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Growth of tamarind seedlings using pre-germinative treatments and different substrates

Camile Dutra Lourenço Gomes[1], Marilia Hortência Batista Silva Rodrigues[2]*, Jolinda Mércia de Sá[1], Marinês Pereira Bomfim[1], Valeria Fernandes de Oliveira Sousa[2], Joyce Naira da Silva[1]

[1]Federal University of Campina Grande, Campina Grande, Brazil
[2]Federal University of Paraíba, Areia, Brazil
*Corresponding author, e-mail: marilia_agroecologa@hotmail.com

Abstract

The growth of tamarind (*Tamarindus indica* L.) trees is increasing in Brazil due to their adaptability to the Northeast region of the country and because their fruits can be used for several purposes. However, tamarind is grown with little specific growth cultural practices, which is essential to improve the commercial exploration of this species, including seedling production processes, which are important to reach high yields, mainly for fruit tree species. Therefore, the objective of this work was to evaluate the effect of pre-germinative treatments and different substrates on the growth of tamarind seedlings. The experiment was conducted in a protected environment at the Federal University of Campina Grande, Pombal, Paraíba, Brazil. A randomized block experimental design with 6 replications was used, with a 5×4 factorial arrangement. The first factor was the pre-germinative treatments: mechanical scarification with sandpaper and 24-hour imbibition in water; integument incision and imbibition in water for 24 hours; 24-hour imbibition in water; 24-hour imbibition in water with *Trichoderma harzianum*; and 24-hour imbibition in water with *Trichoderma longibrachiatum*. The second factor was the substrates: 100% soil; soil + commercial substrate (3:2 v v^{-1}); soil + manure bovine (3:2 v v^{-1}); and soil + caprine manure (3:2 v v^{-1}). The tamarindseedlings showed the best growth rates when using substrates formulated with caprine manure and soil. The use of the pre-germinative treatment with imbibition in water with *Trichoderma* spp. stimulated the growth of tamarind seedlings.

Keywords: Vegetative development, Imbibition of seeds, Organic compounds, *Tamarindus indica* L.

Introduction

Tamarind (*Tamarindus indica* L.) is a legume tree species of the family Fabaceae; it is native to tropical Africa and presents good growth in arid regions due to its tolerance to droughts (Bilcke et al., 2013), thus it is well adaptable to the Northeast region of Brazil (Góes et al., 2016). Tamarind fruits are used for several purposes, such as food, consumed fresh or as processing pulps, and as pharmaceutical and other industrial products (Bello & Gada, 2015).

The main method of propagation of tamarind is through seeds; thus, seedling production process is a technique used for the commercial exploration of this species. However, this is a perennial species and improper managements in the seedling production process may have harmful consequences throughout the exploration period (Góes et al., 2009).

Segato et al. (2017) reported that the use of methods to overcome seed resistance to water absorption is required for the germination of tamarind seeds, since they have an impermeable integument. Among these methods is the scarification, chemical treatment with sulfuric acid, integument incision with a sharp blade, and immersion in water. The use of pre-germinative treatments is needed because healthy tamarind seeds present, naturally, less than 72% germination between 5 to 10 days in the hotter seasons of the year (Pereira et al., 2016).

The use of bioprotectors, such as *Trichoderm* spp., through microbiolization is a method that has been recently studied and been proven efficient to improve seed germination and plant growth and yield due to the solubilization of soil micronutrients, which favor mineral absorption and translocation (Mastouri et al., 2010; Junges et al., 2016). However, the use of this fungus for pre-germinative treatments of seeds had not yet been studied.

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Moreover, the use of an ideal substrate is required to obtain vigorous seedlings after the germinative process; this substrate must have physical, chemical, and biological properties compatible with the germination needs and provide satisfactory conditions for plant growth and mineral nutrition (Pereira et al., 2016). In addition, substrates can be improved using formulations with organic compounds (Ferreira et al., 2017).

Substrates formulated with manure have shown beneficial effects on several seedling productions of fruit trees, including soursop (Costa et al., 2016), cashew (Sousa et al., 2018), tamarind (Mendonça et al., 2014; Pereira et al., 2016), and passion fruit (Melo et al., 2019). However, excessive concentrations of manure can be harmful, depending on the species and growth environment.

Therefore, studies focusing on the production of vigorous and uniform seedlings may assist in the management of orchards, providing high yields and improving the growth of tamarind trees in the Northeast region of Brazil. In this context, the objective of this work was to evaluate the effect of pre-germinative treatments and different substrates on the growth of tamarind seedlings.

Material and Methods

The experiment was conducted from March to June, 2017, at a greenhouse of the Agro-Food Science and Technology Center of the Federal University of Campina Grande (UFCG), Pombal campus, in Paraíba, Brazil (06°46'13"S, 37°48'06"W, and 184 m of altitude). The region presents a BSh, hot and dry semiarid climate, according to the Köppen climate classification (Coelho & Soncin, 1982), with mean annual rainfall depths of 700 to 900 mm, mean annual temperature of 26.1 °C, and mean annual evaporation of 1000 to 1100 mm (Francisco & Santos, 2017). The air temperature and relative humidity inside the greenhouse were monitored during the experiment and showed means of 35±5 °C and 40±15%, respectively.

A randomized block experimental design with 6 replications was used, with a 5×4 factorial arrangement (5 pre-germinative treatments × 4 substrates). The pre-germinative treatments were: mechanical scarification with sandpaper and 24-hour imbibition in water (T1); integument incision and 24-hour imbibition in water (T2); 24-hour imbibition in water (T3); 24-hour imbibition in water with *Trichodermaharzianum* (T4); and 24-hour imbibition in waterwith *Trichodermalongibrachiatum* (T5). The substrates used were: 100% soil (S1); soil + commercial substrate (Basaplant Solaris®) (3:2 v v^{-1}) (S2); soil + manure bovine (3:2 v v^{-1}) (S3); and soil + caprine manure (3:2 v v^{-1}) (S3). The soil was collected from the 0-20 cm layer of a Typic Udifluvent, and the bovine and caprine manure were previously cured before the implementation of the experiment.

The chemical characterization of the soil and substrates was done in the Laboratory of Soils and Plant Mineral Nutrition of the UFCG, using the methodologies described by Donagema (2011) (Table 1).

Table 1. Chemical characteristics of the soil and substrates used to evaluate the growth of tamarind seedlings.

	pH	C.E	P	N	K	Na	Ca	Mg	Al	H+Al	SB	(T)	OM
	H_2O 1:2,5	dS m^{-1}	Mgdm^{-3}	%	.....	.....	$cmol_c dm^{-3}$	.....	.....	.....	.....	$cmol_c dm^{-3}$	g kg^{-1}
Soil	6.50	0.32	16	1.00	1.39	0.61	2.70	2.50	0.00	0.32	7.20	8.21	16
BM	6.47	1.09	98	2.4	3.8	1.54	4.52	2.63	0.00	0.00	12.5	10.9	40
GM	7.26	0.74	2.86	3.8	2.68	4.5	2.6	2.93	0.00	0.00	14.5	11.72	42
BS	5.8	1.41	315	-	468	6.6	15.6	9.5	0.00	6.6	142	33	8,2

SB = sum of bases; CE = electrical conductivity of the saturated paste; T = total cation exchange capacity; OM = organic matter; BV = bovine manure; GM = goat manure; BS = Basaplant Solaris®.

The seeds used were extracted from healthy fruits at the complete maturation stage, which were acquired in a local market in Pombal, PB, Brazil in 2017. The seeds were manually extracted, washed in running water to remove the pulp with aid of a fine mesh sieve, and placed on two paper-towel sheets to dry under room conditions (25 °C) for 48 hours.

The pre-germinative treatments were carried out at the Laboratory of Seed and Seedling Analyses of the UFCG. The seeds were then sown to a depth of 2 cm in 15×21 cm (width× length) black polyethylene bags, using two seeds per bag, and placed in a protected environment (greenhouse) with a 50% shade screen. The seedlings were thinning at 30 days after sowing (DAS), leaving the most vigorous one in each bag. Weeds were manually thinned to avoid competition with the tamarind seedlings. The seedlings were irrigated daily with good-quality water (electrical conductivity of 0.3), using the drainage lysimeter methodology to maintain the substrates close to the field capacity throughout the experiment, as proposed by Bernardo et al. (2006), using Equation 1:

$$Vi = \frac{(Va - Vd)}{(1 - FL)} \qquad (1)$$

where *Vi* is the irrigation water volume; *Va* is the volume applied; *Vd* is the drained volume; and *FL* is the leaching factor (10%).

The stem height and diameter of the seedlings were measured at 30 and 110 DAS, to determine the absolute growth rates in plant heights, stem diameter, and number of leaves. The AGR was determined based on the methodology proposed by Benincasa (2003), using the equation:

$$AGR = \frac{(A_2 - A_1)}{t_2 - t_1} \qquad (2)$$

where *AGR* is the absolute growth rate, *A2* is the plant growth at time *t2*, *A1* is the plant growth at time *t1*; and t2 – t1 is the difference between sampling times.

Seedling height and stem diameter are not adequate characteristics to evaluate the seedling quality due to factors that can affect the treatments, such as competition between plants for light, which cause etiolation, regardless of the controlled environment used for the experiment (Fernandez, 2002). Therefore, the relative growth rate was determined, using measurements carried out at 30 and 110 DAS, according to Equation 3, which provided the relative growth rate for plant height, stem diameter, and number of leaves. These relative growths were determined using the growth as a function of the pre-existing value, by adapting the procedures described by Poorter (1989) and Hunt et al. (2002) to plant height, stem diameter, and number of leaves.

$$RGR = \frac{(lnA_2 - lnA_1)}{t_2 - t_1} \qquad (3)$$

where *RGR* is the relative growth rate, *A2* is the plant growth at time *t2*, *A1* is the plant growth at time *t1*, *t2 – t1* is the difference between sampling times, and *ln* is the natural logarithm.

The tamarind plants were collected in the field and weighed in an analytical balance with precision of 0.001 g to evaluate their total fresh weight. The plants were placed in kraft paper bags and dried in a forced air-circulation oven at 650 °C until constant weight and weighed in an analytical balance with precision of 0.001 g to evaluate their total dry weight.

The results were subjected to analysis of variance, and the means were compared by the Tukey's test at 5% probability, using the Sisvar 5.6 statistical program (Ferreira, 2014).

Results and Discussion

The analysis of variance for absolute and relative growth rates in plant height, number of leaves, and stem diameter, and fresh and dry weights of tamarind seedlings showed that all these variables were significantly affected ($p<0.05$) by the interaction between the factors evaluated (pre-germinative treatments and substrates), denoting the effect of their interaction on the production of tamarind seedlings (Table 2).

Table 2. Summary of analysis of variance of absolute height growth rate (AGRh), relative height growth rate (RGRh), absolute growth rate of stem diameter (AGRsd), relative growth rate of stem diameter (RGRsd), absolute growth rate (AGRnl), relative growth rate in number of leaves (RGRnl), total fresh weight (TFW) and total dry mass (TDM), in the production of tamarind seedlings as a result of pre-treatments germinative and different substrates.

		MEDIUM SQUASE							
VF	DF	AGRap	RGRh	AGRsd	RGRsd	AGRnl	RGRnl	TFW	TDM
T	4	0.01**	0.00001^{ns}	0.0003**	0.0001**	0.04**	0.00002**	17.04**	1.47**
S	3	0.11**	0.0001**	0.00001^{ns}	0.00005^{ns}	0.25**	0.0002**	172.34**	15.57**
T x S	12	0.02**	0.00004**	0.0001**	0.00005**	0.02**	0.00002**	28.71**	4.24**
Block	5	0.001^{ns}	0.000007^{ns}	0.00005*	0.000008*	0.0008^{ns}	0.000001^{ns}	0.18^{ns}	0.56^{ns}
Resídue	95	0.002	0.000008	0.00001	0.000003	0.001	0.000006	0.65	0.26
CV (%)		25.00	33.46	32.53	30.63	17.13	17.23	11.50	19.76
Média		0.19	0.008	0.01	0.0059	0.22	0.01	7.04	2.58

^{ns} not significant, ** significant at 1% probability; * significant at 5% probability by the F test; VF (variation factor); DF (degree of freedom); T: (treatment) and S (substrates);CV (coefficient of variation).

The substrates and the pre-germinative treatments had significant effect on the absolute and relative growth rates in plant height (Table 2). The S4 substrate (soil + caprine manure) presented higher absolute growth rates than the other pre-germinative treatments, as well as relative growth rates in plant height (Table 3).

A morphological characterization of the tamarind

seeds showed that they present varied sizes (Sousa et al., 2010). This may have hindered the pre-germinative treatments that included mechanical scarification and integument incision, which may have caused mechanical damages to the embryos. Moreover, this species has integument dormancy (Oliveira et al., 2017), and pre-germinative treatments involving the breaking of the integument require practice, and are sometimes unsatisfactory.

Segato et al. (2017) evaluated the effect of different pre-germinative treatments of tamarindseeds and found no significant difference between mechanical scarification with sandpaper + 24-hour imbibition in water and the control; therefore, this treatment is not efficient to overcoming dormancy of tamarind seeds.

Pre-germinative treatments using imbibition in hot water are alternatives for legume seeds; however, Freitas (2016) evaluated the germination of tamarind seeds with this treatment and found a germination percentage of 60%, which is similar to the control treatment (50%) and a lower germination when compared to the other treatments.

Table 3. Absolute growth rate (AGRh) and relative height growth rate (RGRh) in the period 30 and 110 days after sowing, in the production of tamarind seedlings as a function of pre-germinative treatments and different substrates.

	AGRh (cm day^{-1})			
	S1	S2	S3	S4
T1	0.23 Aa	0.04 Bb	0.23 Aa	0.25 Aa
T2	0.19 ABCb	0.14 Ab	0.037 Bc	0.28 Aa
T3	0.15B Cbc	0.10 Abc	0.23 Aa	0.22 Aab
T4	0.13 Cb	0.13 Ab	0.27 Aa	0.28 Aa
T5	0.22 ABab	0.15 Ab	0.21 Ab	0.28 Aa
	RGRh (cm cm^{-1} day^{-1})			
	S1	S2	S3	S4
T1	0.013 Aa	0.0053 Ab	0.009 Aab	0.010 Aa
T2	0.013 Aa	0.0068 Ab	0.02 Bb	0.011 Aa
T3	0.006 Bab	0.004 Ab	0.008 Aab	0.009 Aa
T4	0.006 Bb	0.0057 Ab	0.009 Ab	0.13 Aa
T5	0.008 ABa	0.0069 Aa	0.008 Aa	0.009 Aa

Pre-germinative treatments (T1: mechanical scarification with sandpaper and water soak for 24 hours; T2: cut of the skin and water soak for 24 hours; T3: water soak for 24 hours; T4: seed soaked in water with Trichoderma harzianum for 24 hours; and, T5: seed soaked in water containing Trichoderma longibrachiatum for 24 hours) and different substrates (S1: 100% soil; S2: soil + commercial substrate basaplant Solaris® (3: 2); S3: soil + manure bovine (3: 2); and, S4: soil + goat manure (3: 2)). Means followed by the same uppercase letter in the column and lowercase in the row do not differ statistically from each other by the Tukey test at 5% probability.

The T2, T3, and T4 pre-germinative treatments combined with the S2 substrate had significant effect on the stem diameter absolute growth rate (Table 4). This may be related the lowest organic matter concentration found in this substrate (Table 1), which decreases the water retention capacity (aeration) of this substrate and, mainly, its nutrient availability.

Tamarind seedlings from seed subjected to the T1 pre-germinative treatment and S2 substrate presented better stem diameter relative growth rates, differing significantly from the other substrates and pre-germinative treatments. The combinations T3-S3, T4-S3, T5-S3, T3-S4, T4-S4 and T5-S4 presented no significant differences from each other. The combination T4-S2, followed by T3S2, presented lowest stem diameter relative growth rates, making these treatments unfeasible.

Trichoderma spp. have been used as a bioprotector, by acting as an antagonistic of some plant phytopathogens of economic importance and as plant growth promoter, due to benefic effects for rooting; in addition, it can be used for seed treatments (Junges et al., 2016). Santana-Diaz & Castellanos-González (2018) evaluated the use of *Trichoderma* spp. in seed treatments and found increases in growth parameters (plant height, number of leaves, and dry biomass weight) of seedlings.

An ideal substrate should present adequate conditions for seed germination and root system development, that can be achieved by using different proportions of different materials, such as caprine manure and soil, which can increase plant growth (Araújo et al., 2010). The substrate formulations used in the present work, mainly those containing organic compounds (caprine or bovine manure), provided a beneficial effect to the seedlings. According to Pereira et al. (2016), the use of caprine manure results in a higher growth of rootstocks of tamarind trees than the use of bovine manure; this is probably due to its slower release of nutrients when compared to bovine manure (Mendonça et al., 2014).

The use of formulated substrates based on organic compounds (S3 and S4) resulted in higher absolute growth rate of number of leaves than the other substrates evaluated, showing even better performance when combined with the pre-germinative treatments T1 T3, T4, and T5, which presented no significantly differences from each other. The T2 treatment presented lower results than the other treatments, regardless of the substrate

used, denoting that integument incision and imbibition in water affected the growth and development of tamarind seedlings in the evaluated period (30 to 110 days).

The S4 substrate presented the best results of relative growth rate of number of leaves of tamarind seedlings, with no significant difference between the pre-germinative treatments. The S2 substrate was the less efficient treatment for this parameter, regardless of the pre-germinative treatments, except for T5, in which the *Trichoderma* spp. favored the performance of the tamarind seedlings.

Table 4. Absolute growth rate (AGRdc) and relative growth rate in stem diameter (RGRdc) in the period from 30 days to 110 days after sowing, in the production of tamarind seedlings as a function of pre-germinative treatments and different substrates.

	AGRsd (mm day^{-1})			
	S1	S2	S3	S4
T1	0.015 ABb	0.029 Aa	0.016 Ab	0.016 ABb
T2	0.016 Aa	0.006 Bb	0.009 Ab	0.010 Bab
T3	0.010 ABab	0.006 Bb	0.01 Aa	0.011 Bab
T4	0.009 Bab	0.006 Bb	0.01 Aa	0.013 ABa
T5	0.012 Aba	0.013 Ba	0.01 Aa	0.018 Aa
	RGRsd (mm mm^{-1} day^{-1})			
	S1	S2	S3	S4
T1	0.007 ABb	0.017 Aa	0.006 Ab	0.007 Ab
T2	0.009 Aa	0.0031 Bb	0.004 Ab	0.004 Ab
T3	0.004 Ca	0.0029 Ba	0.005 Aa	0.004 Aa
T4	0.004 Ca	0.0028 Ba	0.005 Aa	0.005 Aa
T5	0.005 BCa	0.0055 Ba	0.006 Aa	0.006 Aa

Pre-germinative treatments (T1: mechanical scarification with sandpaper and water soak for 24 hours; T2: cut of the skin and water soak for 24 hours; T3: water soak for 24 hours; T4: seed soaked in water with Trichoderma harzianum for 24 hours; and, T5: seed soaked in water containing Trichoderma longibrachiatum for 24 hours) and different substrates (S1: 100% soil; S2: soil + commercial substrate basaplant Solaris® (3: 2); S3: soil + manure bovine (3: 2); and, S4: soil + goat manure (3: 2)). Means followed by the same uppercase letter in the column and lowercase in the row do not differ statistically from each other by the Tukey test at 5% probability.

Table 5. Absolute growth rate (AGRnl) and relative growth rate in number of leaves (RGRnl) in the period from 30 days to 110 days after sowing, in the production of tamarind seedlings according to pre-germinative treatments and different substrates.

	AGRnl (day^{-1})			
	S1	S2	S3	S4
T1	0.15Ab	0.04Cc	0.33Aa	0.33 Aa
T2	0.16Ab	0.11Bb	0.11Bb	0.27Ba
T3	0.16Ac	0,12Bc	0.34Aa	0.26Bb
T4	0.17Ab	0.14Bb	0.34Aa	0.38Aa
T5	0.18Ab	0.23Ab	0.32Aa	0.34Aa
	RGRnl (day^{-1})			
	S1	S2	S3	S4
T1	0.015Aa	0.008Bb	0.014Aa	0.017Aa
T2	0.015Aa	0.009Bb	0.009Bb	0.016Aa
T3	0.011Cb	0.009Bb	0.015Aa	0.017Aa
T4	0.013ABbc	0.010Bc	0.015Aab	0.018Aa
T5	0.013ABa	0.014Aa	0.016Aa	0.016Aa

Pre-germinative treatments (T1: mechanical scarification with sandpaper and water soak for 24 hours; T2: cut of the skin and water soak for 24 hours; T3: water soak for 24 hours; T4: seed soaked in water with Trichoderma harzianum for 24 hours; and, T5: seed soaked in water containing Trichoderma longibrachiatum for 24 hours) and different substrates (S1: 100% soil; S2: soil + commercial substrate basaplant Solaris® (3: 2); S3: soil + manure bovine (3: 2); and, S4: soil + goat manure (3: 2)). Means followed by the same uppercase letter in the column and lowercase in the row do not differ statistically from each other by the Tukey test at 5% probability.

These results found for the substrate formulated with caprine manure (S4) may be due to the organic source, which favors moisture retention and supplying of part of nutrients; the Semiarid region of the Northeast of Brazil has a prevalence of caprine herds, making caprine manure abundant and a low-costs alternative for substrates that increase plant growth rate (Dantas et al., 2009).

The use of manure in the composition improves the substrate physical characteristics, such as aeration and water retention, and provides high nitrogen, phosphorus, calcium, and magnesium contents, which increases cation exchange capacity, contributing to the plant development (Oliveira et al., 2014; Costa et al., 2015; Taiz et al., 2017). Contrastingly, the commercial substrate is rich in nutrients, but presents a faster leaching of nutrients than organic compounds, showing no satisfactory long-term results for production of seedlings of fruit trees, including tamarind (Souza et al., 2013).

The use of the S3 and S4 substrates, which were

formulated based on organic compounds, resulted in higher total fresh weight than the use of S1 and S2, which were composed of soil (100%), and soil + commercial substrate (3:2 v v^{-1}), respectively. The combination T1-S3 presented he highest total fresh weight; however, with no significant difference from T1-S4. The lowest fresh weight accumulation was found for the combination T1-S2, denoting that the low organic matter concentration of this substrate may hinder the water retention and, consequently, decrease the water available to plants, affecting directly the fresh weight of tamarind seedlings (Table 5). The use of *Trichoderma* spp.(T4 and T5) as pre-germinative treatments is a viable alternative for seedling production, since it does not expose the seeds to risks of germinative unfeasibility.

The T1 pre-germinative treatment combined with the S3 substrate resulted in higher total dry weight than the other treatments; however, with no significant difference from the combinations T1-S4, T2-S4, T3-S3, and T4-S4 (Table 6). This denotes that the use of organic compounds (caprine manure and bovine) in the formulation may have improved the physical and chemical characteristics of the substrates for the development of seedlings, providing higher photoassimilate accumulations, regardless of the pre-germinative treatments (Table 6).

Table 6. Fresh mass (TFW) and total dryness (TDM) at 110 days after sowing, in the production of tamarind seedlings as a result of pre-germinative treatments and different substrates.

	TFW (g)			
	S1	S2	S3	S4
T1	6.09 Ac	1.95 Bd	11.84 Aa	10.06 Aa
T2	5.97 Ab	5.09 Ab	2.44 Dc	9.97 Aa
T3	5.65 ABa	4.46 Aa	8.52 Ca	7.23 Bb
T4	4.53 Bb	5.36 Ab	9.97 Ba	9.93 Aa
T5	5.91 Ab	5.37 Ab	9.75 BCa	10.63 Aa
	TDM (g)			
	S1	S2	S3	S4
T1	2.25 Ab	0.78 Bc	4.04 Aa	3.29 Aa
T2	2.28 Ab	2.29 Ab	0.85 Bc	3.50 Aa
T3	2.24 Aa	1.69 Aa	3.63 Ab	2.24 Ba
T4	2.00 Ab	2.20 Ab	3.59 Aa	3.49 Aa
T5	2.27 Ab	1.79 Ab	3.41 Aa	3.74 Aa

Pre-germinative treatments (T1: mechanical scarification with sandpaper and water soak for 24 hours; T2: cut of the skin and water soak for 24 hours; T3: water soak for 24 hours; T4: seed soaked in water with Trichoderma harzianum for 24 hours; and, T5: seed soaked in water containing Trichoderma longibrachiatum for 24 hours) and different substrates (S1: 100% soil; S2: soil + commercial substrate basaplant Solaris® (3: 2); S3: soil + manure bovine (3: 2); and, S4: soil + goat manure (3: 2)). Means followed by the same uppercase letter in the column and lowercase in the row do not differ statistically from each other by the Tukey test at 5% probability.

Souza et al. (2015) evaluated the production and quality of papaya seedlings grown on different substrates and found that caprine manure at the proportion of 40% of the substrate volume is a viable alternative organic compound for mixtures with soil for substrates, which results in seedlings with better quality and higher production. Bello & Gada (2015) found higher germination percentage for tamarind seeds subjected to pre-germinative treatment with imbibition in acid sulfuric (H_2SO_4) for 30 minutes and attributed this result to the acid degradation capacity of tissues that protect the seeds, making them permeable to water and nutrients; moreover, the use of the substrate with sand + manure (2:1 v v^{-1}) increased the number of leaves and plant height due to a higher aeration and nutrient availability.

Conclusions

Tamarind (*Tamarindus indica*) seedlings present better growth when using substrates formulated with mixtures of soil and manure (3:2 v v^{-1}). Caprine manure is a more viable source of organic compounds than bovine manure.

The use of pre-germinative treatment with imbibition of seeds in water with *Trichoderma* spp. stimulates the growth of tamarind seedlings.

References

Araújo, W.B.M., Alencar, R.D., Mendonça, V., Medeiros, E.V., Andrade, R.C., Araújo, R.R. 2010. Esterco caprino na composição de substratos para formação de mudas de mamoeiro. *Ciência e Agrotecnologia* 34: 68-73.

Bello, A.G., Gada, Z.Y. 2015. Germination and Early Growth Assessment of *Tamarindus indica* L in Sokoto State, Nigeria. *International Journal of Forestry Research* 2015: 1-5.

Benincasa, M.M.P. 2003. *Análise de crescimento de plantas:* noções básicas. FUNEP, Jaboticabal, Brazil. 41 p.

Bernardo, S., Soares, A.A., Mantovani, E. C. 2006 Manual de irrigação. 8 ed., Viçosa: UFV. 625 p.

Bilcke, N.V., Simbo, J., Samson, R. 2013. Water relations and drought tolerance of young African tamarind (*Tamarindus indica* L.) trees. *South African Journal of*

Botany, 88: 352-360.

Coelho, M.A., Soncin, N.B. 1982. *Geografia do Brasil*. Moderna, São Paulo.Brazil. 368 p.

Costa, E., Sassaqui, A.R., Silva, A.K., Rego, N.H., Fina, B.G. 2016. Soursop seedlings: biomasses and biometric relations in different farming environments and substrates – part II. *Engenharia Agrícola* 36, n.2, p.229-241.

Costa, E., Prado, J.C.L., Cardoso, E.D., Binotti, F.F.S. 2015. Substrate from vermiculite and cattle manure for ornamental pepper seedling production. *Horticultura Brasileira*, 33: 163-167.

Dantas, B.F., Lopes, A.P., Silva, F.F.S., Lúcio, A.A., Batista, P.F., Pires, M.M.M.L., Aragão, C.A. 2009. Taxas de crescimento de mudas de catingueira submetidas a diferentes substratos e sombreamentos. *Revista Árvore*, 33: 413-423.

Dantas, A.C.V.L., Queiroz, J.M.O., Vieira, E.L., Almeida, V.O. 2012. Effect of gibberellic acid and the biostimulant Stimulate® on the initial growth of tamarind. *Revista Brasileira de Fruticultura*, 34: 8-14.

Donagema, G.K.; Campos, D.V.B.; Calderano, S.B.; Texeira, W.G.; Viana, J.H.M. 2011. Manual de métodos de análise de solo, Embrapa solos, 225 p.

Ferreira, A.F.A., Boliani, A.C., Monteiro, A.L.H., Silva, M.S.C., Rodrigues, M.G.F., Faria, G.A., Pigari, L.B., Lopes, B.G., Felizardo, L.M., Peixoto, P.B. 2017. Substrates and indolebutyric acid (IBA) concentrations in air-layering rooting of Tamarind tree. *African Journal of Agricultural Research*, 12: 2926-2932.

Ferreira, D.F. 2014. Sisvar: A Guide for Its Bootstrap Procedures in Multiple Comparisons. *Ciência e Agrotecnologia*, 38: 109-112.

Francisco, P.R.M.; Santos, D. 2017. *Climatologia do Estado da Paraíba*, EDUFCG, Campina Grande, Brazil. 74 p.

Freitas, J.G.M. 2016. *Germinação de sementes de Tamarindus indica L. submetidos a diferentes tratamentos de quebra de dormência.* 37p. (Trabalho de Conclusão de Curso - Agronomia) - Universidade Federal do Maranhão, Chapadinha, Brazil.

Fernandez, J.R.C. 2002. Efeito de substratos, recipientes e adubação na formação de mudas de mangabeira (*Hancornia speciosa* Gomes). 65f. (M.Sc. dissertation) – Federal University of Mato Grosso, Cuiabá, Brazil.

Góes, G.B., Dantas, D.J., Mendonça, V., Araújo, W.B.M., Alencar, R.D., Medeiros, L.F. 2009. Crescimento inicial de muda tipo pé-franco de tamarindeiro (*Tamarindus indica* L.) em diferentes níveis de salinidade na água. *Agrarian*, 2: 63-70.

Góes, G.B., Melo, I.G.C., Mendonça, V., Dantas, D.J., Leite, G.A. 2016. Métodos de enxertia na produção de mudas de tamarindeiro. *Revista Ceres*, 63: 853-859.

Hunt, D.F., Shipley, B., Askew, A.P. 2002. A modern tool for classical plant growth analysis. *Annals of Botany*, 90: 485-488.

Junges, E., Muniz, M.F., Mezzomo, R., Bastos, B., Machado, R.T. 2016. *Trichoderma* spp. na Produção de Mudas de Espécies Florestais. *Floresta Ambiente*, 23: 237-244.

Mastouri, F., Björkman, T., Harman, G.E. 2010. Seed treatment with Trichoderma harzianum alleviates biotic, abiotic, and physiological stresses in germinating seeds and seedlings. *Phytopathology* 100: 1213-1221.

Mendonça, V., Melo, J.K.H., Mendonça, L.F.M., Leite, G.A., Pereira, E.C. 2014. Avaliação de diferentes substratos na produção de porta enxertos de tamarindeiro. *Revista Caatinga*, 27: 60-66.

Oliveira, E.P., Oliveira, E.P., Costa, C.B., Santos, G.M.S.S., Guariz, H.R.2017. Superação de dormência em sementes de *Tamarindusindica* L. submetidas a diferentes tratamentos pré-germinativos. *Revista Científica Eletrônica de Agronomia*, 32: 1-6.

Oliveira, F.S., Farias, O.R., Nobre, R.G., Ferreira, I.B., Figueiredo, L.C., Oliveira, F.S. 2015. Produção de mudas de mamoeiro 'Formosa' com diferentes doses de esterco ovino. *Revista de Ciências Agrárias*, 58: 52-57.

Oliveira, L.C., Costa, E., Oliveira Sobrinho, M.F., Binotti, F.F.S., Maruyama, W.I., Alves, A.C. 2014. Esterco bovino e fibra de coco na formação de mudas de baruzeiro. *Revista de Agricultura Neotropical*, 1: 42-51.

Poorter, H. 1989. Plant growth analysis: towards a synthesis of the classical and the functional approach. *Physiologia Plantarum*, 75: 237-244.

Pereira, E.C., Costa, J.M., Câmara, F.M.M., Farias, W.C., Mendonça, V. 2016. Growth and levels of n, p and k in rootstocks of tamarind trees using organic substrates and doses of phosphorus. *Revista Caatinga*, 29: 274-282.

Santana-Díaz,T., González,L.C. 2018. Efectobioestimulante de *Trichoderma harzianum* rifai en posturas de leucaena, cedro y samán. *Colombia Forestal*, 21: 81-90.

Segato, S.V., Munduruca, L.C., Souza, V.M.S. 2017. Sanidade de sementes e emergência de plântulas de sementes de *Tamarindus indica* submetida a diferentes tratamentos pré-germinativos. *Revista Nucleus*, 14: 1-10.

Sousa, D.M.M., Bruno, R.L.A., Dornelas, C.S.M., Alves, E.U., Andrade, A.P., Nascimento, L.C. 2010. Caracterização morfológica de frutos e sementes e desenvolvimento pós-seminal de *Tamarindus indica* L. - Leguminosae: caesalpinioideae. *Revista Árvore*, 34:1009-1015.

Sousa, V.F.O., Santos, G.L., Rodrigues, M.H.B.S., Pimenta, S.F, Diniz, G.L., Ribeiro, M.D.S., Oliveira, A.M.F., Silva, R.A.2018. Production of cashew rootstocks submitted to organic and mineral fertilization. *Journal of Agricultural Science*, 10: 392-401.

Souza, E.G.F., Barros Júnior, A.P., Silveira, L.M., Santos, M.G., Silva, E.F. 2013. Emergência e desenvolvimento de mudas de tomate IPA 6 em substratos, contendo esterco ovino. *Revista Ceres*, 60: 902-907.

Souza, R.R., Matias, S.S.R., Silva, R.R., Silva, R.L., Barbosa, J.S.M. 2015. Qualidade de mudas de mamão produzidas em substrato com esterco caprino e doses de superfosfatosimples. *Agrarian*, 8: 139-146.

Taiz, L., Zeiger, E., Moller, I. M., Murphy, A. 2017. *Fisiologia e Desenvolvimento Vegetal*. Artmed, Porto Alegre, Brazil. 888 p.

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