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Initial growth of *Moringa oleifera* Lam. as a function of poultry litter doses and granulometry[1]

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ABSTRACT

There is an increasing use of poultry litter in seedling production. However, studies regarding the effect of different particle-size litter on plant growth are still scarce. This study aimed to evaluate the growth of *Moringa oleifera* Lam. fertilized with poultry litter doses (0 g dm^{-3}, 40 g dm^{-3}, 80 g dm^{-3} and 120 g dm^{-3}) with distinct particle sizes (1 mm and 4 mm), with four replications. The following variables were evaluated: plant height; root and stem diameter; leaf, stem, shoot and root dry matter mass; shoot/root dry matter mass ratio; and the Dickson quality index. There was no influence of the particle size on the studied variables, except for plant height. The root diameter decreased with the increase of the poultry litter doses. The accumulation of dry matter mass from the shoot and root increased with the increase of poultry litter doses up to 120 g dm^{-3}. A linear increase of the Dickson quality index, relatively to days and poultry litter doses, was observed. It is recommended to apply 80 g dm^{-3} of poultry litter to fertilize *M. oleifera* plants, independently of the granulometry used.

KEYWORDS: Organic fertilization; seedling production; Dickson quality index.

RESUMO

Crescimento inicial de *Moringa oleifera* Lam. em função de doses e granulometrias de cama de frango

O uso do esterco avícola na produção de mudas é crescente. Porém, estudos com o efeito de diferentes granulometrias de esterco sobre o crescimento de plantas ainda são escassos. Objetivou-se avaliar o crescimento de *Moringa oleifera* Lam. adubada com doses de cama de frango (0 g dm^{-3}; 40 g dm^{-3}; 80 g dm^{-3}; e 120 g dm^{-3}) com diferentes granulometrias (1 mm e 4 mm), com quatro repetições. Avaliaram-se a altura de planta; diâmetro da raiz e do caule; massa da matéria seca da folha, do caule, da parte aérea e da raiz; relação massa da matéria seca da parte aérea/raiz; e o índice de qualidade de Dickson. A granulometria não influenciou nas variáveis estudadas, exceto para altura de planta. O diâmetro da raiz diminuiu com o aumento nas doses de cama de frango. O acúmulo de massa da matéria seca da parte aérea e da raiz sofreram incremento com o aumento das doses de cama de frango até 120 g dm^{-3}. Verificou-se aumento linear do índice de qualidade de Dickson, em função dos dias e doses de cama de frango. Recomenda-se a dose de 80 g dm^{-3} de cama de frango para a adubação de plantas de *M. oleifera*, independentemente da granulometria utilizada.

PALAVRAS-CHAVE: Adubação orgânica; produção de mudas; índice de qualidade de Dickson.

INTRODUCTION

Moringa oleifera Lam. is a species of the Moringaceae family, with economic exploitation potential for the Brazilian Northeast region (Carvalho et al. 2017). It is a plant considered as an arboreal vegetable, which has been implanted in several countries, due to its high productive potential, especially in soils that have a low natural fertility. This is added to the fact that it is a soil and water phytoremediation plant, besides being used in the recovery of degraded areas (Leite et al. 2010). In addition, it stands out for its economic, nutritional and medicinal potential, since all its parts are sources of proteins, vitamins and carotenoids (Olayemiv et al. 2016).

It is a species with a good adaptability to the conditions of the Brazilian Northeast region, presenting a diversity of uses as in folk medicine; food source for humans, helping in the fight against malnutrition; fodder feed; and in the pharmaceutical and cosmetics industry (Andrade et al. 2016).

One of the ways to maximize its agricultural production is by applying organic matter sources to

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the soil, thus substantially improving its physical, chemical and biological conditions and favoring plant growth and development. The use of poultry litter in the agricultural production is relevant, since it is an excellent supplier of organic matter to the soil (Fernandes et al. 2013), besides being an excellent supplier of N (Valadão et al. 2011), providing around 2 % of N in its composition.

Another aspect that maximizes its use is the low C:N ratio (Santos et al. 2010), which allows the rapid mineralization and release of the nutrients necessary for the plant growth and development. This characteristic, associated with the low price and great supply (Campos et al. 2017), makes this input a viable alternative for the agricultural production.

It is not uncommon for farmers to worry about finding a fertilizer that will rapidly provide the nutrients needed for plant growth. Fertilizers with particles smaller than 2.0 mm in diameter may cause soil pore clogging, as well as compaction, while providing nutrients faster, depending on how large is the contact surface, enabling a rapid decomposition (Cotta et al. 2015).

In addition, larger particles, although favoring a greater root aeration, present a lower decomposition speed, supplying nutrients gradually. According to Nascimento et al. (2011), pore space, soil density and humidity, among other factors, may or may not favor plant growth. Thus, it is necessary to determine to what extent the granulometry of the poultry litter benefits or impairs the plant growth. So, this study aimed to evaluate the initial growth of *Moringa oleifera* Lam. plants fertilized with poultry litter doses presenting two grain sizes.

MATERIAL AND METHODS

The experiment was conducted in a greenhouse, at the Universidade Federal de Campina Grande, in Pombal, Paraíba state, Brazil (06º46’13’’S, 37º48’06’’W and altitude of around 242 m), from March to June 2017. The predominant climate, based on the Köppen classification, is the hot and dry Bsh (semiarid) type, with rainfall around 700 mm per year, bieng torrential throughout the rainy season (Nóbrega et al. 2018).

Two grain sizes (≤ 1 mm and ranging from 3 mm to 4 mm) and four poultry litter doses (0.0 g dm^{-3}, 40.0 g dm^{-3}, 80.0 g dm^{-3} and 120.0 g dm^{-3}) were evaluated. The experiment was conducted in a randomized complete block design, with four replicates. The experimental unit consisted of four seedlings.

The soil used was the Ta Eutrophic Fluvic Neosol (RYve) (Dantas et al. 2017), which occurs in regions of high water restriction, being distributed mainly in semiarid regions. They are soils that present an eutrophic character, with a significant presence of primary minerals.

The substrate and the soil were analyzed and their physical and chemical characterization was carried out (Embrapa 2011; Tables 1 and 2).

The poultry litter passed through a 1 mm sieve. For the litter with a diameter between 3 mm and 4 mm, the sieving was done in a 4 mm mesh; the material was sieved again, this time in a 3 mm mesh sieve, so that any substrate that did not have a 4 mm granulometry was removed, leaving only the material with the granulometry of interest (4 mm). The chemical attributes of the poultry litter are presented in Table 3.

Table 1. Chemical attributes of the soil used in the experiment.

pH (H_2O)	P (Mehlich 1)	K^+	Na^+	$H^+ + Al^{+3}$	Al^{+3}	Ca^{+2}	Mg^{+2}	SB	CEC	OM
	mg kg^{-3}		cmol$_c$ dm^{-3}							g kg^{-1}
6.5	148.9	263.70	0.07	1.34	0.0	3.0	1.34	5.09	6.42	7.1

Table 2. Physical attributes of the soil used in the experiment.

Sand 2-0.05 mm	Silt 0.06-0.002 mm	Clay < 0.002 mm	SC	DF	SD	PD	TP	Moisture 0.01	0.33	1.50	Texture class
g kg^{-1}			g kg^{-1}	kg dm^{-3}	g cm^{-3}	kg dm^{-3}	m^3 m^{-3}	g kg^{-1}			Frank sand
801	140	59	0.0	1,000	1.54	2.65	0.42	118	125	24	

SC: scattered clay; DF: degree of flocculation; SD: soil density; PD: particle density; TP: total porosity.

Table 3. Poultry litter chemical attributes.

N	P	K	Ca	Mg	Na	Zn	Cu	Fe	Mn	Organic carbon	CEC	C:N
g kg^{-1}				mg kg^{3}						%	$cmol_c\ dm^{-3}$	
19.3	2.10	19.8	12.8	7.94	4.92	57	30	21.9	262	23.6	229.7	12:1

A total of eight *M. oleifera* seeds were sown per polystyrene container (capacity of 5.0 dm^3), and thinning was performed at 10 days after sowing, leaving four plants per container.

Irrigations were carried out in the wee hours of the morning and in the late afternoon, in order to leave the soil with humidity close to the field capacity, based on the equation Av = Pb - D, where *Av* is the applied volume, *Pb* the previous blade and *D* the drainage.

Every 30 days after the emergence, up to 120 days, the following variables were evaluated: a) plant height: measured from the collar to the apex of the plant, with the aid of a graduated ruler and results expressed in cm; b) root and stem diameter: obtained with the aid of a digital pachymeter, considering only the main root and plant collar height, with results expressed in mm; c) root, stem, leaf and shoot weight: plants were divided into root, stem and leaf, which were packed in bags of Kraft paper and dried in a circulation and renovation air greenhouse at 65 ºC, until constant mass, and the root, stem, leaf and shoot weights were determined based on the sum of the values obtained for the stem and leaf dry mass, with results were expressed in g $plant^{-1}$; d) shoot/root dry mass ratio: calculated by dividing the values obtained for shoot dry matter mass by the root dry matter mass; e) Dickson Quality Index (DQI): every 30 days, four plants per treatment were removed to evaluate the morphological quality (Dickson et al. 1960), using the equation DQI = TDM/[(PH/SD) + (SDM/RDM)], where *TDM* is the total dry matter mass (g); *PH* the plant height (cm); *SD* the stem diameter (mm); *SDM* the shoot dry matter mass (g); and *RDM* the root dry matter mass (g).

The data were submitted to analysis of variance, considering the factorial scheme as a function of the poultry litter doses (0.0 g dm^{-3}, 40.0 g dm^{-3}, 80.0 g dm^{-3} and 120.0 g dm^{-3}) and grain sizes (≤ 1 mm and ranging from 3 mm and 4 mm). When significant, the polynomial regression was applied for the poultry litter doses, while the mean particle size was compared by the F test. The SAS software (Cody 2015) was used.

RESULTS AND DISCUSSION

For the granulometry ≤ 1 mm, plant height increased up to 100 days of experiment, reaching a maximum height of 170 cm, at the dose of 120 g dm^{-3} (Figure 1a). The plants produced with granulometry between 3 mm and 4 mm reached the largest height at 120 days, with the dose of 120 g dm^{-3} (Figure 1b). In both grades, the effect of the poultry litter doses was linear.

The fast *M. oleifera* growth may be justified by its possible adaptation to the semiarid conditions and improvements due to the application of poultry litter. Similar results were obtained by Medeiros et al. (2017), evaluating doses of organic compost in the production of *M. oleifera* seedlings, who verified a greater growth in height of the plants fertilized with the compost.

The highest growth of fertilized plants with 4 mm granulometry may be explained by the gradual supply of nutrients to the plants, favoring their growth for a longer period of time. Felini & Bono (2011) point out that one of the advantages of using litter, instead of a synthetic fertilizer, is its residual power, which assumes the role of providing nutrients over time, being more persistent with larger grain sizes.

It was observed that the maximum root diameter was 27 mm. Thereafter, a reduction was observed up to 120 days. It is believed that this is an adaptation to store photoassimilates in the roots of plants that undergo some kind of stress, in order to be able to supply it during the deficiency periods, due to the probable lack of nutrient supply to the plants, cause of the non immediate litter mineralization (Figure 2a).

Padayachee & Baijnathet (2012) point out that the tuberous roots of *M. oleifera* plants are an adaptation for survival to adverse conditions, such as in arid conditions. As the treatments may have had no effect on the plants initially, for the plants to undergo this temporary stress, they concentrated their reserves on the roots, to withdraw their sustenance during the critical period of their survival.

For the stem diameter, the dose of 120 g dm^{-3} provided a value of approximately 21 mm at 105 days after sowing (Figure 2b). This is possibly related to the benefits that the poultry litter provided to the soil, such as increased water retention, aeration and nutrient supply, making it more conducive to plant growth and development. Cavalcante et al. (2016) report that the use of organic supplies directly influences plant growth.

Farias et al. (2016), evaluating the use of aquatic macrophytes in substrate for the production of *M. oleifera* seedlings, obtained a significant increase of the collar diameter, when plants were cultivated in a substrate with 100 % of *Pistia stratiotes* (L.) and

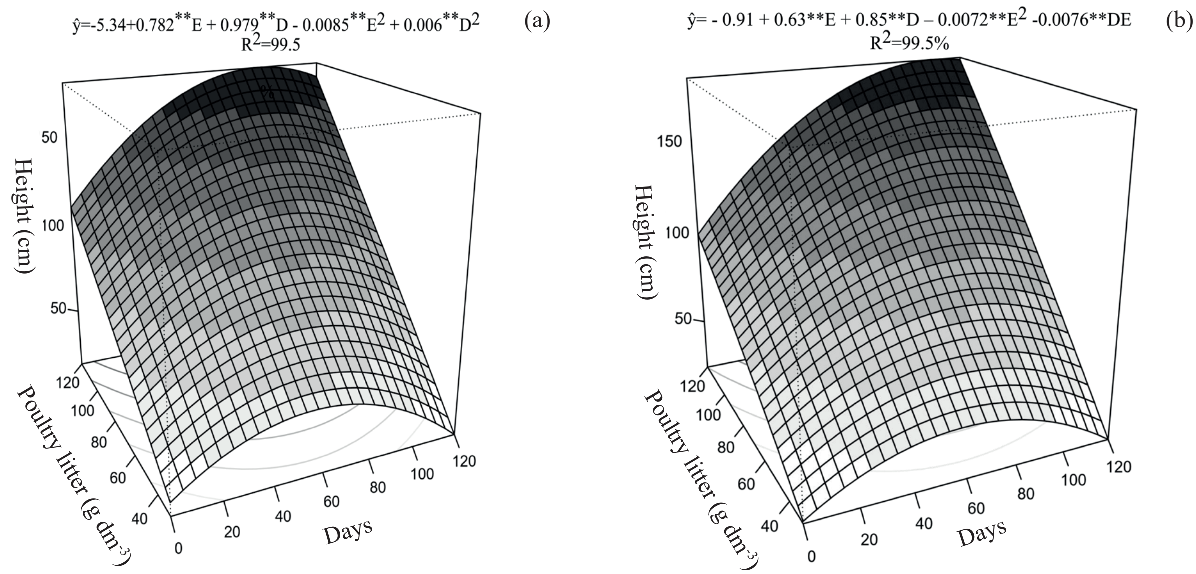

Figure 1. *Moringa oleifera* Lam. plant height, according to days after emergence and poultry litter doses, with grain sizes ≤ 1 mm (a) and between 3 mm and 4 mm (b).

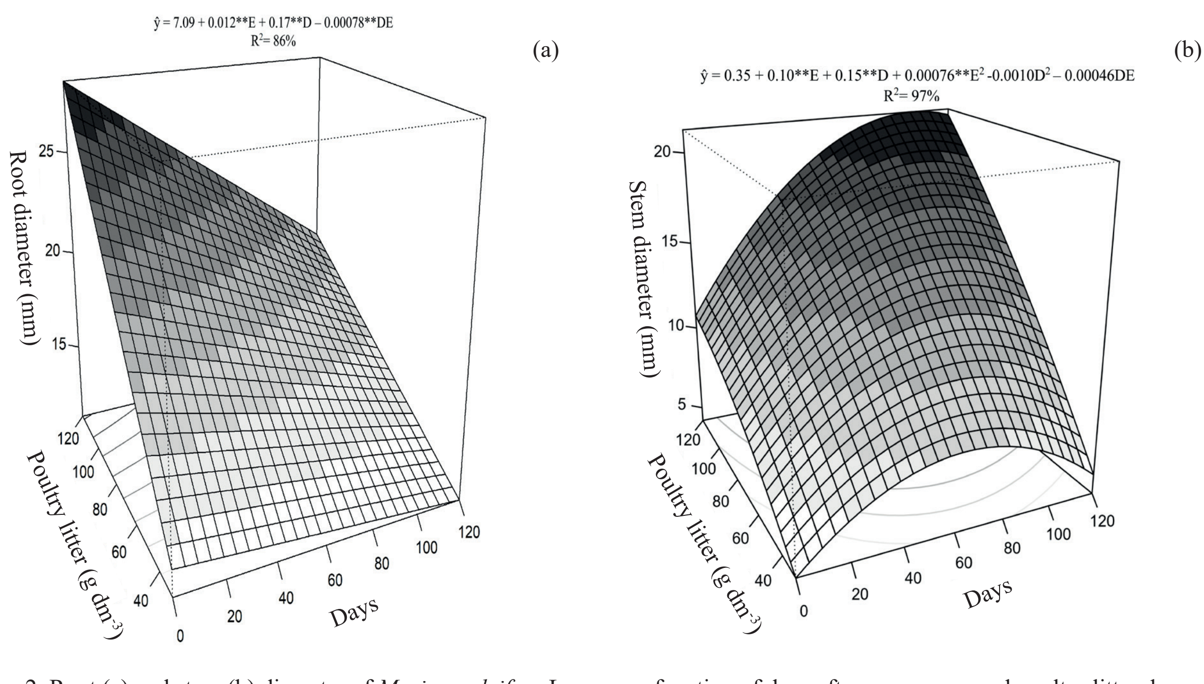

Figure 2. Root (a) and stem (b) diameter of *Moringa oleifera* Lam., as a function of days after emergence and poultry litter doses, with grain sizes ≤ 1 mm and between 3 mm and 4 mm.

100 % of *Typha domingensis* (Pers.). In contrast, Bakke et al. (2010) did not obtain differences between the diameters of *M. oleifera* plants fertilized with various organic fertilizers. According to Carneiro (1995), the larger the collar diameter, the greater the shoot growth equilibrium.

For the stem dry matter, a maximum increase in the biomass accumulation up to the dose of 120 g dm^{-3} of applied litter was observed, whereas the peak was at 120 days of the experiment conduction (Figure 3a). For the leaf dry matter, the 105.9 g dm^{-3} dose showed better production results at 119 days after emergence (Figure 3b).

It is possible to observe that the shoot dry matter mass presented significant production responses with the increase of the poultry litter doses, where the dose of 105 g dm^{-3} provided a larger increase of dry matter mass (Figure 3c). This behavior may be due to the greater nutritional balance promoted by the increase of organic matter to the soil, enabling a greater accumulation of photoassimilates.

With respect to the root dry matter mass, as a function of days, an increasing linear behavior was observed, with the maximum accumulation of root biomass occurring at 120 days, with 8.46 g $plant^{-1}$ (Figure 4a). This effect may have occurred due to the greater mineralization of litter, as a function of time, allowing a greater supply of nutrients throughout the evaluated cycle. The increase of litter to the substrate promotes physical and chemical improvements, resulting in a greater nutritional balance for the plant, thus favoring its growth (Delarmelina et al. 2015).

It is common to increase the root dry matter mass during the course of the experiment, except when the plant undergoes some stress. Souza et al. (2015) found positive results for increasing the dry matter mass of the *M. oleifera* root. However, Cavalcante et al. (2016), evaluating doses of bovine litter in the production of *Gliricidia sepium* (Jacq.) seedlings, did not find any difference in the root dry matter mass.

The mass accumulation of the root dry matter, as a function of the poultry litter doses (Figure 4b), presented a different behavior from that obtained for the accumulation as a function of days (Figure 4a). It was observed that the increase of the litter doses promoted a linear decreasing effect, being the greater accumulation obtained at the dose of 1 g dm^{-3}. The increase of litter doses decreased the dry matter mass of roots by 70.7 %.

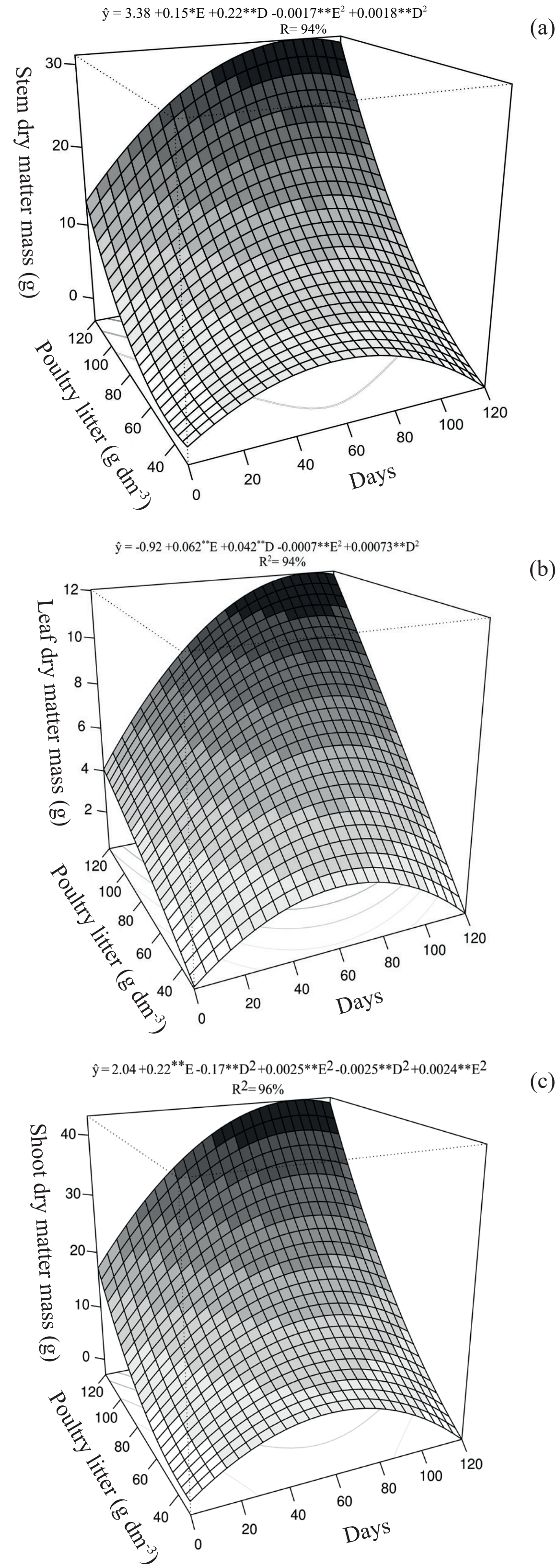

Figure 3. Stem (a), leaf (b) and shoot (c) dry matter mass of *Moringa oleifera* Lam., as a function of days after emergence and doses of poultry litter, with granulometry of 1 mm and 4 mm.

This effect on the root dry matter mass, as a function of the doses, probably caused root toxicity, due to the excess of nutrients with increasing doses up to 120 g dm^{-3}, causing them to decrease the dry matter mass as a function of the increased poultry litter dose applied. Souza et al. (2015) point out that large quantities of fertilizer are not necessary for *M. oleifera* plants to express a significant production.

Another factor to be highlighted is the possibility of the plant, in the lower doses, due to a lack of nutrients in the medium, to expand its root system in search of nutrients, what probably stimulated the root growth. According to Souza et al. (2015), this is a possible adaptation of plants to semi-arid conditions, while Carvalho et al. (2017) points out that *M. oleifera* is a plant with potential to grow under adverse conditions.

There was a decreasing linear behavior, as a function of days, in the shoot/root dry matter mass ratio (Figure 5a), as well as a reduction of 6.1 to 3.8 in the ratio, when reaching 120 days after the emergence of the seedlings. It is noticed that, with the passage of the days, the reduction of the relation narrowed. This behavior indicates that, independently of the granulometry, a higher supply of nutrients to the radicle system occurs, providing a greater root growth and development, thus decreasing the shoot/root ratio.

The shoot/root dry matter mass ratio values, as a function of litter doses, increased linearly with increasing doses, with values of 2.3 and 6.0 in the lowest and highest doses applied (Figure 5b), respectively, with a maximum increase with the maximum dose of 120 g dm^{-3}. This effect indicates that the supply of nutrients through the litter doses applied provided a greater root development and, consequently, a greater availability for the growth and mass accumulation of the shoot dry matter mass, as emphasized by Souza et al. (2017) in the production of *Salvia officinalis* L. under poultry litter doses.

However, Valadares et al. (2015), evaluating P doses in the production of *Acacia mangium* Willd, obtained a decrease in the shoot/root ratio. Also according to the same authors, this decrease occurs due to the greater development of the shoot, because of the photosynthetically development of more active organs. It is important to note that, as emphacized by Carneiro (1995), the shoot/root dry matter mass

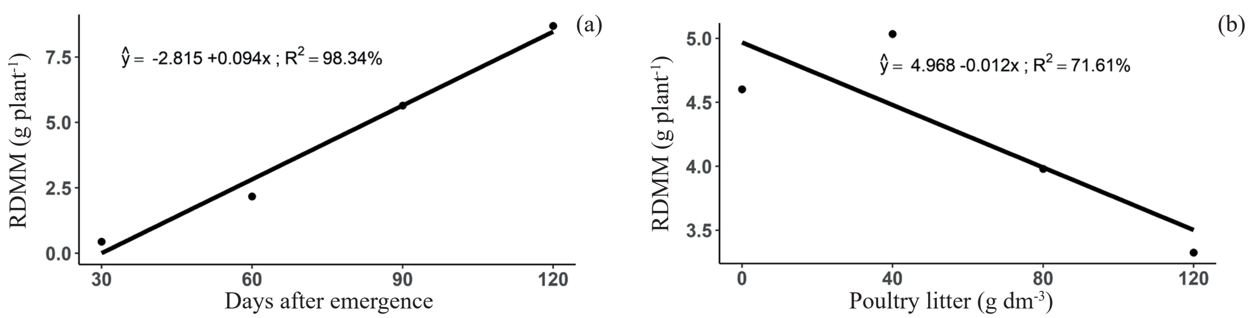

Figure 4. Root dry matter mass (RDMM) in *Moringa oleifera* Lam. seedlings, as a function of days after emergence (a) and poultry litter doses (b).

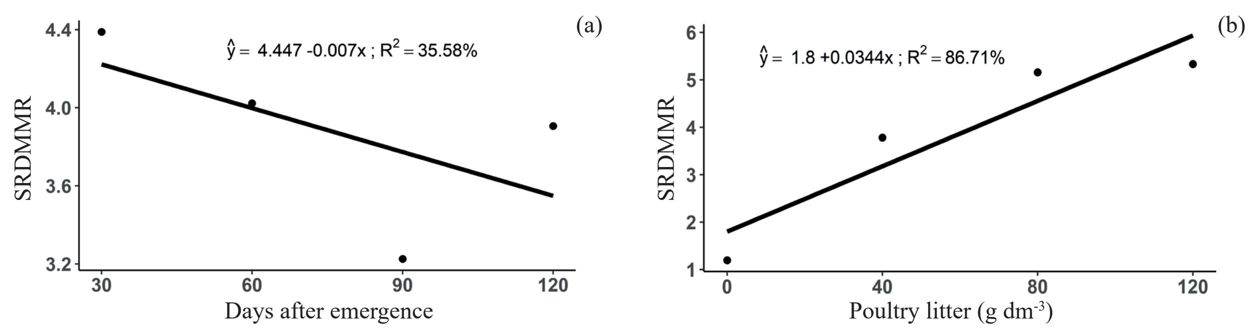

Figure 5. Shoot and root dry matter mass ratio (SRDMMR) in *Moringa oleifera* Lam. seedlings, as a function of days after emergence (a) and poultry litter doses (b).

ratio is an important variable to predict the quality of seedlings, with 2.0 being the most recommended value.

The values obtained for the Dickson quality index were adjusted to an increasing linear trend, as a function of the days, with the maximum increase occurring from 3 to 120 days (Figure 6). This effect indicates that the seedlings have their prolonged quality due to the increase of the time, as a function of the greater availability of nutrients, and, consequently, better conditions for the plant growth. Based on Caldeira et al. (2012), the greater the Dickson quality index obtained, the higher is the quality of the seedlings produced.

Salles et al. (2017) report that the fertilization with poultry litter favors the increase of the soil microbial biomass, being responsible for fomenting the formation of the soil structure, besides increasing the water retention and aeration. In a study evaluating the composition of organic residues of diverse origins, Melo et al. (2008) highlight the superiority of $N\text{-}NO_3$ in the poultry litter, when compared to other sources. These authors found 58 mg kg^{-1} of $N\text{-}NO_3$ in the poultry litter, whereas, in quail litter, the value of 17 mg kg^{-1} of $N\text{-}NO_3$ was obtained, evidencing the quality of the poultry litter as a fertilization source.

Several factors may have contributed to the increase in the Dickson quality index, due to the increment of the poultry litter doses applied. The soil organic matter has the capacity to retain water (Costa et al. 2013), making it remain in the soil for a longer time and be used by plants. Conceição et al. (2005) point out that the organic matter has the ability to decrease the oscillation of the diuturnal temperature, causing the roots to grow steadily, especially in summer times. Still based on the same authors, it is worth noting that, under these conditions, microorganisms act more efficiently in the mineralization of organic matter.

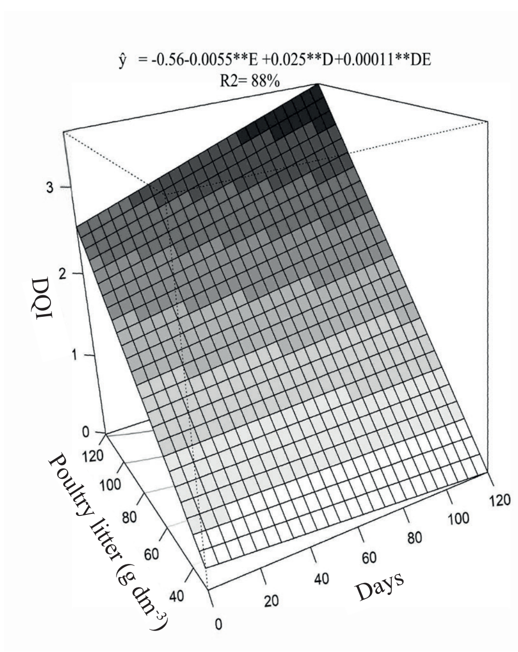

Figure 6. Dickson quality index (DQI) in *Moringa oleifera* Lam. seedlings, as a function of days after emergence and poultry litter doses.

CONCLUSIONS

1. Plant height is larger with the application of poultry litter with 4 mm of diameter;
2. The shoot dry matter mass increases as the dose increases, while the root system decreases with increasing poultry litter doses;
3. There is a linear increase in the Dickson quality index, as a function of days after emergence and poultry litter doses, reaching a maximum value of 3.0;
4. The use of poultry litter is recommended for the production of *Moringa oleifera* Lam. seedlings, being 80 g dm^{-3} the most recommended dose.

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