CLOD STRUCTURE AND THE QUALITY OF MORINGA SEEDLINGS (*Moringa oleifera* LAM.) GROWN IN COMMERCIAL SUBSTRATE AND IN ORGANIC COMPOSTS

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ABSTRACT – The cultivation of tuberous-root species such as *Moringa oleifera* Lam. (moringa) requires well-dimensioned containers and the use of appropriate substrates, since seedlings will be removed from the container before their planting. Sugarcane bagasse, urban waste compost (compost), and vermicompost are promising wastes for substrate composition. The present study aims to assess the quality of moringa grown in substrate produced from sugarcane bagasse associated with compost or vermicompost in different-volume tubes. The study followed a randomized blocks design, at 2x7 factorial arrangement, namely: tubes' volumes (50 and 240 mL) x seven substrates (commercial substrate; sugarcane bagasse associated with urban waste compost at three different ratios (1:3; 1:1 and 3:1) and sugarcane bagasse associated with vermicompost at ratios 1:3; 1:1 and 3:1). In conclusion, the 240 mL container was the most appropriate one for moringa seedlings' production. Substrates presenting higher organic compost ratios led to greater shoot and tuberous root growth and to greater nitrogen-use accumulation and efficiency, which was equivalent to that of the commercial substrate. Higher sugarcane bagasse rates in substrate composition made it easier to remove the seedlings from the tubes and led to better physical quality of the clod after seedling removal from the tubes.

Keywords: Tuberous root; vermicompost; tubes.

ESTRUTURA DO TORRÃO E QUALIDADE DE MUDAS DE MORINGA (Moringa oleifera *LAM.) PRODUZIDAS EM SUBSTRATO COMERCIAL E EM COMPOSTOS ORGÂNICOS*

RESUMO – O cultivo de mudas de espécies com raízes tuberosas como **Moringa oleifera** *Lam. (moringa), requer recipientes bem dimensionados e o uso de substratos adequados, considerando que a muda será retirada do recipiente antes do plantio. Bagaço de cana, composto de lixo urbano (composto) e vermicomposto são resíduos promissores na composição de substratos. O trabalho teve como objetivo avaliar a qualidade das mudas de moringa cultivadas em substratos produzidos a partir de bagaço de cana associado com composto ou vermicomposto em tubetes de diferentes volumes. O delineamento experimental foi em blocos casualizados, em esquema fatorial 2x7, sendo: volumes dos tubetes (50 e 240 mL) x sete substratos (substrato comercial; bagaço de cana misturado a composto de lixo urbano em tres diferentes proporções (1:3; 1:1 e 3:1) e bagaço de cana misturado a vermicomposto nas proporções 1:3; 1:1 e 3:1). Concluiu-se que o recipiente de 240 mL foi o mais adequado para a produção de mudas de moringa. Substratos com maiores proporções de composto orgânico resultaram em maior crescimento da parte aérea e das raízes tuberosas, conteúdo e eficiência do uso de nitrogênio, sendo equivalente ao substrato comercial. Maiores proporções de bagaço de cana na composição do substrato proporcionaram maior facilidade de retirada das mudas dos tubetes e melhor qualidade física do torrão após a retirada da muda do tubete.*

Palavras-Chave: Raiz tuberosa; vermicomposto; tubetes.

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1. INTRODUCTION

Substrate formulation in seedlings production must ensure their physical and chemical quality. Besides providing the necessary nutrients for seedlings' development, substrate must be well-aggregated by the root at the time to remove the seedling from the container, before its planting to protect it from impacts or from drying. The smallest containers possible must be used to minimize the used areas in the nursery and to reduce costs with seedlings' transportation to the field. However, containers' dimensions are particularly relevant for tuberous-root species, such as *Moringa oleifera* Lam.

Moringa is natural from India but, nowadays, it is found in almost all continents. Different moringa parts present compounds with pharmaceutical potential and with different nutritional compounds (Singh and Singh, 2019). Given the outspread of moringa using as phytotherapy in Brazil, the National Health Surveillance Agency (ANVISA, 2019) temporarily forbad this species to be traded for such a purpose. On the other hand, when it comes to agricultural properties, this species presents multiple applications, and it demands large scale supply throughout the year (Sandeep et al., 2019, Sengupta, et al., 2012). Macambira et al. (2018) recommend its leaves for broiler feed (37.7%). Moringa leaves can be offered in the diet of milk cattle as protein supplementation, mainly during drought periods throughout the year, to replace part of the sugarcane (Lisita et al., 2018). Its seeds have abundant oil reserves for biodiesel production (Omonhinmin et al., 2020). Seed polysaccharides have agglutinating and sedimentation power, they can decrease water turbidity (Sengupta et al., 2012; Santos et al., 2019) and can be used for animal feeding. Moringa leaves can also be used as green fertilizer or in composters, and their tree canopy can be used for shading and beekeeping. Cultivation in arid and semiarid regions is recommended, since moringa's tuberous roots are highly capable of absorbing and accumulating groundwater and underground mineral salts. This process allows plants to remain green all year long and survive in times of drought (Ndubuaku et al., 2014).

Moringa's tuberous roots require special care at seedling production, either concerning container dimensions or substrate. The use of agricultural-industrial wastes can oftentimes replace commercial substrates without affecting the quality of seedlings (Araújo et al. 2020); furthermore, fertilization with organic composts is essential for moringa cultivation for phytotherapy-compounds production (Abud-Archila et al., 2018).

Sugarcane bagasse (B) is the material used in substrate composition for seedling production. This bagasse is the waste from sugar and alcohol production, and it represents 30% of the total of ground sugarcane (Silva et al., 2007); part of this waste is reused in ovens and the remaining part of it is disposed. Its high C/N ratio (Rodda et al., 2006) can be reduced by the addition of other organic matters, such as composter products, or by vermicomposting, which results from the metabolism of worms or of microorganisms found in their intestines (Ramnarain et al., 2019). The presence of vegetal growth hormones, enzymes (Garcia et al., 2016), macro and micro-nutrients essential for plants in vermicomposts (Ramnarain et al., 2019) favor plants' nutrition status and, consequently, their growth (Hussain and Abbasi, 2018). Using sugarcane bagasse along with urban waste compost (UWC) or vermicompost in substrate composition for moringa seedling production would be a way to rationally use wastes in order to reach economic and environmental goals, besides the possibility of improving seedling nutrition. Thus, the aim of the present study was to assess the quality of *Moringa oleifera* Lam seedlings grown in substrates sugarcane bagasse mixes with urban waste compost (UWC) or with vermicompost (V), as well as in different-volume tubes.

2. MATERIALS AND METHODS

The experiment was carried out in greenhouse at Instituto Superior de Tecnologia em Ciências Agrárias, Campos dos Goytacazes County, RJ, which is located 21°72'15" (S) and 41°34'43" (W). It was conducted from April to August 2010, under temperature ranging from 17° C to 27° C, and relative humidity ranging from 60% to 80%, with species *Moringa oleifera* Lam. (moringa).

The experiment followed the randomized blocks design (5 blocks), at 2x7 factorial arrangement, namely: two tube volumes (50 mL and 240 mL) x seven substrates (commercial substrate Plantmax® (S-Com); sugarcane bagasse (B) associated with urban waste compost (UWC) at three different ratios (B:UWC) 1:3; 1:1 and 3:1; and B associated with vermicompost (V) at ratios (B:V) 1:3; 1:1 and 3:1. B and UWC or V ratios determined for the composition of each substrate were based on the volume of each material, by taking into consideration density B´s = 105 gdm^{-3}, UWC's = 820 gdm^{-3} and V's = 800 gdm^{-3}.

UWC was produced based on urban organic waste composting process. The material was considered partially composted and ready for vermicomposting right after temperature stabilization in the composter (Cotta et al., 2015) – part of the material was separated to receive the worms. The other part of the material under composting remained on the windrow for the maturation phase. After approximately 30 days, both parts were ready for use as organic compost, based on temperature and pH stabilization, on their dark color (brown), lack of smell, the small and loose grains, and on material of unidentifiable origin. Both materials were sieved (4 mm mesh) before their use. UWC chemical analysis pointed out water pH of 7.7; P and K contents of 462 and 2366 mgdm^{-3}, respectively; Ca, Mg, Al, Al+H, Na and CEC contents of 20.00, 5.30, 0.00, 1.40, 4.07 and 36.80 cmolcdm^{-3}, respectively; and 5.5% C. V chemical analysis showed water pH of 7.8; P and K contents of 528 and 2,782.00 mgdm^{-3}, respectively; Ca, Mg, Al, Al+H, Na and CEC contents of 15.30, 4.80, 0.00, 1.30, 4.68 and 33.20 cmolcdm^{-3}, respectively; and 3.9% C.

B substrate was obtained from sugarcane bagasse waste deriving from alcohol and sugar production in São João da Barra County, RJ. B was left to dry on the shade for 5 days.

The 50 mL tube (2.6 cm in diameter and 12 cm in height) was selected because it is the most used one in nurseries and the one that uses the lowest substrate volume; the 240 mL one (5cm in diameter and 13 cm in height) was selected because it presents the biggest diameter. The 50 mL and 240 mL tubes were installed in plastic supports on a counter in greenhouse. Each treatment comprised four seedlings in each block. All wastes were weighed before they were mixed for substrate composition - it was done by taking into account the pre-defined ratios, based on the volume of each material.

Seeds belonging to species *M. oleifera* Lam. were provided by Embrapa Tabuleiros Costeiros – Aracaju/SE. They were soaked in water for approximately 20 hours and sown right in the tubes (two seeds per tube) – more substrate was added to the tubes to cover the seeds. Thinning was carried out at 18 days after sowing; only one plant was left in each tube. As for irrigation, every 20 days, two tubes of each treatment were added with water until the beginning of the drainage. Water volume was measured and used to irrigate the other repetitions of this same treatment. It was done by having in mind the differential drainage between substrates and tubes' volume.

Approximately 40 days after planting, seedlings started to present mineral-deficiency symptoms under some treatments. Symptoms have started in the oldest leaves and they were identified by chlorosis in leaf blade. According to Römheld (2012), these symptoms are, overall, characteristic of N deficiency.

Plant height was measured at 60 days after planting; subsequently, 60 mg dm^{-3} of N (urea) and 20 mg dm^{-3} of P (Simple Superphosphate) were added to the irrigation water in all treatments, and 100 mg dm^{-3} of FTE-BR12 was added to it in order to provide micronutrients. Plant height (H) was measured with the aid of millimeter ruler at 98 days after sowing, from plant basis (right by the ground) up to the youngest seedling bud; diameter (D) was measured with digital caliper, from the stem basis to approximately 1cm from the substrate.

Seedlings were removed from the tubes; at this moment, it was possible evaluating their ease of removal from the tubes (ERT) and clod structure. Seedlings were classified based on ERT scores – which ranged from 1 to 5, wherein, 1 – root breaking (not possible removing the clod from the tube); 2 – very hard to remove the clod, but it was possible; 3 – moderate difficulty; 4 – moderately easiness and 5 – easy to be removed from the tube.

Clod structure evaluation was carried out by assessing the root system + the amount of adhered substrate after taking the seedling out of the tube. Scores have ranged from 1 to 5: wherein, 1 (root breaking or substrate-free root); 2 (< 25% of substrate adhered to the root); 3 (25% to 50% of substrate adhered to the root); 4 (50% to 75% of substrate adhered to the root); and 5 (75% to 100% of substrate adhered to the root or whole clod).

Shoot were cut right after plants were removed from the tubes; it was done with the aid of a pruning shear and shoot were stored in paper bags. Roots were separated from the substrate by washing them in water on a 2 mm mesh sieve; next, they had their volume measured. The tuberous root was soaked in water with the aid of a stiletto (that is the reason why a 500 mL beaker was used), and water volume displacement difference was considered to be the tuberous root volume. Subsequently, roots were dried in paper, in air circulation oven, under forced air renovation, at 65 ° C, for 72 hours. Next, they were weighed on electronic scale to assess root dry matter weight (RDW) and shoot dry matter weight (SDW). Total dry matter weight (TDW) was obtained by summing SDW to RDW.

Shoot dry matter was subjected to sulfuric digestion; N content was determined based on the method by Kjeldahl (Claessen et al., 1997). N accumulation was calculated based on SDW and N use efficiency (NUE) in the shoot was estimated based on the equation 1. Dickson's Quality Index (DQI) (Dickson et al., 1960) was estimated through the equation 2.

$$NUE=[((SDW.SDW))/(N\ Accumulated)] \quad \text{Eq. 1}$$

$$DQI=[TDW/(((H/D)+(SDW/RDW)))] \quad \text{Eq. 2}$$

Wherein N accumulated (expressed in g plant^{-1}), TDW (Total dry matter weight), SDW (shoot dry matter weight) and RDW (root dry matter weight), expressed in g; H (height) expressed in cm; and D (Diameter stem base) in millimeters.

Statistical analysis was carried out in SAEG software. Data were subjected to analysis of variance, and means were compared through Tukey test, at 5% probability level.

3. RESULTS

Moringa plants in 240 mL tubes, grown in substrate presenting the highest sugarcane bagasse ratios (B+UWC and B+V 3:1), showed visible nutritional deficit. These symptoms started to show up approximately 40 days after planting – this outcome was evidenced by the light green color observed in the oldest leaves. At 60 days (time of the first height

Table 1 – Summary of the Analysis of variance, which indicates the significance based on the F test recorded for variables: shoot dry mass weight (SDW), root dry mass weight (RDW), total dry mass weight (TDW), stem diameter (D), tuberous root volume (V-Root), seedling height at 60 days after sowing (H-60), seedling height at 98 days (H-98), easiness to remove the seedling from the tube (ERT), clod structure (CS), Dickson's quality index (DQI), N content, N accumulation and use N use efficiency (NC, NA and NUE) in moringa plants' shoot.

Tabela 1 *– Resumo da Análise de Variância indicando a significância pelo teste de F para as variáveis: peso da massa seca da parte (TDW), diâmetro caule (D), volume da raiz tuberosa (V-Root), altura das mudas aos 60 dias após semeio (H-60), altura das mudas aos 98 dias (H-98), facilidade de retirada da muda do torrão (ERT), estrutura do torrão (CS), índice de qualidade de Dickson (DQI), teor, conteúdo (acumulação) e eficiência de utilização de nitrogênio (NC, NA e NUE) na parte aérea das plantas de moringa.*

	DF	SDW	RDW	TDW	D	V-raiz
Substrate (S)	6	0,0000	0,0121	0,0018	0,0000	0,0062
Tube (T)	1	0,0000	0,0000	0,0000	ns	0,0000
SxT	6	0,0000	0,0004	0,0008	0,0080	0,0066
Block	4	ns	ns	ns	0,0360	ns
CV (%)		30	44	37	13	28
		H-60	H-98	ERT	CS	DQI
Substrate (S)	6	0,0039	0,0000	0,0000	0,0000	ns
Tube (T)	1	0,0008	0,0481	0,0057	ns	0,0000
SxT	6	ns	0,0232	ns	ns	0,0037
Block	4	ns	0,0366	ns	ns	ns
CV (%)		19	16	37	40	42
		NC	NA	NUE		
Substrate (S)	6	ns	0,0000	0,0002		
Tube (T)	1	ns	0,0000	0,0002		
SxT	6	ns	0,0000	0,0161		
Block	3	ns	0,0048	ns		
CV (%)		25	25	42		

DF=degree of freedom; CV = Coefficient of variation; ns: not significant - F test (at 5% probability level).

DF=grau de Liberdade; CV = Coeficiente de variação; ns: não significativo - teste F (ao nível de 5 % de probabilidade).

Table 2 – Nitrogen in moringa seedlings grown in 50 mL and 240 mL tubes (T) in commercial substrate (S-Com) or substrates of the sugarcane bagasse (B) associated with urban waste compost (UWC) or with vermicompost (V).
Tabela 2 *– Nitrogênio em mudas de moringa cultivadas em tubetes (T) de 50 e 240 mL e em substrato comercial (S-Com) ou substratos de bagaço de cana (B) misturado a composto de lixo urbano (UWC) ou vermicomposto (V).*

T	Urban waste compost (UWC)			Vermicompost (V)			S-Com	M
	B+UWC (1:3)	B+UWC (1:1)	B+UWC (3:1)	B+V (1:3)	B+V (1:1)	B+V (3:1)		
				N content (g kg^{-1})				
50mL	19.81	13.79	20.20	16.19	15.76	22.24	25.28	19.04
240mL	21.35	18.37	16.14	27.73	19.65	21.75	22.86	21.12
M	20.58	16.08	18.17	21.96	17.71	21.99	24.07	
				N accumulation (g plant^{-1})				
50mL	6.59 Ab	3.09ABb	2.85ABa	5.48ABb	1.96 Bb	5.53ABa	6.96 Aa	4.35 b
240mL	22.76Aa	7.79CDa	3.77 Da	15.87 Ba	7.83CDa	4.52 Da	9.32CDa	10.27a
M	14.68 A	5.44 CD	3.31 D	10.68 B	4.90 D	4.02 D	8.14 BC	
				N use efficiency (g^2 kg^{-1})				
50mL	17.29Ab	15.90Aa	7.04 Aa	22.65Aa	7.72Ab	7.34 Aa	11.82Aa	12.82b
240mL	50.34Aa	23.80 Ba	14.06Ba	22.30 Ba	19.48Ba	9.81 Ba	19.81Ba	22.71a
M	33.81 A	19.85BC	10.55BC	22.47AB	13.60BC	8.57 C	15.61BC	

Comparisons between substrates on the horizontal line (capital letters) and between tubes on columns (lowercase letters) were carried out through Tukey test (at 10 % probability level). M = Mean.
Comparações entre os substratos na linha horizontal (em letras maiúsculas) e entre os tubetes, na vertical (em letras minúsculas) foram realizadas pelo teste de Tukey (ao nível de 10% de probabilidade). M= média.

assessment) higher chlorosis was evident in older leaves presenting smaller gradient to younger leaves. These symptoms were not checked during visual evaluation, which was carried out at 98 days of cultivation.

Stem base diameter, clod structure after seedling removal, and N content in seedlings no have presented significant differences between seedlings' responses in the 50 mL and 240 mL tubes (overall average, by taking into account all substrates), based on the analysis of variance (Table 1).

Substrates did not have effect on N content and on Dickson's Quality Index (DQI) (Table 1). Significant interaction between tubes' volume and substrates was observed in all assessed features, except for N content and clod structure (CS) after removal from the tube.

Mean N content values at 98 days after sowing did not differ between treatments (Table 2). However, as for N accumulation, by taking into account the mean of all substrates, it is possible stating that plants grown in 240 mL tubes presented N accumulation 146% higher than those grown in the 50 mL ones – this difference reached 77% for N use efficiency (NUE). Yet, about N accumulation and NUE, B+UWC (1:3) and B+V (1:3) showed the highest values in comparison to substrates B+UWC (3:1) and B+V (3:1) (mean values, by taking into consideration the two tubes). This response was also observed for N accumulation in 240 mL tubes.

The 240 mL tubes resulted in seedlings presenting heavier shoot dry mass (SDW) than those in 50 mL tubes (increase by 112%), as well as heavier root dry mass (RDW) (by 134%), heavier total dry mass (TDW) (by 130%), higher plants at 60 days (by 10%), higher plants at 98 days (by 14%) and larger root volume (by 88%) (Table 3). Yet, about comparisons between tubes, by taking into account each substrate, in separate, it was possible observing that 240 mL tubes led to TDW and tuberous root values significantly higher than the 50 mL ones, in all substrates, except for B+UWC (3:1), B+V (3:1). Similar responses were also observed in shoot dry biomass.

The commercial substrate (S-Com), substrate B+UWC (1:3) and substrate B+V (1:3) presented higher SDW values, stem diameter and plant height at 98 days, whereas significantly lower values were observed for substrates added with B+V (3:1) and B+UWC (3:1) (Table 3).

Substrate B+UWC (1:3), in 50 mL tubes (Table 3), was the one leading to the highest SDW and stem diameter values among all substrates, whereas the best plant height response (at 98 days) was recorded for the B+V (1:3) mix. SDW and stem diameter in 240 mL tubes recorded higher values in substrates B+UWC (1:3) and B+V (1:3), and in S-Com. RDW, TDW and root volume recorded higher values in substrate 1:3 (B+V), and in S-Com.

Table 3 – Biometric characteristics of moringa seedlings grown in 50 mL and 240 mL tubes (T) in commercial substrate (S-Com) or substrates of the sugarcane bagasse (B) associated with urban waste compost (UWC) or with vermicompost (V).
Tabela 3 *– Características biométricas de mudas de moringa cultivadas em tubetes (T) de 50 mL e 240 mL em substrato comercial (S-Com) ou substratos de bagaço de cana (B) misturado à composto de lixo urbano (UWC) ou vermicomposto (V).*

T	Urban waste compost (UWC)			Vermicompost (V)			S-Com	M
	B+UWC (1:3)	B+UWC (1:1)	B+UWC (3:1)	B+V (1:3)	B+V (1:1)	B+V (3:1)		
				Shoot dry matter weight (g)				
50	0.36Ab	0.19ABb	0.14Bb	0.35ABb	0.16ABb	0.14ABa	0.33ABb	0.24b
240	1.07Aa	0.43BCDa	0.28CDa	0.61Ba	0.47BCDa	0.22Da	0.50ABa	0.51a
M	0.71A	0.31CD	0.21D	0.48B	0.32CD	0.18D	0.42BC	
				Root dry matter weight (g)				
50	1.30Aa	1.16Aa	1.31Aa	1.08Ab	0.90Ab	1.20Aa	0.83Ab	1.11b
240	2.01BCa	2.06BCa	2.02BCa	3.57ABa	2.10BCa	1.94Ca	4.48Aa	2.60a
M	1.66AB	1.61 AB	1.66 AB	2.32 AB	1.50 B	1.57 AB	2.65 A	
				Total dry matter weight (g)				
50	1.66Ab	1.31Ab	1.45Aa	1.43Ab	1.06Ab	1.34Aa	1.16Ab	1.35b
240	3.08BCa	2.49Ca	2.30Ca	4.17ABa	2.57Ca	2.16Ca	4.99Aa	3.11a
M	2.37AB	1.92B	1.87B	2.80AB	1.81B	1.75B	3.07A	
				Diameter stem base (mm)				
50	3.96Ab	3.26ABa	3.22ABa	3.48ABa	2.84Ba	3.33ABa	3.94Aa	3.42a
240	4.75Aa	3.82Ba	3.06BCa	3.90ABa	3.44BCa	2.70Cb	3.62Ba	3.61a
M	4.36A	3.54BC	3.14BC	3.69B	3.14BC	3.02C	3.78AB	
				Height - 60 days (cm)				
50	11.00Ab	10.64Aa	9.60Aa	12.36Aa	9.16Aa	8.70Aa	12.10Aa	10.51b
240	14.37 Aa	9.82Ba	10.00 Ba	11.25ABa	11.00ABa	11.30ABa	12.84ABa	11.51a
M	12.68A	10.23AB	9.8B	11.81AB	10.08AB	10.00AB	12.47AB	
				Height - 90 days (cm)				
50	12.2ABb	11.50ABa	10.50ABa	13.60Aa	10.10ABb	9.37Ba	13.0ABa	11.47b
240	17.62Aa	11.66Ba	10.40Ba	13.75Ba	12.87Ba	11.50Ba	13.90Ba	13.11a
M	14.91	11.58BC	10.45 C	13.68AB	11.49BC	10.44C	13.45AB	
				Tuberous root volume (dm³)				
50	7.40Ab	6.66Ab	7.20Aa	6.40Ab	4.00Ab	7.50Aa	6.20Ab	6.48b
240	12.8ABa	10.14Ba	10.40Ba	16.50Aa	10.24Ba	9.90Ba	15.40Aa	12.2a
M	10.10AB	8.40AB	8.80AB	11.45A	7.12B	8.70AB	10.80A	

Comparisons between substrates on the horizontal line (capital letters) and between tubes on columns (lowercase letters) were carried out through Tukey test (at 5 % probability level). M = Mean.
Comparações entre os substratos na linha horizontal (em letras maiúsculas) e entre os tubetes, na vertical (em letras minúsculas) foram realizadas pelo teste de Tukey (ao nível de 5% de probabilidade). M= média.

Physical quality of seedlings (Table 4) grown in 240 mL tubes was significantly higher than that of seedlings grown in the 50 mL ones (seven substrates assessed, on average) – it was 71% higher in easiness to remove plants from clod and 104% better in Dickson's Quality Index (DQI). Clod structure evaluation after seedlings' removal from tubes did not show significant differences. If each substrate is taken into account, seedlings in 240 mL tubes recorded higher DQI than those in 50 mL tubes, in most of the tested substrates.

Regardless of container size, seedlings in S-Com and in B+V (3:1) had their clods easier to be removed from the container and presented better clod structuring. Seedlings in substrates B+UWC (1:3) and (1:1) recorded the lowest values.

There was not substrate effect on DQI in 50 mL tubes (Table 4), whereas values recorded for 240 mL tubes were significantly higher for S-Com, B+V and B+UWC (1:3) and (1:1) than for the other tested substrates.

4. DISCUSSION

According to Römheld (2012), N deficiency symptoms are featured by light-green color, which gets darker due to generalized chlorosis in the leaf blade of mature or old leaves. These symptoms were observed in 60-day plants, grown in 240 mL tubes

Table 4 – Quality of moringa seedlings grown in 50 mL and 240 mL tubes (T) in commercial substrate (S-Com) or substrates of the sugarcane bagasse (B) associated with urban waste compost (UWC) or with vermicompost (V).
Tabela 4 *– Qualidade de mudas de moringa cultivadas em tubetes (T) de 50 e 240 mL em substrato comercial (S-Com) ou substratos de bagaço de cana (B) misturado à composto de lixo urbano (UWC) ou vermicomposto (V).*

T	Urban waste compost (UWC)			Vermicompost (V)			S-Com	M
	B+UWC (1:3)	B+UWC (1:1)	B+UWC (3:1)	B+V (1:3)	B+V (1:1)	B+V (3:1)		
	Easiness of removing the seedling from the tube - ERT							
50	1.00Cb	1.80BCa	2.6ABCb	2.80ABCa	4.00ABa	3.75ABa	4.60Aa	2.94b
240	3.00ABa	2.20Ba	4.60ABa	3.50ABa	3.50ABa	4.80Aa	5.00Aa	5.03a
M	2.00B	2.00B	3.60AB	3.20AB	3.75A	4.78A	4.80A	
	Clod structure after taking the seedling out of the tube							
50	1.00 Ca	1.40BCa	2.00BCa	1.80BCa	2.60BCa	3.25ABa	4.60 Aa	2.38a
240	1.75Ca	2.00BCa	2.00BCa	2.50ABCa	1.74Ca	2.80ABa	4.40Aa	2.46a
M	1.38B	1.70B	2.00B	2.15B	2.17 B	3.53A	4.50A	
	Dickson's Quality Index - DQI							
50	0.05Aa	0.04Ab	0.05 Aa	0.04Ab	0.03Ab	0.05Aa	0.04Ab	0.042b
240	0.08ABCa	0.08ABCa	0.07BCa	0.12ABa	0.07BCa	0.05Ca	0.13Aa	0.086a
M	0.07	0.06	0.06	0.08	0.05	0.05	0.09	

Comparisons between substrates on the horizontal line (capital letters) and between tubes on columns (lowercase letters) were carried out through Tukey test (at 5% probability level). Easiness of removing the seedling from the tube (ERT): 1 – Root breaking (not possible removing the clod from the tube); 2 – Very hard to remove the clod, but it was possible; 3 – moderate difficulty; 4 – Moderately easiness and 5 – Easy to be removed from the tube. Clod structure after taking the seedling out of the tube: 1 (root breaking or substrate-free root); 2 (< 25% of substrate adhered to the root); 3 (25% to 50% of substrate adhered to the root); 4 (50% to 75% of substrate adhered to the root); and 5 (75% to 100% of substrate adhered to the root or whole clod). M – Mean.
Comparações entre os substratos na linha horizontal (em letras maiúsculas) e entre os tubetes, na coluna (em letras minúsculas) foram realizadas pelo teste de Tukey (ao nível de 5% de probabilidade). Facilidade de retirada da muda do tubete (ERT): 1 - quebra da raiz (não é possível remover o torrão do tubete); 2 – Grande dificuldade de remoção do torrão do tubete, mas foi possível; 3- Dificuldade moderada; 4 - Facilidade moderada e 5 - Facilmente retirado do tubete. Estrutura do torrão após a retirada da muda do tubete: 1 (quebra da raiz ou raiz sem substrato); 2 (< 25 % de substrato aderido à raiz); 3 (25 a 50% do substrato aderido a raiz); 4 (50 a 75% do substrato aderido a raiz) e 5 (75 a 100% do substrato aderido a raiz ou torrão integro). M=Média.

and in substrates presenting higher sugarcane bagasse ratios. Plants of all treatments received nitrogen fertilization throughout this period. Plants did not show visible deficiency symptoms at 98 days, and the N content did not differ between treatments (Table 2).

The highest RDW, TDW and root volume values were observed in substrates presenting higher organic compost ratios. The lowest root volume and RDW value observed in substrates accounting for the highest sugarcane bagasse ratio can be a negative factor, if one takes into consideration that this species has tuberous roots.

According to Lynch et al. (2012), N shortage leads to greater root system ramification, and it increases absorption surface and results in increased root/shoot ratio. Although substrates with higher B ratios (B+UWC and B+V both 3:1) have evidenced N deficiency symptoms at 60 days, the lowest N accumulation (which was assessed at 98 days) led to the lowest root volume, RDW and shoot height values. However, the plants have recovered the internal N concentration (since there was not difference between treatments when it comes to N contents), they did not recover growth under these treatments. This finding points out the importance of proper N supply since the beginning of the cultivation process.

Moringa cultivation in substrate added with UWC or V, associated with coconut fiber (Rodrigues et al., 2016), has shown lack of significant RDW differences between these substrates. Furthermore, the highest ratios of these composts also led to seedlings without any N deficiency symptoms and with great plant growth. This finding corroborates results in the present research about shoot and root growth, and about plant nutrition status, either concerning UWC or V using.

Larger volume tubes (240 mL) and substrates presenting higher UWC or V ratios in their composition also led to higher RDW values and to greater root volume. According to Adebisi et al., (2014), moringa tuberous roots can be observed in the first growth stages given the starch accumulation function. Ndubuaku et al. (2014) have indicated that moringa tuberous roots grow deeper in order to absorb and accumulate groundwater and underground mineral salts. These deep roots and the most superficial lateral and tertiary ones represent adaptive features characteristic to *M. oleifera*. This profile allows the species to remain green all year long and, most of all, to survive during drought periods. However, in practical terms, seedling recommendation for the field is oftentimes carried out based on shoot height and on stem dimension. Thus, the highest growth in seedling height can reduce the time they stay in the nursery, but one must pay close attention to seedlings that are long, spindly stems and small leaves. This feature can be indirectly evaluated based on DQI, which also takes into account root growth, rather than just shoot growth.

The observed DQI result highlights that the best quality seedlings were the ones grown under the lowest bagasse: compost ratio (1:3) either with UWC or vermicompost. The best indices recorded for easiness to remove seedlings from tubes and for clod structure were recorded for substrates presenting the highest B ratios, mainly the ones associated with V. The worst results were observed for the lowest B ratios, mainly when they were associated UWC. The greater granulometry and lower density of sugarcane bagasse allowed greater root distribution inside the tube and to greater adherence to substrate components, since it keeps better clod integrity (roots + substrates). Clod structure can be essential for seedling survival in the field under limiting irrigation and/or fertilization conditions. Although the compost, or the vermicompost, leads to higher N accumulation (Table 2) and to seedling shoot growth (Table 3), it is important paying close attention to ratios in substrate mix composition for tuberous-root moringa seedling clods' maintenance.

5. CONCLUSIONS

The 240 mL tube was the most appropriate one for the production of *Moringa oleifera* seedlings. Substrates presenting the highest organic compost ratios (either urban waste compost or vermicompost) led to the highest growth and Dickson's quality index.

Higher sugarcane bagasse ratios associated with vermicompost in substrate composition have made it easier to remove the seedlings from the tubets and led to better clod structure - the combination of these factors have kept seedlings' physical intergrity.

6. AUTHOR CONTRIBUTIONS

Luciana Aparecida Rodrigues conceived, planned the experiment, analyzed the data and contributed to the writing.

Noriel Arruda Figueiredo and Vinícius Porto conducted the experiments and wrote the manuscript.

Deborah Guerra Barroso planned the experiment and provided inputs to the discussion.

All authors provided critical feedback on the manuscript

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