ALTERNATIVE SUBSTRATES FOR THE PRODUCTION OF MORINGA SEEDLINGS IN MOZAMBIQUE

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ABSTRACT: The production of quality seedlings is a fundamental factor for the success of forestry. However, this activity depends on the choice of the substrate that promotes optimal seedling development. In the present study, different substrates for the production of *Moringa oleifera* seedlings in nursery were tested. The experiment was carried out at the campus of the Faculty of Agricultural Sciences, Lúrio University, Unango, Mozambique, using a completely randomized design, with eight treatments and six replicates. The substrates used were combinations of bovine manure, poultry manure, carbonized rice husk, sawdust and sandy-clay soil. At the end of 45 days, the following variables were analyzed: emergence, survival, height, stem diameter, plant height-stem diameter ratio, biomass and Dickson quality index. The substrate composed of bovine manure and sandy-clay soil presented the best results for most of the analyzed variables, while substrate composed of poultry manure and carbonized rice husk was not favorable, as it did not show significant results. The study demonstrated good potential of local substrates for the production of *Moringa oleifera* seedlings in Mozambique. However, further studies should be carried out in order to test other substrates easily accessible to farmers.

KEYWORDS: Nursery; Seedling production; *Moringa oleifera*.

SUBSTRATOS ALTERNATIVOS PARA PRODUÇÃO DE MUDAS DE MORINGA EM MOÇAMBIQUE

RESUMO: A produção de mudas de boa qualidade é fator fundamental para o sucesso da silvicultura. No entanto, essa atividade é dependente da escolha do substrato que promova ótimo desenvolvimento das mudas. No presente estudo foram testados diferentes substratos para a produção de mudas de *Moringa oleífera* em viveiro. O experimento foi desenvolvido no campus da Faculdade de Ciências Agrárias da Universidade Lúrio, em Unango, Moçambique, utilizando um delineamento inteiramente casualizado, com oito tratamentos e seis repetições. Os substratos usados foram combinações de esterco bovino curtido, esterco de aves curtido, casca de arroz carbonizada, serragem e solo areno-argiloso. Ao final de 45 dias foram analisadas as seguintes variáveis: emergência, sobrevivência, altura, diâmetro do colo, relação altura da planta-diâmetro do colo, biomassa e índice de qualidade de Dickson. O substrato composto por esterco bovino curtido e solo arenoso-argiloso apresentou os melhores resultados para a maioria das variáveis analisadas, enquanto o substrato com esterco de aves curtido e casca de arroz carbonizada, não é favorável, pois não mostrou resultados significativos. O estudo demonstrou bom potencial dos substratos locais na produção de mudas de *Moringa oleífera* em Moçambique. No entanto, mais estudos devem ser realizados testando outros substratos de fácil acesso aos agricultores.

PALAVRAS CHAVE: Viveiro; Produção de mudas; *Moringa oleifera*.

INTRODUCTION

Moringa (*Moringa oleifera* Lam) is a perennial plant from India belonging to the Moringaceae family. Its food (leaves, unripe fruits, roasted flowers and seeds), medicinal (all plant parts), forage (leaves, fruits and seeds), cosmetic, flavoring, culinary, melliferous (flowers) and fuel (wood and oil) use justifies its cultivation in several countries around the world (Camargo, 2011). The oil extracted from its seeds has high resistance to oxidation and contains high levels of unsaturated fatty acids, especially oleic acid (71.6%) (Lalas and Tsakins, 2002).

It is a species that propagates through seeds and cuttings, usually through the production of seedlings in nurseries. However, the production of quality seedlings for planting is essential for the formation of equally superior plants. Therefore, several studies have been carried out to define the best containers, substrates, dosages and types of fertilizers for the production of quality seedlings, giving preference to alternative materials for the production of substrates that do not present limitations to seedling growth (Delarmelina et al., 2015).

The substrates used for seedling production can be of any material or mixture of materials that have desirable and fundamental characteristics for efficient plant development, such as balanced water retention, good drainage, good aeration, lightness, easy acquisition and handling and absence of pathogens and toxic substances (Scremin-Dias et al., 2006).

The formulation of substrates can be highly varied, as it depends on the nutritional needs of plants and on the availability of materials in a given location. Thus, in the present study, different substrates easily accessible to farmers in Mozambique were tested in order to indicate those that result in the best development of *Moringa oleifera* seedlings in nursery.

MATERIAL AND METHODS

The experiment was carried out from October to December 2017 in the nursery of the Faculty of Agricultural Sciences of the Lúrio University, Unango, Mozambique, at coordinates 12°26'S and 35°22W. A completely randomized design with 8 treatments, 6 replicates with 3 seeds/pot was used. Polypropylene pots measuring 8 cm in width, 15 cm in diameter and 0.07 mm in thickness were used. Treatments consisted of eight substrate compositions, including the sandy-clay soil substrate, characteristic of the site, which served as control (Table 1).

Table 1. List of substrates used in the experiment, Lúrio University, 2017

Substrate	Proportion (%)							
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
Sandy-clay soil – SAA (Control)	100	50	-	50	40	-	-	-
Bovine manure – EBC	-	50	-	-	-	50	-	30
Poultry manure – EAC	-	-	60	-	40	-	40	30
Carbonized rice husk – CAC	-	-	40	-	20	-	20	20
Sawdust – S	-	-	-	50	-	50	40	20

Forty-five days after seed planting, the following variables were determined: emergence percentage, emergence speed index – ESI, plant height, stem diameter, height-diameter ratio, survival, fresh biomass and dry biomass. Dickson's quality index and Pearson's correlation coefficient were also determined.

The Dickson Quality Index (DQI) (Dickson et al., 1960) was determined using the following formula:

$$DQI = \frac{MST}{\frac{H}{DC} + \frac{MsPA}{MsPR}} \quad \text{(Equation 1)}$$

where MST is the total dry matter (g), H is the plant height (cm), DC is the stem diameter (mm), MsPA is the shoot dry matter (g) and MSPR is the root dry matter (g).

Data were submitted to analysis of variance by the F test and means were compared by the Scott-Knott test at 5% probability using the SISVAR 5.3 software.

RESULTS

Excellent seed emergence was observed in all treatments, with the exception of substrate T3 [poultry manure (60%) and carbonized rice husk (40%)], which presented percentage lower than 50%. Substrates T1 (100% sandy-clay soil) and T5 (40% poultry manure + 20% carbonized rice husk + 40% sandy-clay soil) had 100% emergence (Figure 1). For the seedling survival treatment, substrate T3 also presented lower value compared to the other treatments, which did not differ from each other (Figure 2).

Regarding the emergence speed index, substrate T3 presented the lowest value, with emergence starting at 9 days after sowing and reaching maximum ESI at 11 days. The highest ESI was observed in substrate T4, composed of sawdust (50%) and sandy-clay soil (50%), reached 5 days after sowing (Figure 3).

Analysis of variance detected significant differences among substrates for plant height and stem diameter at 15, 30 and 45 days. Substrate T2 provided one of the highest plant heights in the first evaluation, at 15 days, with the best value both at 30 days and 45 days. The same treatment also stood out over the others at 45 days, and at 15 days, T4, T5, T6, T4 and T8 had the largest diameters and at 30 days, no difference among substrates was observed. Regarding the relationship between plant height and neck diameter, T1 and T3 had the lowest values (Table 2).

Figure 1. Moringa seedling emergence percentages as a function of different substrates, Lúrio University, 2017. T1: 100% sandy-clay soil; T2: 50% bovine manure + 50% sandy-clay soil; T3: 60% poultry manure + 40% carbonized rice husk; T4: 50% sawdust + 50% sandy-clay soil; T5: 40% poultry manure + 20% carbonized rice husk + 40% sandy-clay soil; T6: 50% bovine manure + 50% sawdust; T7: 40% poultry manure + 20% carbonized rice husk + 40% sawdust; T8: 30% poultry manure + 20% carbonized rice husk + 20% sawdust + 30% bovine manure.

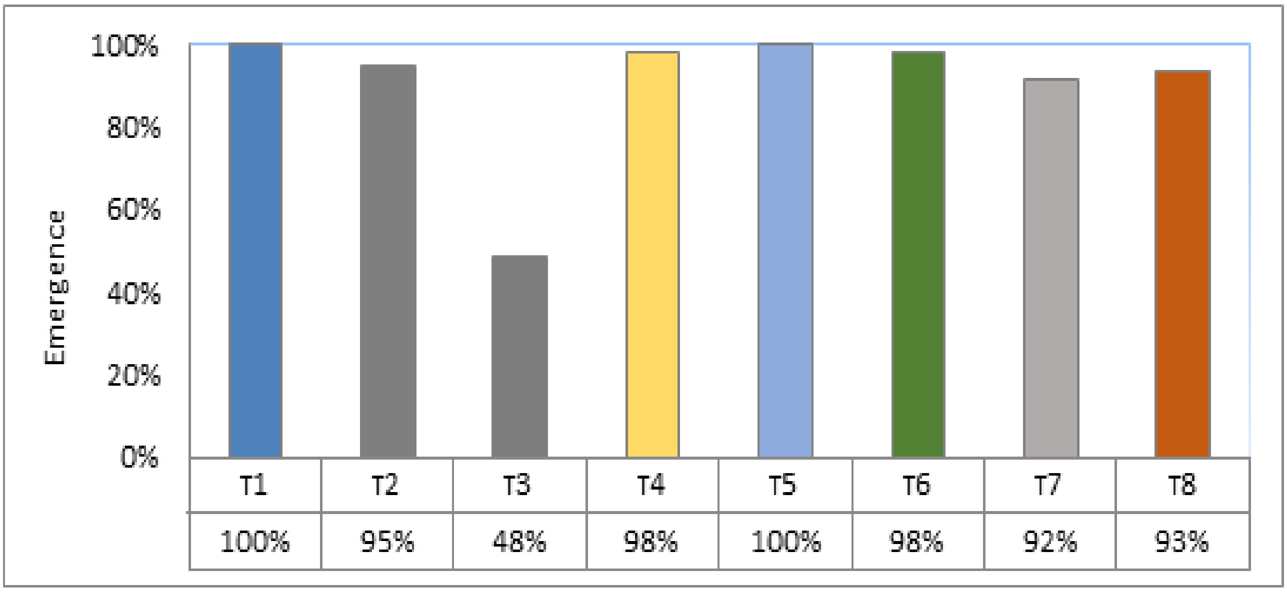

Figure 2. Moringa seedling survival percentage as a function of different substrates, Lúrio University, 2017. T1: 100% sandy-clay soil; T2: 50% bovine manure + 50% sandy-clay soil; T3: 60% poultry manure + 40% carbonized rice husk; T4: 50% sawdust + 50% sandy-clay soil; T5: 40% poultry manure + 20% carbonized rice husk + 40% sandy-clay soil; T6: 50% bovine manure + 50% sawdust; T7: 40% poultry manure + 20% carbonized rice husk + 40% sawdust; T8: 30% poultry manure + 20% carbonized rice husk + 20% sawdust + 30% bovine manure.

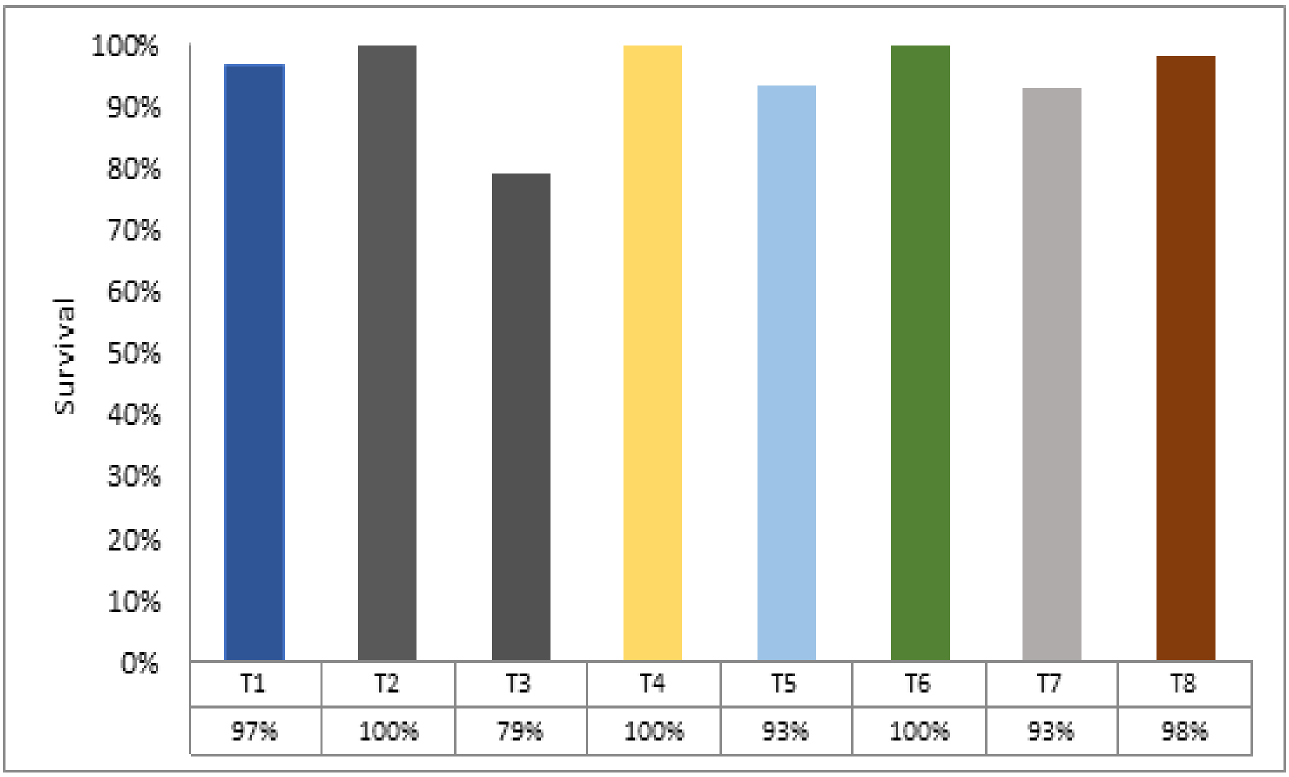

Figure 3. Behavior of emergence speed indices as a function of different substrates, Lúrio University, 2017. T1: 100% sandy-clay soil; T2: 50% bovine manure + 50% sandy-clay soil; T3: 60% poultry manure + 40% carbonized rice husk; T4: 50% sawdust + 50% sandy-clay soil; T5: 40% poultry manure + 20% carbonized rice husk + 40% sandy-clay soil; T6: 50% bovine manure + 50% sawdust; T7: 40% poultry manure + 20% carbonized rice husk + 40% sawdust; T8: 30% poultry manure + 20% carbonized rice husk + 20% sawdust + 30% bovine manure.

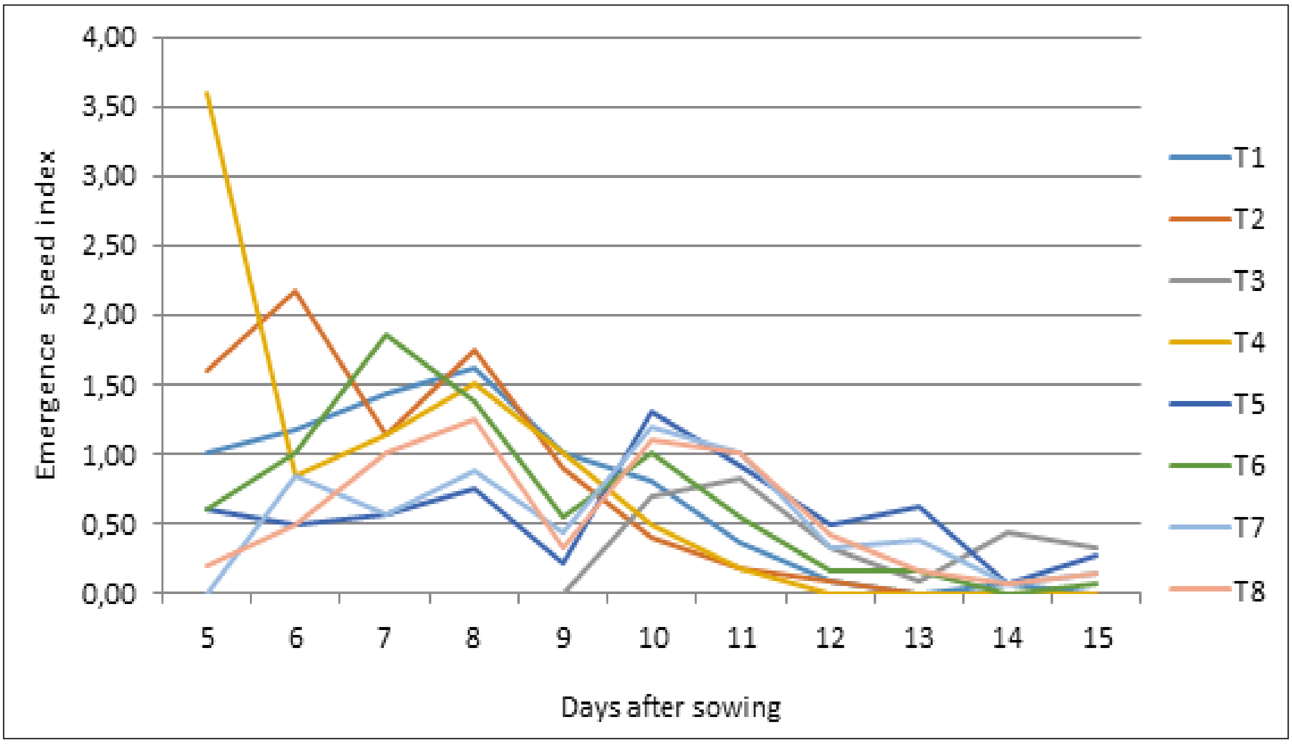

Table 2. Summary of the analysis of variance of height, stem diameter and plant height- stem diameter ratio of moringa seedlings as a function of different substrates, Lúrio University, 2017. T1: 100% sandy-clay soil; T2: 50% bovine manure + 50% sandy-clay soil; T3: 60% poultry manure + 40% carbonized rice husk; T4: 50% sawdust + 50% sandy-clay soil; T5: 40% poultry manure + 20% carbonized rice husk + 40% sandy-clay soil; T6: 50% bovine manure + 50% sawdust; T7: 40% poultry manure + 20% carbonized rice husk + 40% sawdust; T8: 30% poultry manure + 20% carbonized rice husk + 20% sawdust + 30% bovine manure.

Treatment	Height (cm)			Stem diameter (mm)			H/D ratio		
	15 days	30 days	45 days	15 days	30 days	45 days	15 days	30 days	45 days
T1	12.197 b	19.867 c	24.643 c	2.763 d	3.315 a	4.168 b	4.45 a	6.00 a	5.935 b
T2	14.103 a	24.683 a	32.708 a	2.857 c	3.59 a	4.535 a	4.94 a	6.883 a	7.235 a
T3	5.367 c	16.767 d	18.697 d	2.898 b	3.072 a	3.303 d	1.843 c	5.482 a	5.695 b
T4	13.697 a	21.65 b	30.45 b	2.948 a	3.39 a	3.957 c	4.65 a	6.422 a	7.763 a
T5	10.825 b	19.633 c	29.572 b	2.978 a	3.398 a	3.837 c	3.633 b	6.345 a	7.803 a
T6	14.775 a	21.167 b	28.725 b	2.982 a	3.443 a	4.002 c	4.953 a	6.172 a	7.212 a
T7	14.128 a	22.3 b	29.038 b	2.955 a	3.283 a	3.763 c	4.783 a	6.803 a	7.742 a
T8	14.342 a	21.2 b	29.095 b	2.968 a	3.295 a	3.737 c	4.832 a	6.46 a	7.817 a
General average	12.429	20.908	27.866	2.919	3.348	3.913	4.261	6.321	7.15
F value	30.468*	7.643*	19.302*	22.357*	2.71*	9.329*	28.453*	1.886^{ns}	5.469*
CV (%)	11.21	9.71	8.66	1.35	6.64	7.32	11.48	12.66	12.63

Means followed by the same letter in the column do not differ from each other by the Scott-Knott test at 5% probability level

* = significant at 5% error probability level ($p < 0.05$); ns = not significant.

Differences among substrates for shoot dry biomass, root dry biomass and total dry biomass were observed. Substrate T3 had the lowest biomass values, whereas the other treatments did not differ significantly from each other.

Correlation analysis indicated that there was positive correlation among variables at 5% significance, with the exception of neck diameter and plant height-neck diameter ratio, whose correlation was not significant.

DISCUSSION

In the present study, satisfactory plant height and stem diameter growth was observed, with values from 18.697 to 29.572 cm and from 3.303 to 4.535 mm, respectively, at 45 days. Similar values were obtained over a longer period of time (70 days) in studies using organic matter as substrate, with values ranging from 18.33 to 37 cm and from 2.3 to 5.5 mm, respectively (Camargo, 2011).

The least favorable results for all variables were obtained for substrate containing the highest rice husk content in its composition (T3), composed of poultry manure (60%) and carbonized rice husk (40%). This result is consistent with Delarmelina et al. (2015), who do not recommend the use of rice husk in substrates due to inadequate total porosity values and low content of nutrients.

Substrate T2 stood out in the growth variables (plant height and stem diameter). This substrate contains the highest proportion of bovine manure (50%), a component that has been shown to be effective in other studies in which the best results were obtained with substrates composed of bovine manure in the production of *Euterpe oleracea* and *Chamaecrista desvauxi*, respectively (Menezes and Oliveira, 2009; Delarmelina et al., 2015). These authors justify the success with bovine manure due to its nutritional composition and its effect on microbiological processes, aeration, structuring, water retention capacity and temperature regulation of the medium.

In studies with *Moringa oleifera* (Neves et al., 2010), bovine manure stood out among the best biomass production values (shoot and root) while poultry manure was among the least favorable. Biomass is a good indicator of seedling quality. Dry shoot biomass indicates the rusticity of a seedling and higher values represent more lignified and rustic seedlings, which allows greater survival in environments with adverse conditions (Gomes and Paiva, 2011), whereas root biomass is important because root supports the green mass produced by plants (Carneiro, 1995), which is similar to biomass obtained from all other analyzed variables, as they have positive and significant correlation with biomass.

Another indicator of seedling quality is the DQI, whose values ranged from1.625 to 1.9, for T7 and T2, respectively, being within the range obtained by Rodrigues et al. (2016) in *Moringa oleifera* seedlings cultivated in substrates with green coconut fiber and organic compounds, which ranged from 1.0 to 5.0, but higher than those obtained in other tree species. The maximum DQI value obtained in *Eucalyptus urophylla* x *E. grandis* clone seedlings cultivated in substrate with coconut fiber + Vermiculite (1:1) was 0.19 (Da Silva et al., 2012), while *Khaya anthotheca* seedlings cultivated in irrigated sand resulted in DQI values ranging from 0.43 to 1.01 (Vieira et al., 2014). Thus, it could be considered that the seedlings produced in this study are of acceptable quality.

The study demonstrated the potential of local substrates in the production of *Moringa oleifera* seedlings in Mozambique. Substrate composed of bovine manure and sandy-clay soil showed the best results for the production of *Moringa oleifera* seedlings. However, it can be replaced by other substrates used in this experiment, as they had similar performance in most of the analyzed variables, with the exception of substrate with poultry manure and carbonized rice husk, which presented lower results.

Ciência Agrícola, Rio Largo, v. 19, n. 2, p. 115-121, 2021

Table 3. Analysis of variance for shoot (BsPA), root (BsPR) and total (Bstotal) dry biomass and the Dickson quality index of moringa seedlings as a function of different substrates, Lúrio University, 2017.

Treatment	Description	Biomass (g)			DQI
		BsPA (g)	BsPR (g)	Bstotal (g)	
T_1	100% sandy-clay soil	2.667 a	2.983 a	5.65 a	1.853 a
T_2	50% bovine manure + 50% sandy-clay soil	3.417 a	3.783 a	7.2 a	1.9 a
T_3	60% poultry manure + 40% carbonized rice husk	1.167 b	1.733 b	2.9 b	1.197 c
T_4	50% sawdust + 50% sandy-clay soil	2.917 a	3.167 a	6.083 a	1.72 b
T_5	40% poultry manure + 20% carbonized rice husk + 40% sandy-	2.917 a	3.25 a	6.167 a	1.71 b
T_6	50% bovine manure + 50% sawdust	3.367 a	3.767 a	7.133 a	1.898 a
T_7	40% poultry manure + 20% carbonized rice husk + 40% sawdust	2.717 a	3.233 a	5.95 a	1.625 b
T_8	30% poultry manure + 20% carbonized rice husk + 20% sawdust +	3.167 a	3.5 a	6.667 a	1.763 b
	General average	2.792	3.177	5.969	1.708
	F value	8.879*	5.892*	7.466*	29.217*
	CV (%)	20.98	20.62	20.41	6.06

Means followed by the same letter in the column do not differ from each other by the Scott-Knott test at 5% probability level
* = significant at 5% error probability level ($p < 0.05$); ns = not significant.

Table 4. Pearson linear correlation coefficient among variables plant height, stem diameter, plant height-stem diameter ratio (H/D), root dry biomass (BsPR), shoot dry biomass (BsPA) and total dry biomass (Bstotal), Lúrio University, 2017.

	Height	Diameter	H/D	BsPR	BsPA	Bstotal
Height	1					
Diameter	0.4097188*	1				
H/D	0.7942966*	-0.2221567^{ns}	1			
BsPR	0.5837817*	0.5200923*	0.2841445*	1		
BsPA	0.6761815*	0.5071803*	0.3914386*	0.9588175*	1	
Bstotal	0.6366336*	0.5189986*	0.3413983*	0.9896223*	0.9896794*	1

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