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Sheep manure fertilization in *Mimosa caesalpiniifolia* in an Albaquult[1]

Adubação com esterco ovino em *Mimosa caesalpiniifolia* em um Planossolo

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HIGHLIGHTS:

Macronutrients content of Mimosa caesalpiniifolia *in decreasing order was N > Ca > K > Mg > P > S.*
Micronutrients content of Mimosa caesalpiniifolia *in decreasing order was Fe > Mn > B > Zn > Cu.*
Sheep manure increases soil fertility.

ABSTRACT: The use of organic fertilizers can increase the production of forest species for the extraction of wood from monoculture stands or integrated systems. This study aimed to evaluate the effect of applying doses of sheep manure on the biometric traits of *Mimosa caesalpiniifolia* ('sabiá') in a silviculture system in an area previously occupied by native degraded pasture in an Albaquult. The experimental design was randomized blocks with four repetitions, with treatments corresponding to five doses of sheep manure per plant: 0, 2, 4, 8, and 12 kg in the first year, while in the second year the double of the doses (0, 4, 8, 16 and 32 kg per plant) were applied as topdressing under the canopy. The following biometric variables were evaluated: height (H); root collar diameter (RCD); diameter at breast height (DBH); above-ground dry weight (AGDW); accumulation of nutrients (aerial part); and soil fertility. The plants were responsive to the organic fertilization regarding the variables H, DBH, and AGDW. The sheep manure increased the mean values of pH, P, K, Ca, Mg, SB, CEC, BS, $S\text{-}SO_4^{2-}$ and Zn, and reduced the potential acidity in the 0-0.20 m soil layer. The organic matter variable increased up to the dose of 13.70 kg per plant. The accumulation rates of macro and micronutrients in the 'sabiá' plants were N > Ca > K > Mg > P > S and Fe > Mn > B > Zn > Cu, respectively.

Key words: organic fertilizers, soil fertility, semiarid region

RESUMO: O uso de adubos orgânicos pode incrementar a produção de espécies florestais, as quais podem ser usadas para extração de madeira em monocultivos ou em sistemas integrados. Objetivou-se neste estudo, avaliar a aplicação de doses de esterco de ovino na implantação de *Mimosa caesalpiniifolia* (sabiá) em sistema silviagrícola, de uma área anteriormente ocupada por pastagem degradada em um Albaquult (Planossolo Háplico). O delineamento experimental foi em blocos casualizados, com quatro repetições, e os tratamentos corresponderam às seguintes doses: 0, 2; 4; 8 e 12 kg de esterco de ovino por planta no primeiro ano, cujas quantidades empregadas foram reaplicadas em dobro (0, 4, 8, 16 e 32 kg por planta) no ano seguinte na projeção da copa. As variáveis avaliadas corresponderam aos atributos biométricos: altura (ALT); diâmetro do colmo ou coleto (DC) e diâmetro na altura do peito (DAP); massa seca da parte aérea (MSPA); acúmulo de nutrientes (parte aérea); e fertilidade do solo. As plantas de sabiá foram responsivas à adubação orgânica com incrementos nas variáveis ALT, DAP e MSPA. O esterco de ovino aumentou os valores médios na camada de 0-0,20 m para pH, P, K, Ca, Mg, SB, CTC, V, $S\text{-}SO_4^{2-}$ e Zn; com diminuição da acidez potencial. Para a variável matéria orgânica o incremento ocorreu até à dose de 13,70 kg por planta. O acúmulo de macro e micronutrientes, em plantas de sabiá foi N > Ca > K > Mg > P > S e Fe > Mn > B > Zn > Cu, respectivamente.

Palavras-chave: adubos orgânicos, fertilidade do solo, região semiárida

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Introduction

The use of organic inputs is essential to assure the full development of perennial crops by acting as a source of nutrients, principally in areas with low soil fertility and/or small use of conventional fertilizers. Studies have shown that the long-term use of organic fertilizers improves soil fertility in semiarid regions (García-Orenes et al., 2016; Souza et al., 2016).

Although the information is spotty about the general soil fertility in Brazil's semiarid Northeast region, some studies have indicated that phosphorus and nitrogen are the main limiting elements for plant nutrition (Salcedo, 2006; Menezes et al., 2012). On the other side, the continuous use of organic fertilizers could improve the concentration of P in soil, but the most important is the chemical form of P that comes from organic fertilizer (Komiyama & Ito, 2019).

The manure of goats and sheep has larger concentrations of nitrogen, calcium, and manganese; specifically, sheep manure contains higher phosphorus and potassium concentrations than the manure from other animals, such as donkeys and cattle (Souto et al., 2005; 2013).

Crops propagated from seedlings customarily receive more attention when employing organic fertilizers, principally because they exploit the same soil volume for the long-term, considering improving the physical and chemical properties (Rós et al., 2013).

The nutritional state and nutrient cycling of 'sabiá' (*Mimosa caesalpiniifolia*) have been evaluated to produce seedlings, as well as fertilization in shrubland areas, and measurement of the production of leaf litter (Lacerda et al., 2006; Caldas et al., 2009; Freire et al., 2010).

Since organic fertilization improves the chemical properties of the soil, this study aimed to evaluate the effect of sheep manure doses on the biometric traits of 'sabiá' grown and the chemical attributes in an area previously occupied by native degraded pasture in an Albaquult located in a semiarid region of the state of Ceará, Brazil.

Material and Methods

The experiment was conducted from June 2014 to March 2016 on the Triunfo Farm in Ibaretama, Ceará, Brazil, in an Albaquults area. The soil was analyzed beforehand in the surface (0.0-0.2 m) and subsurface (0.2-0.4 m) layers (Table 1)

The variables P, K, Al, and OM had concentrations considered low, while Ca was medium and Mg high, according to the classification proposed by Fernandes (1993). Thus, no lime was applied for pH correction. During the period of the experiment, it rained 1,207 mm. Figure 1 presents the monthly distribution of rainfall during the experimental period.

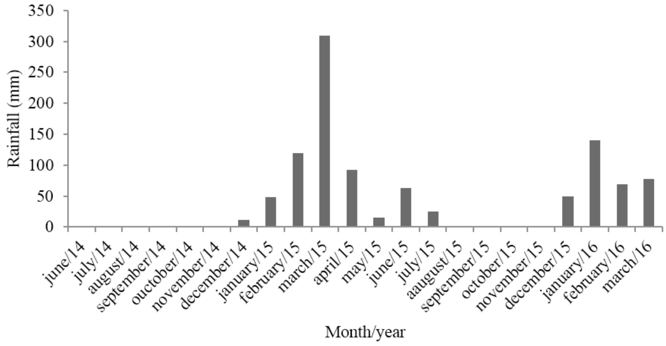


Figure 1. Rainfall in the experimental area from June 2014 to March 2016, in Ibaretama, Ceará, Brazil. Source: Triunfo Farm rain gauge

The experimental area was formerly used for extensive grazing of cattle and sheep and was mainly composed of native Caatinga pasture.

The experimental design was randomized blocks with five sheep manure doses and four repetitions, where the experimental unit was composed of six plants. The block was composed of each double row of 'sabiá', spaced to provide room for the cultivation of annual crops.

The seedlings were produced in a nursery installed at the Quixadá Campus of the Federal Institute of Education, Science, and Technology of Ceará (IFCE). They were transplanted in June 2014 into pits with dimensions of 0.4 x 0.4 x 0.4 m. At the time of planting, 2.0 L of hydrogel was applied per pit. The seedlings were planted with a spacing of 3.0 x 2.0 m in double rows, in turn, spaced 10 m apart, with annual crops (corn, millet, sunflower, cowpea) grown between the double rows in the agricultural years of 2015 and 2016.

The sheep manure was applied directly in the pits with doses of 0, 2, 4, 8 and 12 kg per pit (dry base) (June/2014). The sheep manure was obtained in the farm itself and presented the following chemical characteristics: N, P, K, Ca, Mg, S, Cu, Fe, Zn, Mn, B, cellulose, lignin, and pH_{H20}: 12.6 (g kg^{-1}), 3.2 (g kg^{-1}), 8.4 (g kg^{-1}), 16.6 (g kg^{-1}), 8.4 (g kg^{-1}), 3.1 (g kg^{-1}), 22 (mg kg^{-1}), 3920 (mg kg^{-1}), 91 (mg kg^{-1}), 550 (mg kg^{-1}), 18 (mg kg^{-1}), 95 (g kg^{-1}), 130 (g kg^{-1}), and 8.7, respectively.

After planting, the plants were irrigated manually with 10.0 L of water per plant per week until December 2014. The other crop managements/15, manure was applied as topdressing under the canopy projection, approximately 0.3 m from the trunk, at twice the initial doses: 0, 4, 8, 16, and 24 kg per plant (dry base). The total manure applied in 2014/2015 was: 0, 6, 12, 24, and 36 kg per plant (dry base).

Table 1. Chemical attributes and texture from the experimental area

Layer (m)	pH	OM (g kg^{-1})	P (mg dm^{-3})	K	Na	Ca	Mg	Al	H + Al	BS	CEC	BS (%)
				(mmol$_c$ dm^{-3})								
0-0.2	5.4	6.7	2.6	1	1.6	28	22	2	14	53	67	78
0.2-0.4	5.8	6.1	1.8	1	1.2	46	34	0	27	82	109	75

	Cu	Fe	Mn	Zn	Sand	Silt	Clay	EC
	(mg dm^{-3})				(g kg^{-1})			(mS cm^{-1})
0-0.2	0.36	139	58.4	0.78	672.5	285.4	42.1	0.11
0.2-0.4	0.53	133	50.2	0.97	666.5	238.0	95.5	0.24

OM - organic matter; SB - sum of basis; CEC - cation exchange capacity; BS - base saturation; EC - electrical conductivity; OM - Walkley-Black method; P/K/Na/Cu/Fe/Mn/Zn - Mehlich-1 method; Ca/Mg - KCl 1M method; H + Al - Calcium acetate method; Sand, silt, and clay - Pipette method

The following agronomic variables were evaluated in two plants per plot (6 m^2 of useful area/plot), nine months after planting: height - H (cm) and root collar diameter - RCD (cm) measured at the height from 5 to 8 cm from the soil.

The same variables were measured 22 months after planting, along with diameter at breast height - DBH (cm) and above-ground dry weight - AGDW (grams per plant), in this case, based on one plant per plot. The dry weight was measured after drying the sample material in a forced-air oven at 60 °C until reaching constant weight. The dried samples were then milled to analyze the macro (N, P, K, Ca, Mg and S) and micronutrients (B, Cu, Fe, Mn and Zn), as described by Miyazawa et al. (2009). The data on nutrient concentrations and dry weight were used to calculate the accumulation of nutrients.

The soil fertility was analyzed in single samples (five per plot), in the 0-0.20 and 0.20-0.40 m layers under the canopy projection, always at the start of the rainy season. The samples were collected before fertilization, in 2015 and 2016, to evaluate the following variables: pH; organic matter (OM); phosphorus (P); potassium (K); calcium (Ca); magnesium (Mg); potential acidity (H+Al); sum of bases (SB); cation exchange capacity (CEC); base saturation (BS); sulfur ($S\text{-}SO_4^{2-}$); sodium (Na); boron (B); copper (Cu); iron (Fe); manganese (Mn); and zinc (Zn), according to Donagemma et al. (2011).

The data were submitted to analysis of variance using the SISVAR software (Ferreira, 2011) and regression analysis.

Results and Discussion

In the first year (2015), there were significant differences in the chemical attributes in the surface layer (0-0.20 m) for pH ($p < 0.05$) and Zn ($p < 0.01$); and in the subsurface layer (0.20 - 0.40 m) for pH (Table 2). In both layers, the pH increased with rising doses of sheep manure, as was also the case of zinc, but only in the surface layer (Table 3).

In the subsurface layer in the first evaluation year (2015), the pH increased with rising sheep manure doses in the pits, which can be related to the complexation of H^+ ions.

In the second evaluation year (2016), in the surface layer, there were significant differences ($p \le 0.01$) due to organic fertilizer doses for most variables, except for Na and the micronutrients B, Cu, Fe, and Mn (Table 2). There were significant differences in the 0.20-0.40 m layer ($p \le 0.01$) only for P and Fe (Table 2).

In the surface layer, there was a linear increase with rising sheep manure doses for the variables pH, P, K, Ca, Mg, SB, CEC, BS, $S\text{-}SO_4^{2-}$, and Zn, and a decline of the concentrations

Table 2. Mean values, F-test significance, and coefficients of variation (CV) of chemical attributes of the soil according to the sheep manure doses applied on sabiá plants (*Mimosa caesalpiniifolia*)

Doses	pH	OM	P	K	Ca	Mg	H + Al	SB	CEC	BS	$S\text{-}SO_4^{2-}$	Na	B	Cu	Fe	Mn	Zn
($kg\ plant^{-1}$)		($g\ dm^{-3}$)	($mg\ dm^{-3}$)		($mmol_c\ dm^{-3}$)					(%)	($mg\ dm^{-3}$)						
0-0.20 m layer; 2015																	
0	5.4	5.0	3.8	31	8.0	8.0	24.0	16.0	40.0	40	4.5	39	0.28	0.18	26	5.0	0.28
2	5.7	7.7	4.8	46	14.8	18.0	28.8	32.8	61.6	53	4.5	61	0.30	0.19	35	8.9	0.25
4	5.6	5.5	6.3	34	13.5	13.8	25.8	27.3	53.1	51	3.8	44	0.34	0.2	28	8.2	0.29
8	5.8	10.5	5.7	47	15.8	14.8	25.8	30.6	56.4	54	5.3	49	0.35	0.22	32	14.8	0.56
12	6.1	9.3	5.7	44	18.0	20.3	25.3	38.3	63.6	60	4.5	57	0.32	0.25	32	11.4	0.45
Mean	5.7	7.6	5.2	40	14.0	15.0	25.9	29.0	54.9	52	4.52	50	0.32	0.21	31	9.6	0.37
F-test	**	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	*
CV (%)	3.2	58.7	28.4	12.3	46.2	48.9	20.3	43.7	26.7	16.9	20.2	32.3	18.3	37.6	26.8	59.0	33.5
0.20-0.40 m layer; 2015																	
0	6.7	5.0	3.8	27	28.5	63.5	16.0	92.0	108.0	85	4.5	303	0.27	0.23	25	6.0	0.11
2	6.8	5.0	4.0	34	39.3	70.3	13.8	109.6	123.4	89	3.8	377	0.25	0.23	24	9.9	0.11
4	6.5	5.0	6.5	29	36.5	57.3	16.3	93.8	110.1	85	3.0	318	0.29	0.23	24	7.5	0.10
8	6.7	5.0	4.0	30	31.2	62.5	15.3	93.7	109.0	86	3.8	298	0.24	0.23	23	5.5	0.06
12	7.2	5.0	5.0	36	44.5	76.0	13.5	120.5	134.0	90	3.8	390	0.25	0.23	22	7.3	0.13
Mean	6.8	5.0	4.7	31	36.0	65.9	15.0	101.9	116.9	87	3.7	337	0.26	0.23	23	7.2	0.10
F-test	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV (%)	2.9	1.0	54.8	32.5	17.1	13.5	8.8	34.4	24.1	10.1	28.3	31.7	29.6	45.9	19.3	71.7	54.7
0-0.20 m layer; 2016																	
0	5.1	5.0	6.8	43	11.8	12.0	25.0	23.8	48.8	49	6.3	42	0.20	0.13	59	6.1	0.30
4	5.8	7.0	13.3	52	23.0	22.0	25.0	45.0	70.0	64	8.0	53	0.44	0.15	139	14.7	0.45
8	6.1	7.7	16.5	143	18.5	17.0	18.0	35.5	53.5	66	7.7	48	0.37	0.13	83	9.7	0.45
16	6.3	7.0	24.7	113	22.0	21.0	18.3	43.0	61.3	70	8.0	69	0.46	0.23	139	16.7	0.57
24	6.2	6.3	51.0	163	36.9	25.0	17.0	61.9	78.9	78	10.5	63	0.39	0.18	38	10.4	0.58
Mean	5.9	6.6	22.5	103	22.4	19.4	20.7	41.8	62.5	66	8.1	55	0.37	0.16	92	11.5	0.58
F-test	*	*	*	*	*	*	*	*	*	**	*	ns	ns	ns	ns	ns	*
CV (%)	10.1	19.3	52.7	25.3	15.7	25.9	21.6	17.3	17.3	4.7	18.4	35.8	34.8	32.7	31.2	42.7	28.9
0.20-0.40 m layer; 2016																	
0	6.3	5.5	3.5	27	27.0	50.5	18.0	77.5	95.5	81	9.3	321	0.30	0.23	33	2.9	0.43
4	6.4	5.0	5.3	42	39.0	51.0	17.8	90.0	107.8	83	10.5	357	0.43	0.15	33	6.3	0.38
8	6.4	6.5	7.5	81	24.8	53.3	18.8	78.1	96.9	81	10.5	278	0.36	0.15	50	8.7	0.88
16	6.5	5.0	5.0	35	35.8	73.8	17.3	109.6	126.9	86	13.8	425	0.26	0.13	32	6.9	0.46
24	6.4	5.7	12.3	43	33.8	65.3	17.0	99.1	116.1	85	13.0	300	0.43	0.13	25	8.9	0.53
Mean	6.4	5.5	6.7	46	32.1	58.8	17.8	90.9	108.6	83	11.4	336	0.36	0.16	34	6.7	0.54
F-test	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns
CV (%)	6.7	26.7	39.2	28.1	11.4	25.6	9.8	16.3	13.3	3.9	35.7	20.7	22.6	43.1	20.4	55.7	50.9

OM - organic matter; SB - sum of basis; CEC - cation exchange capacity; BS - base saturation. ns, * and ** - Not significant and significant at $p \le 0.05$ and $p \le 0.01$, respectively for potential acidity in 2016. For organic matter (OM), the best response model was quadratic, with a maximum value at the dose of 13.7 kg per plant (Table 3).

In the subsurface layer, there was a linear increase in phosphorus concentration with rising manure doses. For Fe, the response was quadratic, with a maximum value at the manure dose of 9.9 kg ha^{-1}, followed by a decline in concentration after this dose (Table 3).

In the second evaluation (2016), the variables pH, Ca, and BS were still below the critical levels despite the increase of the averages compared to the previous year. The content of OM was below the value obtained in 2015, which can be possibly be explained by its mineralization. On the other hand, the average P, K, and Mg concentrations were above the critical levels.

Regarding agronomic evaluation, in the first year (2015), there were significant differences for the parameters height (H) and root collar diameter (RCD) according to the doses of organic fertilizer applied (Table 4). The doses of 7.1 and 6.5 kg of manure per pit increased the mean values of the two variables, respectively (Table 4).

In the second evaluation year (2016), the variables height (H), diameter at breast height (DBH), and above-ground dry weight (AGDW) differed according to the organic fertilizer doses, with linear increases with rising doses in all cases (Table 4). For this evaluation (2016), for each kilogram of manure applied, the AGDW increased by 7.05 g per plant (Figure 2).

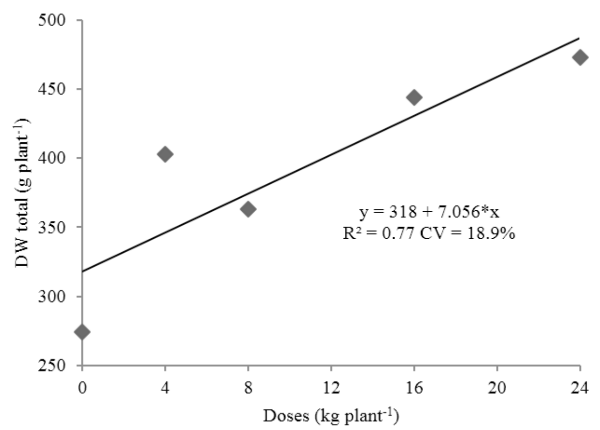
The doses of manure applied caused differences in the contents of nutrients (Table 5), except for Cu, Fe, Mn, and Zn. The average values of content of macro and micronutrients in decreasing order were N > Ca > K > Mg > P > S and Fe > Mn > B > Zn > Cu, respectively.

The average values for pH, P, K, Ca, Mg, and BS in the surface layer obtained in 2015 were below the critical values for subsistence farming in smallholdings, as described by Souza et al. (2014) in the Sertão dos Inhamuns region of Ceará State, Brazil. Only the OM concentration was considered adequate, as indicated by those authors. These authors obtained for areas cultivated with maize and cowpea in the semiarid region the

Table 4. Mean values, F-test significance, and coefficients of variation (CV) of biometric attributes and dry weight according to the sheep manure doses applied to 'sabiá' plants (*Mimosa caesalpiniifolia*)

Doses (kg $plant^{-1}$)	Height (cm)	RCD	DBH	DW leaves ($g\ plant^{-1}$)	DW stalk	DW total
			2015			
0	1.05	1.12	-	-	-	-
2	1.26	1.22	-	-	-	-
4	1.29	1.27	-	-	-	-
8	1.25	1.23	-	-	-	-
12	1.14	1.19	-	-	-	-
Mean	1.20	1.21	-	-	-	-
F-test	*	**	-	-	-	-
CV (%)	9.3	4.3	-	-	-	-
			2016			
0	2.43	2.43	1.31	71	203	274
4	2.46	2.33	1.36	113	290	403
8	2.78	2.43	1.53	63	300	363
16	2.64	2.48	1.56	66	378	444
24	2.83	2.53	1.62	69	404	473
Means	2.63	2.44	1.48	76	315	391
F-test	*	ns	*	ns	*	*
CV (%)	7.4	11.4	10.9	29.8	29.7	18.9

ns, * and ** - Not significant and significant at $p \leq 0.05$ and $p \leq 0.01$, respectively; RCD - Root collar diameter; DBH - Diameter at breast height; DW - Dry weight



* - Significant at $p \leq 0,05$ by F test

Figure 2. Above-ground total dry weight (DW) of 'sabiá' plants (*Mimosa caesalpiniifolia*) according to the sheep manure doses

Table 3. Regression equations and coefficients of determination (R^2) of the chemical attributes of the soil, biometric attributes, dry weight, and accumulation of nutrients according to the sheep manure doses in 'sabiá' plants (*Mimosa caesalpiniifolia*)

Variable	Equation	R^2	Variable	Equation	R^2
	0-0.20 m layer; 2015			0.20-0.40 m layer; 2016	
pH	y = 5.457 + 0.050*x	0.88	P	y = 3.723 + 0.288*x	0.65
Zn	y = 0.223 + 0.042*x -0.001*x^2	0.66	Fe	y = 32.23 + 1.834x - 0.092x^2	0.58
	0.20-0.40 m layer; 2015			2015	
pH	y = 6.594 + 0.035x	0.44	Height (cm)	y = 1.086 + 0.071*x - 0.005*x^2	0.84
			Root collar diameter (cm)	y = 1.137 + 0.039*x - 0.003*x^2	0.83
	0-0.20 m layer; 2016			2016	
pH	y = 5.485 + 0.039*x	0.63	Height (cm)	y = 2.471 + 0.015*x	0.64
OM	y = 5.372 + 0.358*x - 0.013*x^2	0.80	DBH (cm)	y = 1.342 + 0.012*x	0.85
P	y = 4.627 + 1.714*x	0.92	DW stalk (g $plant^{-1}$)	y = 233.0 + 7.877*x	0.91
K	y = 54.45 + 4.639*x	0.70	N (mg $plant^{-1}$)	y = 7297 + 218.1*x	0.74
Ca	y = 13.73 + 0.837*x	0.77	P (mg $plant^{-1}$)	y = 540.6 + 22.78*x	0.80
Mg	y = 15.16 + 0.407x	0.61	K (mg $plant^{-1}$)	y = 2425 + 88.94*x	0.69
H+Al	y = 24.28 - 0.348*x	0.71	Ca (mg $plant^{-1}$)	y = 2784 + 58.64*x	0.72
SB	y = 32.25 + 1.404*x	0.79	Mg (mg $plant^{-1}$)	y = 777.8 + 25.95*x	0.92
CEC	y = 56.54 + 1.055*x	0.60	S (mg $plant^{-1}$)	y = 438.7 + 12.71*x	0.83
BS	y = 83.87 + 0.157x	0.50	B (ug $plant^{-1}$)	y = 7265 + 512.0*x	0.78
$S\text{-}SO_4^{2-}$	y = 9.6 + 0.175*x	0.79			
Zn	y = 0.35 + 0.011*x	0.84			

OM - organic matter; SB - sum of basis; CEC - cation exchange capacity; BS - base saturation; DBH - diameter at the breast height; DW - dry weight. * - Significant at $p \leq 0.05$ by F test

Table 5. Mean values, F-test significance, and coefficients of variation (CV) of accumulation of nutrients according to the sheep manure doses applied to 'sabiá' plants (*Mimosa caesalpiniifolia*)

Doses (kg plant^{-1})	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
	(mg plant^{-1})						(µg plant^{-1})				
0	5.691	401	1.707	2.339	754	382	5.543	2.341	28.629	25.018	5.308
4	9.609	793	3.679	3.423	860	543	13.381	2.670	28.169	25.573	8.646
8	9.234	711	3.104	3.281	986	527	8.559	2.009	26.673	26.822	7.500
16	11.625	945	3.825	3.995	1.318	706	16.064	2.921	54.190	26.867	9.865
24	11.670	1.038	4.437	3.934	1.321	697	19.407	1.983	31.146	15.868	8.362
Means	9.566	778	3.350	3.394	1.048	571	12.591	2.385	33.761	24.030	7.936
F-test	*	*	**	*	*	*	*	ns	ns	ns	ns
CV (%)	22.5	20.7	19.9	21.3	24.1	28.1	43.4	37.9	57.1	47.7	25.9

ns, * and ** - Not significant and significant at $p \leq 0.05$ and $p \leq 0.01$, respectively

values: OM (g kg^{-1}): 7.3 and 7.5; pH: 6.6 and 6.5; P (mg dm^{-3}): 8.6 and 8.2; K (mmol$_c$ dm^{-3}): 2.8 and 2.7; Ca (mmol$_c$ dm^{-3}): 33.3 and 22.4; Mg (mmol$_c$ dm^{-3}): 11.2 and 9.9; and base saturation (%): 73 and 71, respectively (Souza et al., 2014).

The results reported in Table 3, obtained during the two years, show increases in pH and zinc concentration in the surface layer. The higher pH can be associated with the increased organic matter content in the second year since, among other attributes, OM can absorb H^+ (Lourenzi et al., 2011).

The reduction of aluminum due to the application of organic fertilizers and the consequent increase of base saturation can be attributed to the complexing effect of organic matter, which keeps the Al concentrations low (Naramabuye & Haynes, 2006).

There are no reports in the literature of soils in Brazil's Northeastern semiarid region with high availability of Zn. However, it is logical to expect that increasing pH reduces these micronutrient concentrations (Nachtigall et al., 2009).

Results of studies of fertilization using wastes from hog breeding indicate that there is an increase in pH and zinc in the soil. Still, the diets typically given to these animals contain high levels of this micronutrient, explaining increases in the soil by applying these waste materials (Ernani et al., 2001). In the present study, the sheep manure employed came from animals of Triunfo Farm, in an extensive grazing system (with native Caatinga pasture), without feed supplementation.

Applications of organic compost made from wastes from small ruminants (goat and sheep slaughterhouse wastes and manure) were able to increase the concentration of zinc in the soil, rising with increased doses (Souza et al., 2016), indicating that even the dung from sheep with diets not rich in zinc can be a source of this nutrient. Nachtigall et al. (2009) evaluated the concentrations of zinc fractions due to the addition of poultry litter in the soil, concluding that despite the increase in OM, the added material had low complexation, so it did not contribute to increasing adsorption of this element.

The results for the variables P, K, Ca, and Mg concentrations in the soil have also been reported in other studies of the use of organic fertilization (Oliveira et al., 2014; Silva et al., 2015; Souza et al., 2016).

The reduction of the potential acidity can be explained by analogous reasoning to that involving pH. The increase of the CEC can be attributed to the rise of organic matter from the sheep manure. Similar results were observed by Oliveira et al. (2014).

Concerning sulfur, Abreu Júnior et al. (2002) evaluated organic composts and observed higher S concentrations, mainly due to mineralization of organic matter, similar to our findings.

The organic matter concentration fitted to a quadratic model, being the possible explanation a priming effect, that is a stimulus to microbial activity by the additional source of organic matter (like sheep manure), and this stimulus increases the decomposition rate of the native organic matter (Kuzyakov et al., 2000); thus, the priming effect and the organic matter protection depends on soil and native organic matter properties, including aspects related to texture and mineralogy (Pereira et al., 2018). On the other side, the soil texture is sandy (Table 1), corroborating this justified.

At the field conditions, the manure decomposition rate is strongly influenced by rain in the experimental period (Souto et al., 2005). About the priming effect, there are experiments in laboratory conditions that mention high doses of organic composts proportion to this stimulus of microbial activity (Pereira et al., 2018). The authors said that high doses would surpass the protection capacity of the soil, sharing the added organic material into two pools: protected and unprotected against microbial decomposition; thus, the greater the amount applied, the greater will be the share of the unprotected pool (Pereira et al., 2018). So, a higher decomposition rate at higher doses would be expected (Pereira et al., 2018).

With a dose of 25 Mg ha^{-1} in lettuce, Figueiredo et al. (2012) mention that sheep manure increases soil microbial activity.

The results obtained for P in the second evaluation (2016) in the subsurface layer corroborate those of Souza et al. (2016), who noted increases in the concentration of this nutrient due to the surface application of organic fertilizers.

When planting the 'sabiá' seedlings, the manure was mixed with the soil used to refill the pit, with a depth of 0.4 m. The second application was as topdressing on the surface under the projection of the canopy. According to Novais et al. (2007), the addition of organic materials reduces the soil's capacity to adsorb P, increasing its availability. Further, according to those authors, the organic matter blocks the adsorption sites of the Fe and Al oxides present in the soil, diminishing the phosphorus fixation capacity.

Another explanation for the increase of P in the subsurface layer is the slow release of this nutrient by mineralization from the manure applied in the pit (García-Orenes et al., 2016). For the increase of Fe in the subsurface layer, a possible explanation is related to the high concentration in the manure (3.9 g kg^{-1}).

In an experiment that studied the nutrient release during decomposition of different manures in the semiarid region of Paraíba State, Brazil, the sheep manure had the highest levels of N, P, Ca, and Mg (Souto et al., 2013), which contributed with the results that showed increase in the attributes of soil fertility (Tables 3 and 4).

Even though 'sabiá' is a leguminous species, with the capacity for biological nitrogen fixation (BNF), according to García-Orenes et al. (2016), the sheep manure application increases the nitrogen present in the soil and plants.

It was not verified increases of B in the soil with rising doses of sheep manure. Still, there was higher content of this micronutrient in the plants, so organic fertilizers can be an excellent source to supply this nutrient, as reported by Dey et al. (2015).

Another impressive result was the content increase of all macronutrients and B in the plant with the rise of sheep manure doses (Table 2), which reinforce the results obtained in the soil.

Conclusions

1. 'Sabiá' plants were responsive to the organic fertilization, with increments in height, diameter at breast height, and above-ground dry weight.

2. The sheep manure doses increased the values of pH, P, K, Ca, Mg, SB, CEC, BS, S-SO_4^{2-}, and Zn and reduced the potential acidity in the surface soil layer, whereas in the 0.20-0.40 m layer increased the concentration of P.

3. The doses of sheep manure increases the content of macronutrients and B in 'sabiá' plants.

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