REVISTA CAATINGA — ISSN 0100-316X
UNIVERSIDADE FEDERAL RURAL DO SEMI-ÁRIDO (UFERSA)
Pro-Reitoria de Pesquisa e Pós-Graduação

GROWTH AND NODULATION OF LEUCAENA AND PROSOPIS SEEDLINGS IN SOIL PLUS TANNERY SLUDGE

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ABSTRACT - The objective of this paper was to evaluate the growth and nodulation of Leucaena and Prosopis seedlings in soil plus tannery sludge. The study was conducted in a greenhouse, using bags containing soil plus tannery sludge. Seedlings of Leucaena and Prosopis inoculated with *Bradyrhizobium sp* were used. Results were evaluated 90 days after plant emergency. The application of tannery sludge, in the rate of 11.250 kg per hectare significantly increased plant height, stem diameter, and above ground dry mass of Leucaena. Regarding Prosopis, there were no significant increases in these variables with tannery sludge application, except for aerial dry mass. No significant differences were seen between the treatments with sludge and inoculated with *Bradyrhizobium sp*. as to nodule number and dry mass. Tannery sludge evaluated in this work did not affect nodulation, besides favoring Leucaena and Prosopis seedling growth.
Keywords: *Bradyrhizobium*; industrial residue; biological indicator

CRESCIMENTO E NODULAÇÃO DE MUDAS DE LEUCENA E ALGAROBA EM SOLO COM ADIÇÃO DE LODO DE CURTUME

RESUMO - O objetivo deste trabalho foi avaliar o crescimento e a nodulação de mudas de leucena e algaroba em solo com adição de lodo de curtume. O estudo foi conduzido em casa de vegetação utilizando-se sacos com solo e adicionado lodo de curtume. Foram utilizadas mudas de leucena e algaroba inoculadas com *Bradyrhizobium sp*. Os resultados foram avaliados 90 dias após a emergência das plantas. A aplicação do lodo de curtume na taxa de 11.250 kg por hectare aumentou significativamente a altura das plantas, diâmetro do caule e a massa seca da parte aérea da leucena. Em relação a algaroba, não houve aumentos significativos nestas variáveis com a aplicação do lodo de curtume, exceto para a massa seca da parte aérea. Não houve diferenças significativas no número e na massa seca dos nódulos entre os tratamentos com aplicação de lodo e inoculado com *Bradyrhizobium sp*. O lodo de curtume avaliado neste trabalho não prejudicou a nodulação, além de favorecer o crescimento das mudas de leucena e algaroba.
Palavras-Chave: *Bradyrhizobium*; resíduo industrial; indicador biológico.

INTRODUCTION

Industrialization in the world has contributed for the increase in the generation of potentially toxic solid residues. Tannery companies produce residues, called as sludge, with high organic and inorganic content, plus trivalent chromium (Cr^{3+}) used in the process of tanning (CASTILHOS *et al*., 2002). The most used method for disposal of tannery sludge is the sanitary sites, presenting a high risk of environmental contamination (KONRAD & CASTILHOS 2001).

On the other hand, application of tannery sludge in agricultural soils can be an alternative for chemical fertilization, mainly in relation to macronutrients. According to Ferreira et al. (2003) the tannery sludge can be recommended for application to the soils because the corrective and fertilizing value of residue, that providing increases in the plant growth. Thus, tannery sludge can be benefic to Leucaena and Prosopis growth, that is legumes species used as forages, in semi-arid regions, favoring the animal feeding as protein, vitamins and minerals sources (ARAÚJO *et al*., 2001 a, b).

However, the use of sludge in agricultural soils needs of defined action, in order to not cause damage to environment, mainly to the soil (COSTA *et al*., 2001). The content of Cr^{3+} in the sludge, in organic form, it has relatively ineffective to soil microbial (KONRAD & CASTILHOS, 2001). Some paper had been published about the effects of tannery sludge on soil microbial activity (ANDRÉ & MATTIAZZO, 1997; KONRAD & CASTILHOS, 2001). Recently, others studies evaluated the effects of sewage sludge (FERREIRA & CASTRO, 1995; VIEIRA, 2001) and textile sludge (ARAÚJO, 2004) on nodulation and biological nitrogen fixation (BNF) in legumes, but none was carried out to evaluate the effect of tannery sludge on these biological indicators. Viser & Parkinson (1992) reported that nodulation and BNF have been proposed as one of the most important biological indicators of soil pollution and according to Wetzel & Werner (1995), the reactions of both the legumes and *Rhizobium*, as well as the nodulation, are important parameters related with toxic effects of pollutant residue application to the soil.

The aim of this paper was to evaluate the growth and nodulation of Leucaena and Prosopis seedlings in soil plus tannery sludge.

MATERIAL AND METHODS

The experiment was carried out in a greenhouse. Five-kilogram sacks were filled with Ultipsamment Soil collected at 0-20 cm depth, whose chemical characteristic are: pH, 6.5; organic matter, 8.95 g dm^{-3}; P, 56.6 mg dm^{-3}; K, 0.16; Ca, 1.37; Mg, 0.83; H+Al, 0.36 and CEC, 2.92 $Cmol_c\ dm^{-3}$. The chemical characteristic of sludge derived from tannery Company, in Teresina, Piauí, Brazil, are presented in Table 1.

Table 1. Chemical composition of tannery sludge.

pH	OM	N	P	K	Ca	Mg	Na	Cr
	-----	-----	-----	-----	g kg^{-1}	-----	-----	-----
7.7	407.4	22.9	1.3	6.4	46.4	27.2	4.2	43.0

OM = Organic matter

A randomized completely design with six treatments and six replications was used. The treatments consisted of T_1, control; T_2, complete fertilization (NPK); T_3, Inoculation with *Bradyrhizobium sp*. + PK; T_4, tannery sludge (11,625 kg ha^{-1}) + Inoculation + PK; T_5, tannery sludge (23,250 kg ha^{-1}) + Inoculation + PK; T_6, tannery sludge (46,500 kg ha^{-1}) + Inoculation + PK. The nitrogen, phosphorus and potassium fertilization was carried out with the application of 110 mg kg^{-1} of urea, 200 mg kg^{-1} of simple super phosphate and 50 mg kg^{-1} of potassium chloride at the plantation. Doses of tannery sludge corresponded, respectively, to incorporation of 250, 500 and 1000 mg Cr kg^{-1} of soil. Tannery sludge was mixed into the whole soil inside the sacks. Leucaena (*Leucaena leucocephala*) and Prosopis (*Prosopis juliflora*) seeds were inoculated with a commercial inoculum at rate of 1 kg per 40 kg seed. Six Leucaena and Prosopis seeds were planted per sacks and after emergence, seedlings were thinned to one plant per sacks.

Evaluations for plant height and diameter, dry mass, nodule number and dry mass were made at 90 days after emergence. Plant height and diameter were determined by ruler and paquimeter, respectively. Nodules were separated, dried and weighed. The shoots were also dried and weighed. The chemical characteristics of soils, in all treatments, were analyzed after the experiment.

An univariate analysis of variance was applied to the data and the means comparison was made through Duncan's multiple range test ($P<0.05$).

RESULTS AND DISCUSSION

Tannery sludge increased the soil organic matter, phosphorus, calcium and sodium contents (Table 2). There was an increase of approximately three times in soil organic matter and calcium contents with application of sludge in the rate of 46,500 kg ha^{-1} (T6). The increase of soil sodium content was approximately two times, compared to the control. The increase in these chemical attributes of soil is consequence of the high organic matter, calcium and sodium

Table 2. Chemical composition of soils at 90 days after experiment.

	OM	P	K	Ca	Mg	Na
	g kg^{-1}	mg dm^{-3}	——	cmol$_c$ dm^{-3}	——	
T1	9.26 c	33.8 b	0.05 a	1.32 c	1.14 a	0.17 b
T2	10.85 bc	20.3 c	0.04 a	1.27 c	1.11 a	0.17 b
T3	8.57 c	42.7 a	0.06 a	1.55 c	0.85 a	0.17 b
T4	15.04 b	39.2 a	0.05 a	3.22 b	0.97 a	0.21 b
T5	21.85 ab	40.3 a	0.05 a	4.33 a	0.66 b	0.26 ab
T6	28.41 a	47.2 a	0.05 a	4.78 a	0.84 a	0.35 a

OM – Organic matter
T1 = control; **T2** = complete fertilization (NPK); **T3** = Inoculation with *Bradyrhizobium sp.* + PK; **T4** = Tannery sludge (11,625 kg ha^{-1}) + Inoculation + PK; **T5** = Tannery sludge (23,250 kg ha^{-1}) + Inoculation + PK; **T6** = Tannery sludge (46,500 kg ha^{-1}) + Inoculation + PK. Values followed by the same letter in the columns are not significantly different by Duncan's test ($P \leq 0.05$).

contents in the residue (Table 1). Similar results were founded by Selbach *et al*. (1991), Castilhos *et al*. (2002) e Ferreira *et al*. (2003) in soils of temperate regions.

The use of tannery sludge favored the Leucaena growth (Table 3). The plant height was larger in the soil plus tannery sludge in the rates of 11,625 kg ha^{-1} (T4), being superior to soil with application of N, P and K (T2). In relation to plant diameter and dry mass, the behaviors were similar, statistically, among the soils with tannery (T4). On the other hand, there were not significant differences, among the treatments, in the plant height and diameter of Prosopis, although there was an increment in these variables with the application of tannery sludge (T4, T5 and T6) (Table 3). There was a significant increase, compared to the control (T1), in dry mass of Prosopis with the application of the tannery sludge (T4, T5 and T6).

These results indicate that the tannery sludge, due the high organic matter content, it provided

Table 3. Plant height and diameter, and dry mass of Leucaena and Prosopis seedlings in soil plus tannery sludge and inoculation[1].

Treatment	Plant height (cm plant^{-1})		Plant diameter (mm plant^{-1})		Plant dry mass (g plant^{-1})	
	Leucaena	Prosopis	Leucaena	Prosopis	Leucaena	Prosopis
T1	55.0 c	85.0 a	60.0 b	50.0 a	5.51 b	4.61 b
T2	65.5 bc	84.0 a	71.4 ab	46.0 a	6.72 ab	6.14 ab
T3	65.0 bc	95.3 a	63.3 ab	56.0 a	7.70 ab	8.66 ab
T4	92.6 a	112.0 a	85.3 a	66.0 a	13.75 a	10.97 a
T5	71.0 bc	115.6 a	69.0 ab	66.0 a	10.98 ab	12.07 a
T6	81.0 ab	113.3 a	83.3 a	63.0 a	10.51 ab	10.70 a

T1 = control; **T2** = complete fertilization (NPK); **T3** = Inoculation with *Bradyrhizobium sp.* + PK; **T4** = Tannery sludge (11,625 kg ha^{-1}) + Inoculation + PK; **T5** = Tannery sludge (23,250 kg ha^{-1}) + Inoculation + PK; **T6** = Tannery sludge (46,500 kg ha^{-1}) +

sludge, fertilized with N, P and K and inoculated with *Bradyrhizobium sp.* (T2, T3, T4, T5 and T6). The lower plant growth of Leucaena was observed in the soil control (T1), being statistically different of the soil with application of tannery sludge in the rate of 11,625 kg ha^{-1} the release of nutrients, mainly N, P and Ca, for the Leucaena and Prosopis growth. Similar results were observed by Ferreira et al. (2003) in maize and soybean, and Singh & Sinha (2004) in plants of *Helianthus annuus.* However, the increase in the rates of tannery sludge (T5 and

T6) did not provide significant increases of the plant growth, probably, due the high soil sodium content after application of tannery sludge (Table 2), that can be favored the increase in the soil salinity (COSTA et al., 2001), and can be inhibited the higher plant growth. Although, according to Franco et al. (1992) the Leucaena and Prosopis are adapted species to saline soils.

Table 4. Nodule number and dry mass of Leucaena and Prosopis seedlings in soil plus tannery sludge and inoculation[1].

Treatment	Nodule number (nº plant^{-1})		Nodule dry mass (mg plant^{-1})	
	Leucaena	Prosopis	Leucaena	Prosopis
T1	18.0 c	25.3 b	119.0 c	106.6 b
T2	35.0 c	36.0 ab	233.0 bc	184.3 ab
T3	44.7 bc	39.6 ab	378.3 ab	232.0 a
T4	97.0 a	36.3 ab	494.3 a	191.3 ab
T5	75.3 ab	63.3 a	419.7 ab	352.0 a
T6	39.0 c	44.3 ab	312.0 abc	186.6 ab

T1 = control; **T2** = complete fertilization (NPK); **T3** = Inoculation with *Bradyrhizobium sp.* + PK; **T4** = Tannery sludge (11,625

The data observed to nodule number and dry mass of Leucaena and Prosopis seedlings are presented in the Table 4. The application of tannery sludge, in the rate of 46,500 kg ha^{-1} (T6), decreased the nodulation of Leucaena and Prosopis seedlings, but without statistical differences compared to the inoculated treatment with *Bradyrhizobium* sp. (T3). However, there was a higher nodule number in Leucaena with the application of sludge at 11,625 kg ha^{-1} (T4). There were not significant differences to nodule dry mass, for Leucaena and Prosopis seedlings, among the treatments with tannery sludge and inoculation of *Bradyrhizobium*. Although the application of tannery sludge, in high rates (T5 and T6), it provides increases in sodium content and, consequently, in soil salinity (Table 2), there was negative effect on nodulation process by inoculated *Bradyrhizobium*. According to Cavallet (1992) and Costa *et al*. (2001) the application of tannery sludge, in high rates, it provides increases in sodium content and soil salinity that can be a limiting factor to the nodulation. Nodule number, mass and size are the usual indicators of nodulation (FERREIRA & CASTRO, 1995) and small nodules and in low quantity can be an index of adverse environmental conditions (VARGAS *et al*., 2004).

CONCLUSIONS

The tannery sludge evaluated in this study was not harmful to nodulation, besides favoring the Leucaena and Prosopis growth.

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