



AENSI Journals

Australian Journal of Basic and Applied Sciences

ISSN:1991-8178

Journal home page: www.ajbasweb.com



***Chamaecrista debilis* Growth Fertilized with Organic Compound Doses in a Degraded Area by Gravel Mining**

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ARTICLE INFO

Article history:

Received 12 January 2014

Received in revised form 20 March 2014

Accepted 25 March 2014

Available online 2 April 2014

Keywords:

Re-vegetation, mining activity, composting, Fabaceae.

ABSTRACT

The species *Chamaecrista debilis* (Vogel) Irwin & Barneby is native from the “Cerrado” biome (Brazilian Savannah) and belongs to the Fabaceae family. Species from this genus, generally own mycorrhizal associations that play important role in the capture and mobilization of nutrients of the soil. The composting process has been widely used by Brazilian enterprises as a way of treatment of the organic soil residues, changing them into humus, which can be used directly in the forest planting as soil conditioners. The current work had as object to evaluate the initial development of the seedlings of *Chamaecrista debilis* in planting with doses of organic compound of residue of spinning and weaving industries and the species potential in the recovery of an area of “Cerrado” degraded by the gravel mining. The casual randomized blocks experimental delineation was used with three repetitions and four treatments: 0.0; 30.0; 60.0 and 120.0 g dm⁻³ of organic compound as fertilizer in each pit. The results have indicated that there was not an important difference among the treatments for increasing in height and diameter. The higher value between the amount of compound evaluated of height and diameter increasing occurred without the addition and with the application of 60.0 g dm⁻³ of organic residue compound from the spinning and weaving industry, however it is necessary to perform future evaluations. The survival rate presented significant decreasing with the application of the highest dosages of organic compound. The *Chamaecrista debilis* species has presented important features for the recovery of degraded area, as fast growth and production of biomass.

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To Cite This Article: Izabel Cristina Marques, Israel Marinho Pereira, Paulo Henrique Graziotti, Márcio Leles Romarco de Oliveira, Leandro Carlos, Luiz Eduardo Dias., *Chamaecrista debilis* Growth Fertilized with Organic Compound Doses in a Degraded Area by Gravel Mining. *Aust. J. Basic & Appl. Sci.*, 8(3): 332-341, 2014

INTRODUCTION

The lack of planning in the use of the natural resources has resulted in the degradation of the forest ecosystems. In the past years, several programs aiming these environments recovery have appeared, considering several factors, among them the ecological, the silvicultural, the social and the economic ones (Santos *et al.*, 2012).

The use of the native vegetation in the recovery of degraded areas has been instituted as a one of the major instruments of use, with satisfactory results (Angelis Neto *et al.*, 2004), both in the aspect of soil protection against the direct action of rain and sun rays, as in the availability of nutrients and organic matter.

The re-vegetation of degraded areas originated from the mining activity by the extraction of gravel demands proper techniques, being important to notice the positive interaction between fertilization and coverage plants which may have higher potentiality of biomass addition, as in these borrow areas all the vegetation and fertile soil layer were removed (Alves, 2008).

The *Chamaecrista* genus presents great importance to the biological nitrogen fixation having mycorrhizal associations with microorganisms that play important roles in the acquisition and mobilization of soil nutrients, promoting gains in the growth and development of the plants (Moreira and Siqueira, 2006).

The *Chamaecrista debilis* is native from the “Cerrado” biome and belongs to the Fabaceae family. It generally occurs in open areas, has fast growth and great production of biomass. This way, it highlights the importance of the species in projects of re-vegetation of degraded areas.

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Among the major existing gaps about the recovery of degraded areas, highlights the lack of acknowledges in what refers to the native species fertilization, considered a conditioning factor for the growth of seedlings in environments whose soil is totally degraded.

Today, due to the growing urban and industrial activity, a problem generated by the accumulation of residues derived from those activities. Among the generated residues, we can cite the textile industry solid residue (Gonçalves, 2011).

Industrial residues are gross-matter that can be used as organic fertilizer (Emater, 2007). The composting process has been widely used by Brazilian companies as a form of treatment of the organic solid residues, transforming them into humus, which can be used directly in the forest plantings as soil conditioners (Guerra *et al.*, 2012).

This way, it was aimed to evaluate the initial development of the seedlings of *Chamaecrista debilis* in planting with growing doses of organic compound of spinning and weaving industry residues. And the species potential for recovery, in an area of the “Cerrado” degraded by the gravel mining.

MATERIAL AND METHODS

The experiment was conducted in February 2011 in an area degraded by mining gravel in the Biribiri State Park (BSP) in Diamantina - MG. The gravel area is ten acres and is located between the coordinates 0649511.86 and 649640.24m longitude and 7987114.81 and 7,987,250.62 m latitude (UTM) and average altitude of 1412 m.

The BSP is in the southern “Espinhaço”, where the climate regime is typically Mesothermal, Cwb according to the Köppen classification, characterized by mild and humid summers (October to April) and cooler and dryer winter (June to August) and short transitions performed in the months of May and September (Silva *et al.*, 2005).

The area called gravel originated in the need to extract gravel to be used in the construction of highway BR -36 in the mid-50s. After this period, the area continued to be used for gravel extraction for performing landfills in civil works by the population of Diamantina.

The layer of fertile soil was removed because of the advance of mining, without storage in piles, unlike the technical recommendation for later replacement. Therefore, the operation was performed without proper planning, leaving only the substrate, formed by the deeper soil horizons. The removal of all topsoil resulted in slip of soil and rocks, aggradation of valleys and waterways, besides visual degradation.

With the creation of the BSP in 1998, the gravel extraction was ceased, leaving large environmental liabilities. The substrate has no current vegetation cover being composed primarily of deep erosion rocks and ruts.

The predominant vegetation in the vicinity of the study area is the rocky fields, and patches of lowland forest. The predominant soils in the study area prior to gravel extraction were characterized as Plinthic soils. Soil Consisting of mineral material, presenting Plinthic, lithoplinthic or concretionary horizon starting within 40 cm, or within 200 cm immediately below the horizon A or E, or another horizon to submit pale colors, variegated or mottled colors in abundant quantity (Embrapa, 2006).

In this area, it can be noticed in some points the absence of vegetation, erosions, gullies or some sites with predominance of invasive species, *Urochloa brizantha* (Hochst. Ex. A. Rich) R.D., and *Melinis minutiflora* P. Beauv. and planting of *Eremanthus erythropappus*.

The compost used in this work as organic fertilizer was gotten by the composting of 2.31 m³ of cotton cloths dirty with oil and grease used in the maintenance of the looms of the spinning and weaving industry in Diamantina – MG and Gouveia – MG and with 0.78m³ of cattle manure. After the mounting of the pile of composting in cone form, it was turned over three times a week until 90 days and twice a week until the end of the process at 176 days, when the pile temperature was under 40°C. The compost was passed through a sieve with a mesh of 15 mm and had a density of 0.63 mg L⁻¹ and humidity at 100-110°C of 18.80%. Composting was performed in the courtyard for this purpose, the Integrated Center for Propagation of Forest Species (CIPEF), Federal University of the Jequitinhonha and Mucuri Valleys (UFVJM).

The seedlings used in the experiment were produced in the Integrated Center for Propagation of Forest Species (CIPEF) situated in the JK Campus of the Federal University of the Jequitinhonha and Mucuri Valleys (UFVJM). Containers with capacity of 55 cm³ containing substrate (70% vermiculite, 30% of carbonized rice hull) and slow release fertilizer (4g/L of Osmocote) containing 15-09-12 (N-P₂O₅-K₂O) + micronutrients (3.8% Ca, 1.5% Mg, 3.0% S, 0.02% B, 0.05% Cu, 0.5% Fe, 0.1% Mn, 0.004% Mo and 0.05% Zn) were used. The seedlings were plant height, diameter and canopy average of 19.25 cm, 1.80 mm and 45.00 cm².

The experimental design adopted was performed in randomized blocks (3x11m) with three blocks; each block was composed by 4 plots represented by the treatments. In each plot 12 seedlings were planted, 48 seedlings in each plot and a total of 144 seedlings in the planting.

The treatments consisted of different doses of organic compost: 0.0g dm⁻³ (T1); 30.0 g dm⁻³ (T2); 60.0 g dm⁻³ (T3) and 120.0 g dm⁻³ (T4), each plot has constituted a treatment distributed randomly in each block.

The seedling planting was manual, in pits with 30x30x30 cm, a volume of 21l per pit, with spacing of 1.0x1.0m between plants. The compost with the respective dosage was mixed to the soil taken during the opening of the pit, homogenized and replaced in the pit for future introduction of the seedling.

After the planting, due to the Indian summer period, the seedlings were manually irrigated with the aid of watering pots during three weeks and the control of the weed plants was held with manual weeding when necessary, adopting the crowning of plants technique with radius nearly 50cm.

Daily meteorological data of precipitation and temperature from January 2011 to April 2012 were provided by the Principal Climatological Station Diamantina (18 ° 15 'S, 43 ° 36' W in 1296 m altitude), located 5.6 miles away from the study area. These data were used to calculate average temperature and precipitation during the implementation and evaluation of the experiment.

The organic compost was characterized by the Laboratory of Organic Matter and Residues of the Department of Soils of the Federal University of Viçosa (UFV).

At 12 months after the planting the chemical analyses of the mined substrate were performed, for so samples were collected in the experimental area in the depth of 0 to 20 cm. In each plot, 3 samples were collected, with the aid of an auger, forming a composite. Thus, being four samples per plot and 12 samples in total.

The chemical analyzes were performed at the Laboratory of Fertility and Soil Physics of UFVJM according to the protocol of Embrapa (1997) being analyzed the chemical parameters of soil: water pH, percentages of P, K, Ca²⁺, Mg²⁺ and Al³⁺; potential acidity (H + Al), base saturation (V), sum of bases (SB), CEC at pH 7 (T), effective (t), aluminum saturation (m%) and organic matter (OM).

The interpretation of the chemical analysis of the substrate was performed according to the interpretation of soil fertility made by Alvarez *et al.* (1999).

Evaluation of survival was based on calculations of the survival rate by the equation described by Oliveira (2006).

$$T = \frac{n \times 100}{N}$$

Where:

T%=survival rate

N= number of planted individuals

n= number of individuals from the last evaluation.

The survival data were submitted to the analysis of variance at 95% probability, being tested the variance homogeneity by the Cochran test and the normality by the test of Lilliefors both at 95% probability. If the ANOVA is significant, the regression analysis was performed using the logistic model as Draper and Smith (1998):

$$y = \frac{\beta_0}{1 - \beta_1 * e^{-\beta_2 * x}}$$

y= survival percentage

β1= model parameter

i= 0.1 and 2

x= doses of the organic compound.

The statistical analyses were performed with the aid of the software Statistica 10.0 (Statsoft, 2010).

The height was measured from the soil to the apical bud and the crown diameter was measured north-south and east-west with the aid of the measuring tape in cm. The measures of stem diameter were held with digital caliper in mm. For the calculation of the crown coverage (cm²), obtained with the values of crown diameter, the following formula by Leles *et al.* (2011) was used.

$$CC = \frac{A \times B \times \pi}{4}$$

Where:

CC = crown coverage in cm

A= diameter of crown north-south in cm

B= diameter of crown east-west in cm

The results of growth among the held measures were to calculate the height, diameter and crown coverage increasing for the species according to the dose of organic compound applied.

The calculus of increasing was performed by the difference between the final and initial values (Encinas *et al.*, 2005). The data of increasing in height (cm), diameter (mm) and crown coverage (cm²) were submitted to the presuppositions, normality and homogeneity tests, for the variance analysis.

When necessary a constant was added to the negative data (X+K) and submitted to the transformation in logarithm of the evaluated variable. Being F significant, the regression analysis was performed. The statistical analysis was performed with the aid of the software Statistica 10.0 (Statsoft, 2010).

Climatological data showed that in the month before the planting, January 2011, the average rainfall recorded in the gravel bed was 114.5 mm, and the month of the establishment of the experiment 87.2 mm. One month after planting, the average rainfall was 273.9 mm returning the rainy season in October of the same year (Figure 1). The last review was conducted at the end of the rainy season in April 2012.

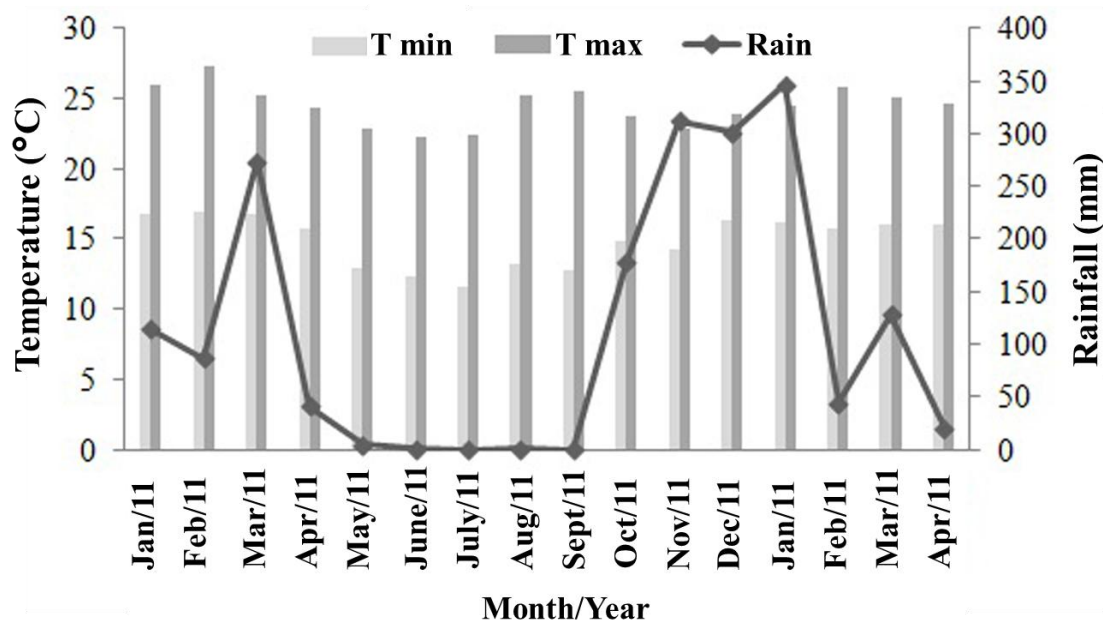


Fig. 1: Monthly average rainfall and temperatures recorded by the National Meteorology Institute (INMET) for the Diamantina – Minas Gerais, from January 2011 to April 2012.

The maximum and minimum temperature averages did not vary over that period, being minimum and maximum between 10.6 to 16.91 °C and 22.31 to 27.32 °C.

The table 1 shows the results of the organic compound analysis, showing that it presents high pH, going from the neutrality to alkaline. The percentage of organic matter (MO) is considered proper and it should contain at least between 25 to 30% and the humidity is reduced in relation to the fresh manure (Kiehl, 2001).

Table 1: Organic compound Chemical characterization of residues from the spinning and weaving industry of Diamantina and Gouveia – MG.

pH	MO	MI	AH	AF	CO	Ca	Mg	N	P	K	Fe	Zn	Cu
dag Kg ⁻¹ (%)													
7.34	46.70	11.08	4.76	2.85	28.40	2.27	0.50	0.84	0.65	0.62	2.31	364.00	78.76

MI= inert material

Regarding the presence of the metal, the compound showed: Cd = not detectable; Pb = 40.46 mg kg⁻¹, Ni = 44.66 mg kg⁻¹ and CR = 45.86 mg kg⁻¹. No known contamination for any of the 16 polycyclic aromatic hydrocarbons considered as priority pollutants by the U.S. Environmental Protection Agency (United States Environmental Protection Agency - USEPA) (Carvalho, 2012).

Table 2: Chemical characterization of the substrate, with the application of doses of textile industry organic compound residue, after 12 months of the planting of *Chameacrista debilis*, in a gravel pit in PEB in the City of Diamantina – MG.

Doses (g dm ⁻³)	pH	P	K	Ca ²⁺	Mg ²⁺	Al ³⁺	H+Al	SB	T	T	m	V	M.O
	Mg dm ⁻³						Cmocdm ³						
0.0	5.57	0.51	7.90	0.41	0.27	0.11	2.77	0.70	0.81	3.47	14.90	23.56	0.36
30.0	5.80	0.68	8.69	0.48	0.24	0.08	2.53	0.74	0.82	3.27	7.26	24.37	0.27
60.0	5.90	3.53	8.69	0.58	0.24	0.07	2.77	1.07	1.15	3.34	6.26	33.80	0.28
120.0	6.27	29.55	21.33	0.94	0.44	0.08	2.13	1.21	1.28	3.84	6.41	37.88	0.53

pH (H₂O) relation 1:2.5 (soil: water); P and K: Mehlich-1; Ca, Mg Al exchangeable: KCl 1 mol L⁻¹, H + Al: calcium acetate 0.5 mol L⁻¹ at pH 7.0, T: cation exchange capacity (CTC) Effective, T: CTC pH 7.0, m: aluminum saturation, V = base saturation.

The chemical analysis of the substrate (Table 2) has shown that the compound applied provided increasing in the pH going from a high acidity to an average acidity next to neutrality. There was an increase in the indexes

of MO, K, Ca^{2+} , Mg^{2+} , effective and total CTC, V and SB. The available P went from low to average to high and the V went from very low to low, with the addition of increasing doses of organic compound.

The survival of seedlings at planting *Chamaecrista debilis*, regardless of treatments, averaged 51.4%. For treatments with 0.0, 30.0, 60.0 and 120.0 g dm^{-3} of compost average survival were 75, 78, 22 and 31%.

Analysis of variance was significant (p -value = 0.00481), at 95% probability, indicating that there is difference between the doses of compost applied.

The significant decrease in survival rate can be observed with the application of higher dosages, showing sigmoidal behavior shown by the logistic model that increased by 2% with the addition of 30 g dm^{-3} and decreased by around 50% with the application of 60 and 120 g dm^{-3} of organic compound as compared to the substrate without addition of the compound (Figure 2).

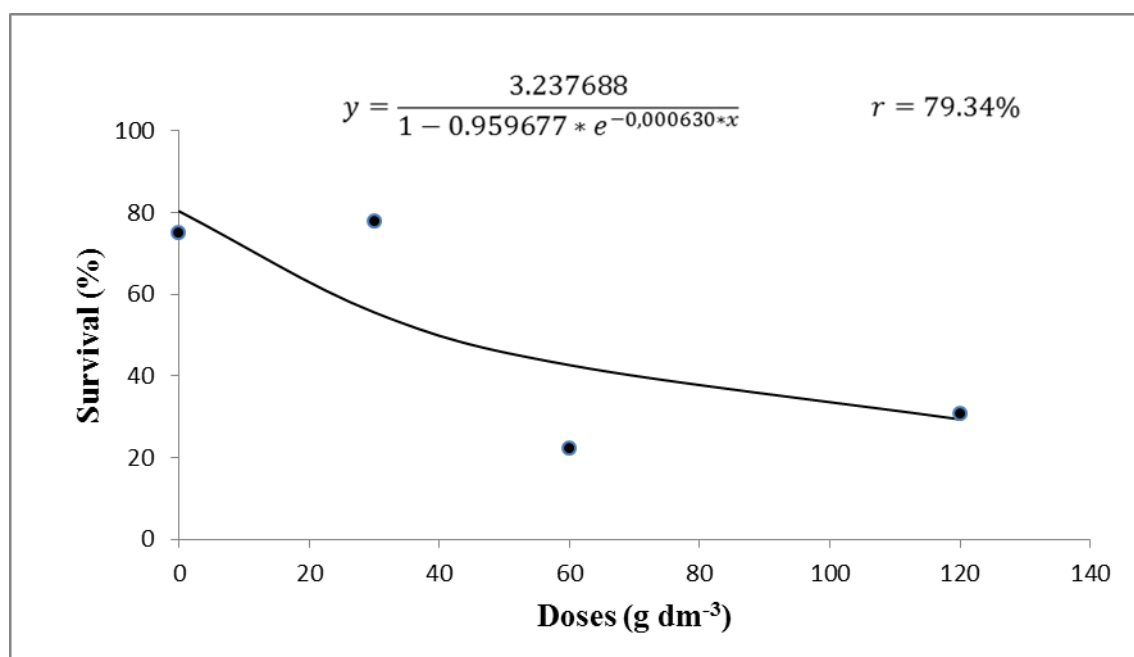


Fig. 2: Survival curve of seedlings *Chamaecrista debilis* (Vogel) Irwin & Barneby, in response to application of increasing doses of compost from organic waste spinning and weaving, planting in recovery in a gravel pit in PEB industry in Diamantina-MG.

The overall average increase in height, diameter and canopy in planting seedlings of *Chamaecrista debilis* was respectively 40.9 cm, 4.32 mm and 1884.37 cm^2 .

Data for increase in height, diameter and canopy showed normality and homogeneity. The analysis of variance showed no significant difference between the doses of compost applied. However, there were changes in average values for the variables.

The highest average height increment occurred when there was no application of organic compost, 42, 7 and 4% higher than the application of 30.0, 60.0 and 120.0 g dm^{-3} of compound (Figure 3).

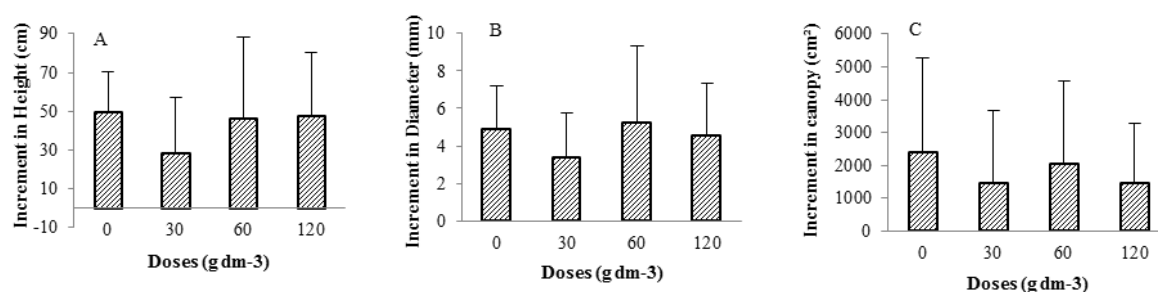


Fig. 3: Increment in height (A), diameter (B) and canopy (C) after 12 months planting *Chamaecrista debilis* (Vogel) Irwin & Barneby under different doses of spinning and weaving industry organic compost, in a gravel pit in PEB, Diamantina – MG.

For diameter increment the highest value obtained with the application of 60.0 g/dm^{-3} of compost, being 7, 35 and 14% higher compared to the not-addition of compound and the addition of 30.0 and 120.0 g/dm^{-3} (figure 3).

The increase in canopy cover was around 40% higher without the addition of organic compost, compared to the addition of 120.0 and 30.0 g/dm^{-3} . Regarding the application of 60.0 g/dm^{-3} , this percentage was 15% (Figure 3).

The seedlings flowering and seed production at the planting site of *Chamaecrista debilis*, this one year period, was observed.

Discussion:

The results found in the analysis of the soil evidenced higher levels of fertility in the substrate (Lopes *et al.*, 2010).

The application of the compound reduced the aluminum saturation, exchangeable aluminum and potential acidity. The reduction of aluminum saturation can cause the elevation of the base saturation (Ribeiro and Rodrigues, 2006), which can be noticed in this work.

The aluminum is toxic for most of the cultivated plant species, promoting the stopping of the radicular growth and, consequently, spoiling the plants development (Adams and Lund, 1986; Pavan and Bingham, 1982; Cançado *et al.*, 2001).

The potential acidity is the sum of exchangeable and not exchangeable acidity being the most harmful for growth of most plants the exchangeable. Furthermore, the lower the potential acidity is the less the buffer capacity of the soil will be, that is, soil resistance decreases for having its pH value changed (Oliveira *et al.*, 2005).

The survival percentage, 90 %, is a reference in re-vegetation projects (Almeida and Sanchez, 2005). For restoration of mined areas, such as the area under study, a rate greater than 60 % survival is considered satisfactory for planting and less than 60 % is considered low (Duboc and Guerrini, 2006). In this sense, when analyzing the survival rate of seedlings to the addition of 60.0 and 120 g/dm^{-3} of organic compost, survival was low. However, without the application of the compound and with the addition of smaller dosage it may be regarded as satisfactory.

Values between 55-83 % for survival rate of seedlings were found by Sampaio and Pinto (2007), in plantations with native species for restoration of degraded area in the "Cerrado". The values found in this work when no application of the compound and the application of lower doses are within this range. In the application of higher doses and in general, the values are lower than expected.

Durigan (1990), when evaluating the survival and early growth in plantations of degraded areas recovery in low fertility acidic soils, found that native species showed better pace in development. Based on the categories used to classify the performance of species described by Sampaio and Pinto (2007), unfertilized seedlings showed high increment value and high survival rate. These studies may reveal the characteristic of adaptability of *Chamaecrista debilis* species for the degraded ecosystem.

The *Chamaecrista debilis* is a bush that can reach approximately 2.5 m tall (Birth and Del - Claro, 2007; Oliveira and Godoy, 2007; Foresto, 2008) and the average increase in height may be considered high, $20.0 \text{ cm/year}^{-1}$. Based on the proposed diametric range, the growth in the planting of *Chamaecrista debilis* presented in this work was considered good (Duboc and Guerrini, 2006).

The quick growth of 40.0 cm , after three months, was observed in planting of *Chamaecrista desvauxii* in studies by Cruz (1994) that after one year the increase was lower than that achieved in this study, which is considered slow.

The results obtained for height increment can be explained by the fact that some Cerrado species do not grow well when fertilized, may be an indicative of greater adaptation to low fertility and acid soils (Smith *et al.*, 1995) or tough adjustment of growth rate to conditions of low nutrient availability, which restricts its response to improvement of soil fertility (Resende *et al.*, 1999).

In addition, in environments with low supply of water and nutrients, particularly phosphorus, usually symbiotic associations ensure the development of the plants. However, high levels of phosphorus, as in the organic compound used, can promote the reduction of the root colonization and cause a reduction in growth (Carneiro *et al.*, 2004).

The *Chamaecrista rotundifolia* species has shown itself adapted to the ecosystem when planted in sandy soils with low organic matter and without fertilization (Cross, 1994).

The smaller increase in height to Copaiba, also a species from the Fabacea family, was observed in substrate containing 70% vermiculite, 15 % of carbonized rice husk and 15% vermi-compost residue textile industry. While responding to the addition of higher concentrations of nutrients, the species has low nutrient requirements (Dutra *et al.*, 2012).

Revegetation of barren without the addition of black soil or compost was possible with some of the nitrogen-fixing species of the Fabaceae family in bauxite mining areas in "Porto Trumbetas" - PA (Franco *et al.*, 1996)

. In agreement, other studies have concluded that the soil substrate without addition of organic matter from various sources, the seedlings of native species of the Fabaceae promoted best development (Coutinho *et al.*, 2006; Santos *et al.*, 2011.).

The characteristic adaptation does not mean that native species are not able to respond to a greater nutrient availability (Vilela and Haridasan, 1994). Most “Cerrado” native species are able to respond to fertilization, however there is difference among the species and in the individual responses to nutrients (Haridasan, 2000).

The initial growth of *Dimorphandra wilsonii*, also from the Fabaceae family, showed a positive response to fertilization in different fertility conditions in the “Cerrado” soil (Fonseca *et al.*, 2010). Other studies result in beneficial effects of organic fertilization with the use of various organic compounds on growth of seedlings of native species of the Cerrado (Faustino *et al.*, 2005; Cunha *et al.*, 2006; Souza *et al.*, 2006; Boiler *et al.*, 2008; Calgaro *et al.*, 2008; Silva *et al.*, 2008; Paiva *et al.*, 2009). However, several studies should be carried out by the plethora of native species in Brazil, with little knowledge of the different responses to silvicultural practices (Souza *et al.*, 2006).

Another factor that may be considered in growth is the fact that the compound used increased the pH of the substrate, which indirectly influences the development by increasing the availability of nutrients especially micronutrients in soil (Carvalho Jr. *et al.*, 2011). Some works result that increasing the pH, thus reducing the acidity and increase of the the availability of nutrients, promotes the development of seedlings mostly exotic fruiting or agronomic species (Schumacher *et al.*, 2001; Almeida, 2003; Prado *et al.*, 2003; Maeda *et al.*, 2008). However, there are large variations in the degree of sensitivity to chemical limitations of the soil, since the native species react differently to correct soil acidity and increased nutrient availability (Furtini Neto *et al.*, 1999).

Acidic pH values promoted better growth of the seedlings of *Hancornia speciosa*, a species native from the Cerrado unfussy of fertility of poor and acidic soils, while values close to neutrality caused the reduction in growth (Rose *et al.*, 2005).

The reduction in the growth of *Apuleia leiocarpa* seedlings (Vog.) Macbride, Brazilian tree species, subjected to fertilization and liming, indicates the species adaptation to acid soil conditions. Raising the pH of the soil used may have caused deficiency of nutrients to plants (Nicoloso *et al.*, 2008).

The growth of seedlings of *Enterolobium contortisiliquum*, a Cerrado species from Fabacea family, was hampered by the high pH of the limed sludge tested as a fertilizer in the nursery (Teles *et al.*, 1999).

When evaluating the increment in diameter, based on studies by Duboc and Guerrini (2006), the growth in planting for *Chamaecrista debilis* species was considered fast for all doses of compound applied and without the addition of the same soil, with the exception of lowest dosage that caused an average growth for the seedlings.

The largest value for canopy cover without organic compound makes interesting use of *Chamaecrista debilis* in recovery projects in order to reduce fertilization cost. Once the recovery process, initially consists, in adding more organic matter to the mineralized quantity. At this stage, it is interesting to use species that can provide plant litter forming material for decomposition (Franco *et al.*, 2003) and promote nutrient cycling.

The deposition of leaves observed at the planting site, increases the biological activity in the soil and creates conducive conditions to the establishment of other most demanding species (Franco *et al.*, 1992). Moreover, the higher the coverage, the less the impacts caused by drops of rain and other inclement weather, which consequently decreases the degree of soil degradation by erosion.

Given the preliminary findings of this study with the objective of rapid soil covering in the Cerrado region, the use of textile industry compost from organic waste as organic fertilizer in planting of *Chamaecrista debilis* to recover from a degraded by the gravel extraction area becomes unnecessary.

Flowering and seed production in the reported time period may encourage improvements in the seed bank of soil, dispersion, pollination and provide the natural healing process in place. This shows that even in the short time since the species provides an ecological interaction by pollinators.

Conclusions:

The higher average value of height increment and canopy coverage has occurred without the addition of snipping and weaving industry organic waste, and for diameter with application of 60.0 g/dm³ of compost, although it has not presented static difference, being necessary to perform future evaluation.

The survival decreased significantly with the application of larger doses of compost.

The *Chamaecrista debilis* (Vogel) Irwin & Barneby presented proper for the recovery of the area degraded by the gravel extraction, the fast growth, the elevated biomass production and premature flowering.

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