Disciplinarum Scientia. Série: Naturais e Tecnológicas, Santa Maria, v. 24, n. 2, p. 191-202, 2023.
Recebido em: 28.04.2023. Aprovado em: 26.10.2023.
ISSN 2176-462X
DOI: 10.37779/nt.v24i2.4541

MOLASSES ASSOCIATED THE INOCULATION OF EFFICIENT MICROORGANISMS IN INITIAL DEVELOPMENT OF CASHEW TREE[1]

MELAÇO ASSOCIADO À INOCULAÇÃO DE MICRORGANISMOS EFICIENTES NO DESENVOLVIMENTO INICIAL DE CAJUEIRO

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ABSTRACT

Cashew tree is considered one of the most important fruit crop in the semi-arid regions of tropical climate in the world. The low levels of crop productivity are linked to the semi-arid climate, inadequate management of correction and fertilization and the non-adoption of sustainable forms of cultivation. In view of this, organic fertilizer emerges as a promising alternative source. Sugarcane molasses is residue rich in minerals, is easy to handle, inexpensive and of has great agricultural potential. Efficient microorganisms, community of microorganisms naturally found in fertile soils and in plants, can also be key parts in the biological processes of the soil, favoring its fertility and consequently the development of plants. In this context, the objective was to evaluate the initial development of cashew trees in response to the application of sugarcane molasses associated with the inoculation of efficient microorganisms. The experimental design used was completely randomized, with four replications and the treatments organized in a factorial arrangement (4 x 2), being formed by the combination of four doses of molasses (0, 1/2, 1 and 2 x the recommended dose) and application of efficient microorganisms (presence and absence), thus totaling 32 pots. At 90 days after transplanting, the following variables were evaluated: stem diameter, plant height, leaf blade length, number of leaves, total foliage dry mass, root dry mass, root volume and shoot/root ratio. Inoculation with efficient microorganisms maximized the development of cashew tree seedlings. Molasses did not influence in the development of cashew tree seedlings.

Keywords: *Anacardium occidentale L*, Organic fertilization, Semiarid.

RESUMO

O cajueiro é considerado umas das frutíferas mais importantes das regiões semiáridas de clima tropical do mundo. Os baixos níveis de produtividade das lavouras estão ligados ao clima semiárido, manejo de correção e adubação inadequado e a não adoção de formas sustentáveis de cultivo. Diante disso, a adubação orgânica surge como uma fonte alternativa promissora. O melaço da cana-de-açúcar é um resíduo rico em minerais, de fácil manuseio, barato e de grande potencial agrícola. Microrganismos eficientes, comunidade de microrganismos encontrados naturalmente em solos férteis e nas plantas, também podem ser peças-chave nos processos biológicos do solo, favorecendo sua fertilidade e consequentemente o desenvolvimento das plantas.

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Nesse contexto, objetivou-se avaliar o desenvolvimento inicial do cajueiro em resposta à aplicação de melaço de cana-de- açúcar associada à inoculação de microrganismos eficientes. O delineamento experimental utilizado foi o inteiramente casualizado, com quatro repetições e os tratamentos organizados em um arranjo fatorial (4 x 2), sendo formados pela combinação de quatro doses de melaço (0, 1/2, 1 e 2 x a dose recomendada) e aplicação de microrganismos eficientes (presença e ausência), totalizando assim 32 vasos. Aos 90 dias após transplantio, foram avaliadas as seguintes variáveis: diâmetro de caule, altura da planta, comprimento da lâmina foliar, número de folhas, massa seca de folhagem total, massa seca de raiz, volume radicular e relação parte aérea / raiz. A inoculação com microrganismos eficientes maximizou o desenvolvimento das mudas de cajueiro. O melaço não influenciou no desenvolvimento das mudas de cajueiro.

Palavras-chave: *Anacardium occidentale L, Adubação orgânica, Semiárido.*

INTRODUCTION

Cashew tree (*Anacardium occidentale* L.) is considered one of the most important fruit crop in the semi-arid regions of tropical climate in the world (MARTINS; LIMA: SERRANO, 2019). According to Serrano and Pessoa (2016) cashew cultivation has contributed considerably to the generation of employment and income both in the field and in industry. This occurs due to the production in periods of drought, in the off-season of other cultures.

Data from the year 2022 showed that Brazil had a harvested area of 424,609 hectares and a production of 147,174 tonnes (IBGE, 2022). The state of Piauí was the second largest producer of the fruit with a production of 21,674 tons in an area of 73,047 hectares (IBGE, 2022). This is due to the culture's high adaptability to low fertility soils, high temperatures and water deficit (SERRANO; PESSOA, 2016). However, the state of Piauí had the lowest productivity index, with an average yield of 297 kg ha^{-1}, below the average of the Northeast region, which registered a productivity of 346 kg ha^{-1}, still considered very low. (IBGE, 2022).

The low levels of crop productivity in the state are linked to climatic conditions, such as the semi-arid region, which has high temperatures and prolonged drought, in addition to inadequate correction and fertilization management practices and the absence of the adoption of sustainable forms of use (ALENCAR *et al*., 2018; SILVA *et al*., 2019; MORAIS *et al*., 2020).

The technique of soil fertility correction for the production of a crop is usually carried out by recommending soluble mineral fertilizers. However, the application of this type of fertilizer can encumber production, contaminate the environment and negatively affect the development of crops (SILVA, 2014; SOUZA; RESENDE, 2014), like the cashew tree.

In view of this, organic fertilizer emerges as a promising alternative source, as it provides nutrients to the soil, acts in the sustainability of production systems, providing improvement in the physical, chemical and biological attributes of the soil, with a positive impact on the stability and productivity of the crop (SEDIYAMA *et al*., 2016), and reduces environmental pollution caused by waste generated in the production of mineral fertilizers (MELO; MARQUES, 2000; CARVALHO JÚNIOR *et al*., 2009). According to Johansen *et al*. (2019), organic fertilizers can be reused on the property, without generating costs, which makes them a potential source for replacing mineral fertilizers.

Sugarcane molasses, a by-product of the sugar production industry, is rich in minerals, being considered a good substrate for the cultivation of microorganisms and development of plants (DELGADO, 1975; CASALI, 2011). In addition, this residue is easy to handle, inexpensive and has great agricultural potential (HUANG *et al*., 2013; INTASIT *et al*., 2020).

Efficient microorganisms, community of microorganisms naturally found in fertile soils and in plants (CASALI, 2011; TEIXEIRA; WITT; SILVA FILHO, 2017), can also be key parts in the biological processes of the soil, favoring its fertility and consequently the development of plants (CASALI, 2011; TEIXEIRA; WITT; SILVA FILHO, 2017).

The use of these microorganisms reduces environmental impacts and enables the maintenance of clean systems, the production of healthy and nutritionally balanced foods free of chemical residues. In addition, it contributes to the quality of life and sustainability of the environment (CASALI, 2011).

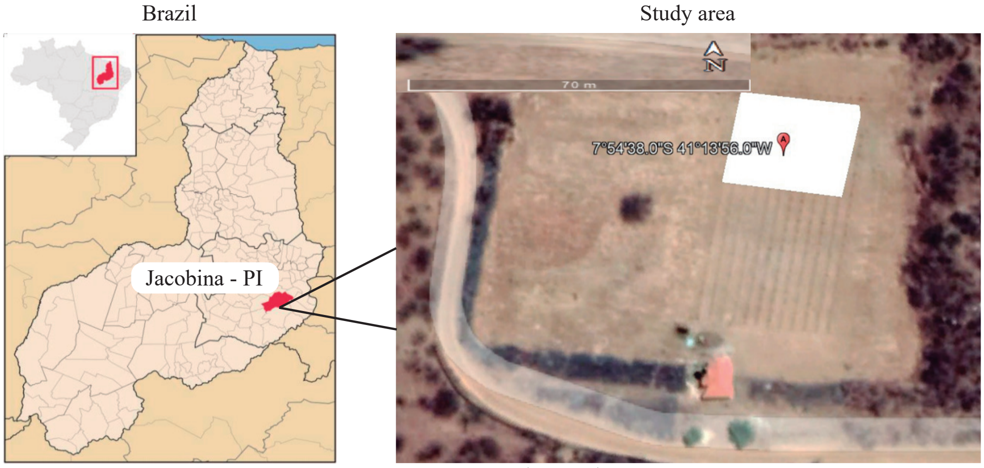
Due to the lack of research that verifies the potential of associed molasses to the efficient microorganisms as plant growth inducers, especially for crops with great regional potential such as cashew tree, this study is relevant and necessary.

In this context, the objective was to evaluate the initial development of cashew trees in response to the application of sugarcane molasses associated the inoculation of efficient microorganisms.

MATERIAL AND METHODS

The work was carried in protected environment, covered with shade at 50% shading, in the municipality of Jacobina do Piauí (latitude 07º 54' 38" S and longitude , altitude of 336 m a.s.l.), 445 km from the state capital, Teresina. The climate, according to the Köppen-Geiger climate classification is BSh, dry climate, steppe type, with average anual rainfall in between 380 and 760 mm, with average temperatures greater than 18ºC (KOTTEK *et al*., 2006). The area location is shown in Figure 1.

Figure 1 - Location of study area.



Source: Google Earth

The experimental design used was completely randomized, with four replicates, and treatments were arranged in a factorial arrangement (4 x 2), composed of the combination of four molasses doses (0; 50; 100 and 200% of the recommended dose), which corresponded to 0; 0.195; 0.39 and 0.78 L respectively and application of efficient microorganisms (presence and absence), thus totaling 32 experimental units.

The soil used in the experiment was collected in an area of native vegetation of rural property in the municipality, in the layer of 0.00-0.03 m. After collection, the soil was dried and crushed, where a sample was placed in plastic bag and sent to the laboratory for chemical and grain size analysis (Table 1), according to Donagema *et al*. (2011).

Table 1 - Chemical and grain size characterization of soil in the 0-20 cm layer

pH	P	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H+Al	SB	T	m	V	OM
	$mg.dm^{-3}$				$cmol_c.dm^{-3}$					%	
6.60	13.30	0.43	5.72	1.85	0.00	2.40	8.00	10.40	0.00	76.92	0.66

pH in water, phosphorus (P), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), aluminum (Al^{3+}), hydrogen+aluminium (H+Al), sum of bases (SB), CEC potential (T), aluminum saturation (m), base saturation (V) and organic matter content (OM). Sand: 58.09%; Silt: 19.76%, Clay: 22.15%.
Source: The author

Cashew tree seedlings of cv CCP 76 were purchased from a nursery in the city of Santo Antônio de Lisboa. The selection occurred based on the greatest possible uniformity, in order to avoid problems of superiority of one seedling in relation to the other.

The molasses used came from sugarcane processing mills in the region of Picos-PI. For this, a sample was sent to the laboratory for analysis (Table 2), as organic fertilizer (OSAKI; DAROLT, 1991).

Table 2 - Chemical characterization of organic syrup (molasses)

pH	N	P	K^+	Ca^{2+}	Mg^{2+}	C	B	Cu^{2+}	Fe^{2+}	Mn^{2+}	Zn^{2+}	Na^+
			$g L^{-1}$							$mg L^{-1}$		
4.7	7.5	0.2	3.0	2.6	1.1	328.5	569.8	1.0	113.0	16.0	1.0	170.0

Source: The author

Efficient microorganisms (EM) were captured in an area of native vegetation. For this, 700 grams of rice were cooked and placed in closed plastic tray with small openings, placed in virgin forest and covered with a layer of litter (CASALI, 2011).

After a period of 10 days, EM were collected to be multiplied. With that, parts of the rice with the pinkish, blueish, yellowish and orange colorations were used. Parts with gray, brown and black colorations were discarded in the native vegetation (CASALI, 2011).

The selected material was distributed in five two-liter plastic bottles, along with 200 mL of molasses in each bottle. Subsequently, the bottles were filled with rice water to form the solution. The bottles were closed and placed in shade for a period of 15 days. The gas stored in the bottles was are released every two days (CASALI, 2011).

The EM solution was diluted in dechlorinated water at a ratio of 1:1000 and applied on the soil, so as to make it wet, with subsequent rest for a period of 10 days (CASALI, 2011).

After this period, the doses of molasses and the soil treated with EM were placed in plastic pots with capacity of 20 dm^3. The molasses doses were applied taking into account the potassium content of the soil and molasses, and based on the potassium requirement of the crop, according to the fertilizer recommendation for the crop (CRISÓSTOMO; NAUMOV, 2009).

After 30 days, the cashew tree seedlings were transplanted.

At 90 days after transplantation, the following variables were evaluated: plant height (PH, cm), stem diameter (SD, mm), leaf blade length (LBL, cm), number of leaves (NL), total foliage dry mass (TFDM g $vaso^{-1}$), root dry mass (RDM g $vaso^{-1}$), root volume (RV, cm^3) and shoot/root ratio (S/R).

To PH and LBL, a tape graduated was used, where the PH measured from the soil up to the insertion of the last expanded leaf was taken as a basis, and for LBL, measured from the base of the blade up to its apex was considered. For the evaluation of SD, a caliper was used, where the measurement was performed at 2 cm from soil. NL was assessed by simple counting. To determine the TFDM, the leaves were removed, packed in paper bags, dried in an oven with air circulation at 65°C for 72 hours and and later weighedon analytical scale. To determine the RV, the roots were removed from the vases and washed in running water using sieves with decreasing meshes and, subsequently, the roots were immersed in graduated cylinders, observing the displaced volume. Posteriorly roots were all dried in an oven with forced air circulation at 65ºC for 72 hours, to determine RDM. PH and root length variables were used to determine the shoot: root ratio.

Data obtained were submitted to analysis of variance using the F test ($P \leq 0.05$). efficient microorganisms factor means, when significant, were compared by the Tukey's test at 5% probability.

RESULTS AND DISCUSSION

There was significant effect of the efficient microorganisms (EM) to stem diameter (SD), leaf blade length (LBL), number of leaves (NL), total foliage dry mass (TFDM), root dry mass (RDM) and root volume (RV). However, there was no significant effect of molasses doses to analyzed variables (Table 3).

Table 3 - Analysis of variance for plant height (PH), stem diameter (SD), leaf blade length (LBL), number of leaves (NL), total foliage dry mass (TFDM), root dry mass (RDM), root volume (RV) and shoot/root ratio (S/R) according to treatments

Variation sources	**Mean Squares**							
	PH	**SD**	**LBL**	**NL**	**TFDM**	**RDM**	**RV**	**S/R**
Efficient microorganisms (EM)	136.86^{ns}	18.56^{*}	35.88^{*}	814.83^{*}	44.99^{*}	14.90^{*}	34.20^{*}	0.10^{ns}
Molasses doses (MD)	24.35^{ns}	1.60^{ns}	3.36^{ns}	105.34^{ns}	5.37^{ns}	0.70^{ns}	11.29^{ns}	0.11^{ns}
EM X MD	76.86^{ns}	0.00^{ns}	5.52^{ns}	0.00^{ns}	0.00^{ns}	0.21^{ns}	0.00^{ns}	0.07^{ns}
CV(%)	12.62	8.50	11.08	24.88	24.72	13.28	11.94	15.73

*Significant at the level of 5%; ^{ns}Not significant by F-test. CV - Coefficient of variation

Source: The author

Non occurrence of the molasses effect may be associated the high fermentation capacity of the residue, as seen *in loco*. This can impair both EM performance and root growth. Rhee *et al*. (1984) and Camilos Neto *et al*. (2005) explain that sugarcane molasses has high concentration of sucrose, in addition to other substances, inducing fermentation processes.

Another possible explanation for lack of positive effect of this residue on cashew tree development is the reduction of water drainage in the soil, seen *in loco*, with the application of molasses doses. Substantial concentrations of Na^{+} and K^{+} in the residue (Table 2) can disperse soil clay particles and cause soil pore clogging, reducing its permeability (BONINI *et al*., 2014). Furthermore, the high sodium content in molasses can result in salt stress in plant, even if the molasses has good concentrations of nutrients. This can lead to limited seedling growth, due the expenditure of energy to absorb water and nutrients (BITENCOURT *et al*., 2022).

The increase in SD provided by application of EM (Table 4), may be related to the better use of nutrients from the mineralization of plant residues in the soil, because EM act to increase the speedw of decomposition of soil organic matter, favoring the mineralization of nutrients for plants (BERBARA *et al*., 2002).

In addition, EM may have produced substances such as phytohormones that contribute to the processes of cell division and expansion, resulting in increased SD and productivity of plant species (PUGAS *et al*., 2013).

This result corroborates with what found by Diering *et al*. (2022) working with citrus, where EM inoculation with provided SD greater.

Table 4 - Mean value of stem diameter (SD), leaf blade length (LBL), number of leaves (NL), total foliage dry mass (TFDM), root dry mass (RDM) and root volume (RV) according to efficient microorganisms

Variation sources	Variable					
	SD	LBL	NL	TFDM	RDM	RV
With microrganisms	8.26 a	11.13 a	21.81 a	4.60 a	3.91 a	12.00 a
Without microrganisms	6.65 b	8.89 b	11.15 b	2.09 b	2.47 b	7.23 b
CV (%)	8.50	11.08	24.88	24.72	13.28	11.94

*Means followed by the same letter in the column do not differ by Tukey test at 5% probability of error. CV - Coefficient of variation

Source: The author

The highest means of LBL and NL were provided by presence of EM, with an increase of approximately 25.19 and 95.60%, respectively (Table 4). The presence of EM enriches the soil with vital energy, increasing the soil production natural capacity (SILVA *et al*., 2020; SILVA; CORDEIRO; ROCHA, 2022). This results in improved metabolism and photosynthetic capacity of plants (ANDRADE, 2020).

According to Martínez *et al*. (2016) and Olanrewaju *et al*. (2017) EM, like rhizobacteria, are capable of improving the photosynthetic rate of plants, due to increase in stomatal conductance and photochemical efficiency. This may explain the increase in LBL and NL of cashew tree seedlings.

The effect of ME on increasing LBL and NL was also observed in strawberry (ALVAREZ *et al*., 2018), common bean (HURTADO *et al*., 2019a) and cucumber (HURTADO *et al*., 2019b).

For TFDM, the application of EM provided higher value for this variable (Table 4). This possibly occurred due to the high ability of EM to promote greater availability of nutrients the plants, better photosynthetic functioning and dry matter accumulation (DIERING *et al*., 2022).

Peralta-Antonio *et al*. (2019) point out that ME stimulates greater plant dry matter. According to the authors, this occurs due to fungi Aspergillus sp., Penicillium sp., Cladosporium sp., Rhizophus sp., some actinomycetes and bacteria that decompose, mineralize and soluble nutrients make available to plants. According to Díaz et al. (2009), the use of EM increases leaf growth and photosynthetic area, greater nutrient production, which results in greater accumulated dry mass. Sousa *et al*. (2020) evaluating the efficiency of the application a biological cocktail of EM on crisphead lettuce, concluded that the plants submitted to this product obtained a greater increase in shoot biomass, resulting in a greater crop productivity.

Regarding the RDM, the EM provided increase of this variable (Table 4). This occurred, probably by greater availability of nutrients and greater efficiency in absorption, resulting in increase RDM. According to Andrade (2020), EM provide increased soil aggregation and porosity, favoring mineralization and nutrient availability for plant, activating metabolism and root growth.

According to Bonfim *et al*. (2011), EM synthesize different types of metabolites, in fermentation process, such hormones, vitamins and bioactive substances that are used by plant to activate root development.

The effect of EM on RV (Table 4) must be associated with their ability to synthesize substances that promote root development, such as phytohormones. According to Avila et al. (2021), the different EM species produce organic acids, plant hormones (gibberellins, auxins and cytokinins), in addition to vitamins, antibiotics and polysaccharides, which positively influence in plant development.

Similar results were obtained by Zydlik and Zydlik (2008) and Filipp *et al*. (2009) using preparations based EM in M9 apple tree rootstocks and Diering *et al*. (2022) in citrus, who found an increase in the RV of these cultures in presence of EM.

CONCLUSIONS

Inoculation with efficient microorganisms maximized the development of cashew tree seedlings, and is therefore recommended for the initial production of early dwarf cashew under study conditions.

Molasses did not positively influence the development of cashew tree seedlings. Therefore, we do not recommend the use of this residue, in the doses tested, for the initial production of early dwarf cashew under study conditions.

ACKNOWLEDGEMENTS

The authors thank the State University of Piauí (UESPI), the Dean of Research and Graduate Studies (PROP) and the Institutional Program for Scientific Initiation Scholarships (PIBIC).

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