.775b	4.053b	7.346a	0.692b
60% Cocopeat + 40% areia grosa	30,941from	4.095b	7.558a	1.037from
Overall average	31.078	4.243	7.3 36	0.948
F-treatment	3.2723*	8.057**	2.7653*	4.359*
F-block	0.2939ns	3.074ns	6.0425	0.314ns
CV (%)	28.95	3.98	28. 96	26.22

Biomass seca (g)			
	BsT	BsPA	BsPR
100% Cocopeat	8.147d	3.143d	5.004d
80% Cocopeat + 20% areia fina	16.595ª	4.750a	11.845a
80% Cocopeat + 20% areia grosa	8.874c	3.154c	5.720c
60% Cocopeat + 40% areia fina	5,174e	1.612e	3,562e

60% Cocopeat + 40% areia grosa	9.758b	3.500b	6.258b
Overall average	9.709	3.231	6.478
F-treatment	1.930 *	5.8705 **	2.775 **
F-block	0.305 ns	1.294 ns	1.656 ns
CV (%)	18	6	33

ns=not significant, *=significant at 0.05 and **=significant at 0.01, F=treatment, F=blocks, CV=coefficient of variation height. Means followed by the same letter do not differ statistically from each other, by Tukey's test at the level of 1% probability. Source: The Authors (2024).

Neck diameter

From the results, presented in the table above, for the diameter, it is observed that the T2 substrate (80% cocopeat + 20% fine sand) obtained the highest average with 4,573 mm, Silva et al. (2014), evaluating different substrates based on coconut fiber in forest species, found that the diameter of the stem can be used to indicate the survivability of the seedling in the field. In turn, Gonçalves et al. (2000) consider that the diameter of the stem suitable for seedlings of fast-growing forest species, particularly good quality conifers, is between 5 and 10 mm.

The T4 treatment (60% cocopeat + 40% fine sand) obtained the lowest average with 4,053 mm statistically different from each other. Wendling and Gatto, (2002), evaluating substrates with 50% fine sand in forest nurseries, found that the seedlings of Pinus tecunumanii and Pinus caribeae obtained diameters ranging from 2 to 3 mm.

The values found in this study are below the values found by (Gonçalves et al, 2000), and above the values found by (Wendling and Gatto, 2002), even so the seedlings showed a balanced development. Carneiro (1995), working with various substrates based on coconut fiber and Pinus bark, in the production of Pinus taeda and Pinus tecunumanii seedlings, observed that seedlings that had an average height of 16cm, had an average stem diameter that varied between 1.9-2.9 mm, and those with a stem diameter of less than 1.9 mm did not present balanced growth.

Diameter height ratio (H/D)

The ratio (H/D) is used to evaluate the quality of forest seedlings, because, in addition to reflecting the accumulation of reserves, it ensures greater resistance and better fixation in the soil (Binotto et al. 2007), evaluating the commercial substrate for seedlings in forest nurseries, observed that the ideal values for this ratio should be between 5.4 and 8.1, expressing the growth balance of seedlings in the nursery. For the ratio (H/D) of Pinus tecunumanii showed a variation from 4,147 to 7,599 and the highest average was obtained by the T1 treatment (100% cocopeat), and the lowest average was obtained by the T4 treatment (60% cocopeat + 40% fine sand), based on the findings of Arthur et al (2007), it can be stated that the seedlings in this study had a balanced growth.

Seca biomass

In terms of dry biomass production, the substrates showed statistically significant differences between them, the T2 treatment (80% cocopeat + 20% fine sand), was superior to the other treatments, obtaining the following average values: BsPA (4,750) g, BsT (16,595) g and BsPR (11,845) g. It should be considered that the higher this value, the better the quality of the seedlings produced (Cruz, 2006).

Gomes and Paiva (2004), when working with seedlings of the genus Pinus ssp and substrates based on coconut fiber in the nursery, found that the dry mass of the aerial part should always be considered, since it indicates the rusticity of a seedling, the larger, the more rustic it will be. In this study, the (BsPR) its average values vary from 3,562g to 11,845g, with the treatment T2 (80% cocopeat + 20% fine sand), with the highest average, and T4 (60% cocopeat + 40% fine sand) with the lowest average 3,562g, but not enough to affirm that the seedlings produced from this treatment were not rustic. Aguiar et al., (1989), in the production of Eucalyptus and Pinus ssp, found that the (BsPR) presented values that were between 1.9 and 2.4, results that were different from the results presented in this study.

DINCKSON QUALITY INDEX (IQD)

According to Gomes (2001), the higher the value of the DQI, the better the quality standard of the seedlings. In this case, comparing with the value recommended of 0.20 by the authors (Gomes and Paiva, 2006), it can be stated that the values found in this work show that the seedlings produced were of good quality. The T treatment (80% cocopeat + 20% fine sand) presented the highest average of the Dickson Quality Index and the T treatment (60% cocopeat + 40% fine sand) with 0.692, presented the lowest average referring to the value of the Dickson Quality Index, but not enough to classify them as seedlings of low quality, since the same treatment presented higher values in relation to the value of the Dickson Quality Index with 0.2, recommended by (Gomes and Paiva, 2006). These results found in this study are probably due to the higher proportion of cocopeat and because it is within the ideal pH range.

CORRELATION BETWEEN MORPHOLOGICAL VARIABLES

In the table. It is observed that the correlation coefficients analyzed present a clear existence of positive correlations for the variables analyzed, however, the variable height (H) presented a relatively high index when related to (H/D). Significant differences were

observed in the variables (H and BsPA, H and BsT, BHEI and BsPA, BHEI and BsT, BHEI and BsPR, BsT and D, BsPA and D, BsPR and D, H/D and H, H/D and BsT,

H/D and BsPA, H/D and BsPR) at a significance level of 1% at 120 days when correlated. The variables (D and H, H/D and D, BHEI and H, DQI and H/D) were not significant when correlated.

Table 4. Summary of the correlations between the morphological variables of Pinus tecunumanii seedlings.

VARIABLES	H	D	BsT	BsPA	BsPR	H/D	IQD
H	1						
D	0.292ns	1					
BsT	0.586**	0.608*	1				
BsPA	0.608**	0.558*	0.979**	1			
BsPR	0.535*	0.634*	0.978**	0.916**	1		
H/D	0.986*	0.833ns	0.466*	0.506*	0.403*	1	
IQD	-0.126ns	0.522*	0.704**	0.670**	0.710**	-0.249ns	1

ns= not significant, * = significant at 0.05 and ** = significant at 0.01, the t-test was applied at the 1% probability level and the correlations are linear. IQD - Dickson Quality Index H-height, D-diameter, H/D-Ratio of shoot height and stem diameter, BsT-Total dry biomass, BsPR- Dry biomass of the radical part, BsPA-Dry biomass of the aerial part. Source: The Authors (2024).

Eloy et al (2013) evaluating Pinus ssp in different substrates, found correlation values of person equal to 0.97 referring to height (H) when related to (H/D), not differing enough with the values found in this work. Carneiro (1995) found that the (IQD) showed a high correlation with the variable diameter, height, BsPA, BsPR, BST, but with BsPA/BsPR the correlation was low when evaluating different substrates in the seedlings of Pinus tecunumanii and Pinus taeda. This differs from the results found in this study regarding the parameters (IQD, H, H/D).

FINAL CONSIDERATIONS

According to the results obtained, for the conditions under which the study was carried out, based on the objectives set, it is concluded that in the five substrates tested, the substrates with (80% cocopeat + 20% fine sand), (60% cocopeat + 40% rasp sand) and (80% cocopeat + rasp sand), these presented better average and adequate values in all the morphological parameters evaluated, in relation to the other substrates evaluated in this present work, in the seedlings of Pinus tecunumanii. The ideal porosity for the development of Pinus tecunumanii seedlings is in the range of 83% and The ideal pH for the development of Pinus tecunumanii seedlings is in the range of 6.4. Although there is a management in the substrates themselves, the substrate (60% cocopeat + 20%) was the one that least stood out in most of the morphological parameters evaluated. The best substrate for the production of Pinus tecunumanii seedlings was (80% cocopeat + 20% fine

sand), since it stood out as the best substrate in all parameters such as height, diameter, height diameter ratio (H/D), Dickson quality index, as well as in dry biomass.

REFERENCES

1. De Aguiar, I. B., et al. (1989). Selecção de substrato para produção de mudas de eucalipto em tubetes. *IPEF*, (41/42), 36-43.

2. Binotto, A. F. (2007). Relação entre variáveis de crescimento e o índice de qualidade de Dickson em mudas de *Eucalyptus grandis* W. Hill ex Maiden e *Pinus elliottii* var. *Elliottii-II* [Dissertação de mestrado, Universidade Federal de Santa Maria].

3. Carneiro, J. C. (1995). *Produção e controle de qualidade de mudas florestais*. Curitiba: UFPR/FUPEF.

4. Cruz, C. A. F. (2006). Efeito da adubação nitrogenada na produção de mudas de sete-casca *Samanea inopinata*. *Revista Árvore*, 30(4).

5. Cunha, A. de M., et al. (2006). *Efeito de diferentes substratos sobre o desenvolvimento de mudas de acácia sp.* Viçosa, MG: Sociedade de Investigações Florestais.

6. Cunha, A., et al. (2005). Efeitos de substratos e das dimensões dos recipientes na qualidade de mudas de *Tabebuia impetiginosa*. *Revista Árvore*, 29(4), 507-516.

7. Dickson, A., Leaf, A. L., & Hosner, J. F. (1960). Quality appraisal of white spruce and white pine seedling stock in nurseries. *Forestry Chronicle*, 36(1), 10-13.

8. Eloy, E., et al. (2013). Avaliação da qualidade de mudas de *Eucalyptus grandis* e *Pinus spp.* utilizando parâmetros morfológicos em substratos. *Floresta*, 43(3), 373-384.

9. Gomes, J. M., & Paiva, H. N. (2004). *Viveiros florestais (propagação sexuada)*. Viçosa: Editora Universidade Federal de Viçosa.

10. Gomes, J. M., & Paiva, H. N. (2006). *Viveiros florestais (propagação assexuada)* (3ª ed.). Viçosa: Universidade Federal de Viçosa.

11. Gomes, J. M. (2001). Parâmetros morfológicos na avaliação de mudas de *Eucalyptus grandis*, produzidas em diferentes tamanhos de tubete e de dosagens de N-PK [Tese de doutorado, Universidade Federal de Viçosa].

12. Gonçalves, J. L. M., & Poggiani, F. (1996). Substrato para produção de mudas florestais. In *Congresso Latino-Americano de Ciência do Solo*, Águas de Lindóia (Anais, 17 p.).

13. Gonçalves, J. L. M., et al. (2000). Produção de mudas de espécies nativas: substrato, nutrição, sombreamento e fertilização. In J. L. M. Gonçalves & V. Benedetti (Orgs.), *Nutrição e fertilização florestal* (pp. 310-350). Piracicaba: IPEF.

14. Hoppe, et al. (2004). Utilização de diferentes substratos na produção de mudas de *Pinus elliottii* e *Pinus tecunumanii*. In *Uso do Bacsol® em diferentes pesquisas* (pp. 96-102). Santa Maria: Universidade Federal de Santa Maria.

15. Ministério de Administração Estatal – MAE. (2012). *Perfil do distrito de Chimbonila, Província de Niassa*. Maputo.

16. Muetanene, B. A. (2014). *Introdução à experimentação agrária*. Niassa: Universidade Lúrio, Faculdade de Ciências Agrárias.

17. Mula, H. C. A. (2011). Avaliação de diferentes substratos na produção de mudas de *Sebastiania commersoniana* (Baillon) L. B. Smith & R. J. Downs [Tese de mestrado, Universidade Federal do Paraná].

18. Pocinho, M. (2010). *Estatística II, teoria e exercícios passo-a-passo* (48 p.).

19. Shimizu, J. Y. (2006). *Pesquisa e desenvolvimento florestal em Moçambique* (1ª ed.). Colombo: Embrapa Florestas.

20. Da Silva, R. F., et al. (2014). Produção de mudas de *Eucalyptus grandis* em substratos orgânicos alternativos. *Ciência Florestal*, 24(3), 609-613.

21. Sodré, G. A., et al. (2005). Características químicas de substratos utilizados na produção de mudas de cacaueiros. *Revista Brasileira de Fruticultura*, 27(3), 514-516.

22. Thomas, R. (2000). *Determinação do melhor substrato para a produção de mudas de Pinus taeda L.* [Dissertação de mestrado, Universidade Federal de Santa Maria].

23. Wendling, E., & Gatto, C. (2002). *Substratos, adubação e irrigação na produção de mudas*. Viçosa: Aprenda Fácil.