PERFORMANCE OF SPECIES *Mabea fistulifera* AND *Eucalyptus urograndis* WITH USE OF CELLULOSE RESIDUE IN DEGRADED AREAS

Rômulo Guimarães Giácomo[1], Marlene Cristina Alves[2], Rodrigo Camara[3], Marcos Gervasio Pereira[4 *], Sebastião Nilce Souto Filho[2], Mário Luiz Teixeira de Moraes[2]

[1]Comlurb, Urban Information System, Rio de Janeiro, Rio de Janeiro, Brazil - romuloflorestal@gmail.com
[2] Universidade Estadual Paulista "Júlio de Mesquita Filho", Department of Plant Protection, Rural Engineering and Soils, Ilha Solteira, São Paulo, Brazil- marlenecristinaalves@yahoo.com.br ; sebastiaosouto87@gmail.com ; teixeira@agr.feis.unesp.br
[3]Federal Rural University of Rio de Janeiro, Postgraduate Program in Environmental and Forest Sciences, Seropédica, Rio de Janeiro, Brazil - rcamara73@gmail.com
[4]Federal Rural University of Rio de Janeiro, Department of Soils, Seropédica, Rio de Janeiro, Brazil - mgervasipereira01@gmail.com

Recebido para publicação: 06/03/2018 – Aceito para publicação: 03/09/2018

Abstract

The planting of forest species contributes to the recovery of degraded areas, and the use of industrial waste can favor this process. However, there is still little information on this aspect in Cerrado. The objective of this work was to evaluate the performance of seedlings of the native species *Mabea fistulifera* Mart. and of the exotic hybrid *Eucalyptus urograndis*, under fertilization with residue of the industrial production of cellulose, in monospecific plantations in degraded area. Fertilization treatments, applied in the planting line, were three doses of the residue (10, 15 and 20 Mg ha $^{-1}$); conventional mineral fertilizer (NPK); absence of fertilization (control). The experimental design was a randomized block design, with a portion of subdivided parts: species in the portions (15 m x 60 m, n = 4 / species) and treatments in the subportions (15 m x 12 m, n = 1 / treatment / portion) total of 18 plants in each subplot. Survival rate and growth attributes (height, crown diameter, stem diameter at ground level) were evaluated for two consecutive years. The largest increases in seedling survival and growth of both species were provided by mineral fertilization, followed by the 10 Mg ha $^{-1}$ dose of the residue, which should be the recommended.
Keywords: environmental recovery, soil management, plant nutrition.

Resumo

Performance de Mabea fistulifera *e* Eucalyptus urograndis *com o uso de resíduo de celulose em área degradada*. O plantio de espécies florestais contribui para a recuperação de áreas degradadas, e o emprego de resíduos industriais pode favorecer este processo. No entanto, ainda há poucas informações sobre este aspecto em Cerrado. Neste trabalho, objetivou-se avaliar o desempenho de mudas da espécie nativa *Mabea fistulifera* Mart. e do híbrido exótico *Eucalyptus urograndis*, sobre adubação com resíduo da produção industrial de celulose, em plantios monoespecíficos em área degradada. O delineamento foi de blocos ao acaso, em esquema de parcelas subdivididas: espécies nas parcelas (15 m x 60 m, n = 4/espécie) e tratamentos nas subparcelas (15 m x 12 m, n = 1/tratamento/parcela), com um total de 18 plantas em cada subparcela. Os tratamentos de adubação aplicados na linha de plantio, foram três doses do resíduo (10, 15 e 20 Mg ha^{-1}); adubação mineral convencional (NPK), ausência de adubação(controle). Avaliou-se taxa de sobrevivência e atributos de crescimento (altura, diâmetro de copa, diâmetro do caule à altura do solo), durante dois anos consecutivos. Os maiores incrementos de sobrevivência e crescimento de mudas de ambas espécies foi proporcionado pela adubação mineral, seguido da dose de 10 Mg ha^{-1} do resíduo, que deveria ser a recomendada.
Palavras-chave: recuperação ambiental, manejo do solo, nutrição de plantas.

INTRODUCTION

The Cerrado is located in the central portion of Brazil, in parts of the Federal District and the states of Bahia, Goiás, Maranhão, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Paraná, Piauí, São Paulo, and Tocantins, it has approximately 2,036,448 km^2, which is equivalent to about 22% of the national territory (SANO et al., 2008). This biome is the most diverse tropical savanna in the world (MENDONÇA *et al.*, 2008), and due to its high endemism and only 20% of its original extension, it is internationally recognized as one of 25 *hotspots* for the conservation (MYERS *et al.*, 2000). The main causes of its devastation are the implantation of cultivated pastures and agricultural crops, as well as mining and urbanization activities (SANO *et al*., 2008). This panorama demonstrates the importance of its preservation and conservation, which involves the creation of areas of protection, recovery and connection between the remaining areas.

The classical concept of "recovery" refers to the establishment of a new dynamic balance, with the development of a new soil and new landscape, in a degraded area (IBAMA, 1990). This term, which is very general, can cover the concept of "rehabilitation", which refers to the taking of measures or treatments aimed at recovering elements of the structure or ecological functioning of the ecosystem before its degradation, without necessarily reaching its original state (ENGEL; PARROTTA, 2003). According to the aforementioned authors, the term "restoration", which is also included within the recovery, aims at implanting treatments with a focus on restoring structure, dynamics and biological interactions as close as possible to what occurred in the original ecosystem, so that the area becomes self-sustaining at long term.

The planting of forest species is a practice aimed at recovering physical, chemical and biological attributes of degraded soils (ROCHA et al., 2016). In fact, some pioneering and rustic native or exotic species are able to survive in areas where the soil has been degraded (MARQUES *et al.*, 2014). These plants are configured as facilitators of the regeneration of deforested ecosystems, in cases where such dynamics would probably not occur without human intervention (FERREIRA *et al.*, 2010). This occurs because the litter produced is capable of protecting the soil from erosion (LI *et al.*, 2014), as well as being responsible for the input of organic matter and nutrients to the soil, which will consequently be made available to the plants (HÜLLER, *et al.*, 2009).

However, there is variation even among native species as to the effective facilitating role of natural regeneration, as verified in areas of Cerrado (MELO et al., 2015). In addition, the planting of certain exotic forest species, such as eucalyptus, for example, may favor the natural regeneration of native species of this biome (SOARES, NUNES, 2013). This pattern is more frequent in Cerrado, due to the capacity of regrowth of the native species, which is fundamental to the regeneration of the plants in the sub-woods of the forest plantations (VIANI *et al*., 2010).

With respect to tropical forest communities, such as the Atlantic Forest, eucalyptus plantations may not favor the regeneration of native species (EVARISTO *et al.*, 1669, 2011). According to an extensive review of the effect of exotic forest species plantations on the natural regeneration of Brazilian flora, this is due to the fact that the preservation of seed rain and the seed bank is more important in these ecosystems, when compared to areas of Cerrado (VIANI *et al.*, 2010).

In programs for the recovery of degraded areas, it is important to investigate the growth potential of seedlings, both for the native species that make up the highly diverse Brazilian flora and for exotic species due to the incipient knowledge around the subject (CALDEIRA *et al*., 2013). In this context, it is included the studies focusing on the effect of different industrial residues on the survival and growth of seedlings of forest species in plantations in degraded areas. This practice encourages the adequate disposal of waste, such as those from cellulose and paper production, which contributes to minimizing the environmental liabilities of industries. These residues are formed by a nutrient-rich organic compound which is an alternative for the use of mineral fertilizers, which allows the cost of planting to be reduced (ARRUDA *et al.*, 2011).

This measure may favor the recognition and adherence of different segments of Brazilian society to this purpose. Thus, even representatives of agricultural production sectors can benefit from the ecological services provided by forest species, with the potential of facilitating natural regeneration and promoting the recovery or improvement of the chemical-physical quality of the soil. This approach is especially important in the case of the Cerrado biome, where there is little existing information on the recovery of degraded areas with the planting of native forest species (SILVA *et al*., 2012) or exotic ones (VIANI et al., 2010), especially in the case of the State of Mato Grosso do Sul, whose remaining natural vegetation cover index was strongly diminished and currently is estimated to be of the order of only 32% of its original area (SANO *et al*., 2008).

The present study aimed at evaluating the performance of seedlings of *Mabea fistulifera* Mart., a native species of Cerrado, and the exotic hybrid *Eucalyptus urograndis*, under fertilization with residue of the industrial production of cellulose, in monospecific plantations in degraded area in Selvíria, MS. For such, a hypothesis was tested: the increasing of the dose of fertilization with the industrial residue of cellulose production favors the growth and survival of seedlings of both species, *Mabea fistulifera* and *Eucalyptus urograndis*, in comparison with the conventional mineral fertilization.

MATERIAL AND METHODS

The experimental campus of Ilha Solteira at Universidade Estadual Paulista (UNESP) is located in Selvíria, MS, under the geographical coordinates of 51°22' west longitude of Greenwich and 20°22' south latitude. The climate is type Aw (humid tropical climate, with rainy season in the summer and drought in the winter) (ALVARES *et al*., 2013). The average annual rainfall is 1,370 mm, with the rainy season between October and March, and the dry period between June and August. The annual average temperature is 23.5°C, and the annual average of relative humidity is between 70 and 80%. The soil is classified as Red Distrophic Latosol, where the relief varies from mild to flat, and the original vegetation belonging to the Cerrado biome.

In the area, there was removal of the soil layer with a thickness of approximately 8.60 m in the year of 1969. After the extraction of this material, which was used in the earthmoving and foundation of the Ilha Solteira Hydroelectric Plant, SP, Brazil (ALVES; SOUZA, 2011), the remaining horizon B was exposed.

For the present study, seedlings of the species *Mabea fistulifera* (strawberry) and of the hybrid *Eucalyptus urograndis* (eucalyptus) were selected, which was obtained by the crossing between the exotic species *Eucalyptus*

FLORESTA, Curitiba, PR, v. 49, n. 2, p. 363-372, abr/jun 2019
Giácomo. R. G. *et.al.*
Electronic ISSN 1982-4688
DOI: 10.5380/rf.v49 i2.58256

urophylla ST Blake and *Eucalyptus grandis* W. Hill. ex. Maiden. *Mabea fistulifera* is a pioneer species, characteristic of secondary vegetation of sandy soils, which occurs naturally in the Cerrado Biome and Atlantic Rainforest (CHRISTO *et al.*, 2009; KUNZ *et al*., 2009). Seedlings of *Mabea fistulifera* were produced from seeds, while seedlings of *Eucalyptus urograndis* were obtained from clone "h-17".

The preparation of the experimental area consisted in the mechanical decompression of the soil, by means of cross-subsoiling up to the layer of 0,40 m and leveling of the ground by means of light harrowing in December 2009. In February 2010, another subsoiling was carried out up to the 0.50 m layer, in the planting line. Next, four blocks, 32 m wide by 60 m long (1,920 m^2, each), were delineated in the area. Each block was constituted of two plots of 15 m x 60 m (900 m^2 each), which were spaced between each other by 2 m. Each parcel, which was destined to an individual forest species, was subdivided into five subplots of 15 m x 12 m (180 m^2, each), for the application of a different treatment by subplot. Therefore, the experimental design used was randomized blocks in a subdivided plot scheme.

In February 2010, 200 seedlings of each species were planted in their respective plot within each block. In this way, 40 seedlings were planted per subplot (treatment) for each species. The planting spacing in the monospecific plantations was 3.0 m x 1.5 m (between lines x line), with 2 m dividers between the main plots and 3 m between the blocks, which totaled 230 m^2 per block. Only the three central rows in each treatment were considered as useful, in which 18 seedlings were distributed, leaving the edges as border. Thus, the study contemplated data collection in four repetitions (subplots) per treatment, in a total of 72 seedlings of each species per treatment. In each subplot, five types of fertilizer were distributed manually in the planting line, in February 2010, whose incorporation to the soil was made by light harrowing, which constituted the fertilization treatments tested (Table 1).

Table 1. Scheme of the experimental design in a randomized block design, in a subdivided plots scheme, with the plantation of *Mabea fistulifera* (MF) or *Eucalyptus urograndis* (EU) in the plots, and the application of fertilization treatments in the subplots (D0: without fertilization, DAM: mineral fertilization, D10, D15, and D20: fertilization with the industrial residue of the cellulose production in doses of 10, 15, and 20 Mg ha^{-1}, respectively), in monospecific plantations in Selvíria, MS.

Tabela 1. Esquema do delineamento experimental em blocos ao acaso, em esquema de parcelas subdivididas, com o plantio de *Mabea fistulifera* (MF) ou *Eucalyptus urograndis* (EU) nas parcelas, e a aplicação dos tratamentos de adubação nas subparcelas (D0: sem adubação, DAM: adubação mineral, D10, D15 e D20: adubação com o resíduo industrial da produção de celulose nas doses 10, 15 e 20 Mg ha^{-1}, respectivamente), em plantios monoespecíficos em Selvíria, MS.

MF_D0	EU_DAM	EU_D20	MF_D20	EU_D0	MF_D20	MF_D0	EU_D0
MF_D20	EU_D20	EU_D15	MF_D15	EU_D15	MF_D0	MF_D10	EU_DAM
MF_D15	EU_D10	EU_D10	MF_D0	EU_D10	MF_D10	MF_DAM	EU_D10
MF_DAM	EU_D15	EU_D0	MF_D10	EU_DAM	MF_D15	MF_D15	EU_D20
MF_D10	EU_D0	EU_DAM	MF_DAM	EU_D20	MF_DAM	MF_D20	EU_D15

The residue was produced through the Kraft method and was constituted of a mixture of *dregs* (dark-colored sediment), *grits* (yellowish granules), lime sludge, ash and other residues, which were conceded by the Central of Composting of the Ambitec Group. This material underwent a 30-day composting process, with outdoor exposure in piles and mechanical stirring periodically. The chemical characteristics of this residue are presented in Table 2.

Table 2. Mean values of the chemical attributes of the industrial residue of cellulose production.

Tabela 2. Valores médios dos atributos químicos do resíduo industrial da produção de celulose.

pH	**Reason C / N**	**OC**	**Ca**	**Mg**	**K**	**P**	**N**	**Na**	**S**	**B**	**Cu**	**Fe**	**Mn**	**Zn**
$CaCl_2$		**-------------------- g kg^{-1}--------------------**								**----------- mg kg^{-1}-----------**				
6.6	6.6	186	86.9	3.8	5.9	2.4	6.6	1.4	1.8	30.3	14.3	5458	845	27.9

OC: organic carbon.

The chemical soil attributes in both monospecific plantations in each fertilization treatment are shown in Table 3. According to these data, which were not published, the H + Al values in the soil solution at all depths (0.00-0.05, 0.05-0.10, and 0.10-0.20 m) were higher under treatments D0 and DAM, which did not differentiate between them, in comparison with the other treatments, in both monospecific plantings. On the other hand, in the treatments D10, D15 and D20, which did not differentiate between them, the values of pH and K (0.05-0.10 and 0.10-0.20 m, in both plantations), Ca (0.10-0.20 m in both fields, 0.00-0.05 in the planting of *Eucalyptus* *urograndis*), SB and CTC (0.10-0.20, in both fields, and 0.00-0.05 and 0.05-0.10 m in the planting of *Eucalyptus urograndis*), Mg (0.05-0.10 m in both fields, and 0.00-0.05 and 0.10-0.20 m in the planting of *Eucalyptus urograndis*), and P (0.00-0.05 and 0.05-0.10m in the planting of *Mabea fistulifera*), when compared with D0 and DAM. In the D20 treatment, it was observed higher values of Ca (0.00-0.05 m in the planting of *Mabea fistulifera* and 0.05-0.10 m in both fields), in addition to higher values in the planting of *Mabea fistulifera* (0.00-0.05 m), CTC and SB (both 0.00-0.05 and 0.05-0.10 m), and P (at all depths).

Table 3. Mean values of soil chemical attributes in the layers of 0.00-0.05, 0.05-0.10, and 0.10-0.20 m, in February 2011, in the treatments D0 (without fertilization), DAM (mineral fertilization), D10, D15, and D20 (fertilization with the industrial residue of the cellulose production in doses of 10, 15, and 20 Mg ha^{-1}, respectively), in monospecific plantations of *Mabea fistulifera* and *Eucalyptus urograndis* in Selvíria, MS.

Tabela 3. Valores médios dos atributos químicos do solo nas camadas de 0,00-0,05, 0,05-0,10 e 0,10-0,20 m, em fevereiro de 2011, nos tratamentos D0 (sem adubação), DAM (adubação mineral), D10, D15 e D20 (adubação com o resíduo industrial da produção de celulose nas doses 10, 15 e 20 Mg ha^{-1}, respectivamente), em plantios monoespecíficos de *Mabea fistulifera* e *Eucalyptus urograndis* em Selvíria, MS.

Treatment	**pH**	**Ca**	**Mg**	**K**	**H + Al**	**CEC**	**SB**	**P**
	$CaCl_2$	-------------------- **$mmol_c$ dm^{-3}**	--------------------					**mg dm^{-3}**
				Mabea fistulifera				
				0.00-0.05 m				
D0	5.3 C	8.0 c	7.2 b	1.3 a	15.5 a	32.0 c	516.5 c	5.5 c
D10	6.7 b	35.0 b	10.5 a	1.9 a	11.0 b	58.4 b	47.4 b	10.7 b
D15	6.7 b	34.0 b	9.0 b	1.8 a	10.5 b	55.2 b	44.8 b	13.5 b
D20	7.4 a	100.0 a	12.5 a	1.5 a	8.8 b	123.0 a	114.0 a	32.8 a
DAM	5.5 c	9.8 c	7.8 b	1.5 a	15.0 a	34.0 c	19.0 c	4.5 c
				0.05-0.10 m				
D0	5.4 b	8.8 c	7.3 b	0.9 b	14.5 a	31.4 c	16.9 c	5.0 c
D10	7.1 a	42.5 b	9.8 a	1.5 a	9.5 b	63.2 b	53.7 b	12.3 b
D15	7.0 a	31.,0 b	9.8 a	1.3 a	9.5 b	50.9 b	41.3 b	13.0 b
D20	7.5 a	64.3 a	11.0 a	1.2 a	8.0 b	84.5 a	76.5 a	28.3 a
DAM	5.7 b	11.0 c	7.5 b	0.8 b	13.3 a	32.5 c	19.3 c	4.5 c
				0.10-0.20 m				
D0	5.8 b	7.8 b	6.8 b	0.8 b	13.0 a	28.3 b	15.3 b	4.0 b
D10	6.5 a	19.8 a	11.3 a	1.0 a	11.0 b	43.0 a	32.0 a	5.8 b
D15	6.6 a	20.8 a	8.0 b	1.0 a	10.0 b	39.8 a	29.8 a	6.8 b
D20	7.0 a	23.7 a	10.3 a	1.2 a	9.3 b	44.4 a	35.1 a	14.3 a
DAM	5.7 b	8.8 b	7.3 b	0.8 b	13.0 a	29.08 b	16.8 b	4.7 b
				Eucalyptus urograndis				
				0.00-0.05 m				
D0	5.3 b	7.7 b	7.0 b	1.2 a	15.0 a	30.9 b	15.9 b	4.7 c
D10	6.8 a	42.0 a	10.3 a	1.7 a	10.3 b	64.2 a	53.9 a	20.3 b
D15	7.3 a	56.3 a	11.3 a	1.8 a	9.3 b	78.6 a	69.3 a	26.5 a
D20	7.5 a	53.7 a	12.3 a	1.5 a	8.0 b	75.4 a	67.4 a	27.5 a
DAM	5.3 b	8.0 b	7.5 b	1.4 a	15.8 a	32.6 b	16.9 b	5.3 C
				0.05-0.10 m				
D0	5.3 b	7.7 c	6.3 b	0.8 b	14.7 a	29.4 b	14.8 b	4.7 b
D10	6.9 a	44.8 b	11.8 a	1.4 a	9.8 b	67.6 a	57.9 a	13.3 a
D15	7.2 a	38.7 b	11.3 a	1.6 a	9.0 b	60.5 a	51.5 a	12.7 a
D20	7.5 a	61.3 a	11.0 a	1.4 a	8.3 b	81.9 a	73.7 a	16.0 a
DAM	5.3 b	8.3 C	7.5 b	1.0 b	15.8 a	32.5 b	16.1 b	5.5 b
				0.10-0.20 m				
D0	5.7 b	7.3 b	5.7 b	0.5 b	12.7 a	16.1 b	13.5 b	4.3 a
D10	6.3 a	14.8 a	7.8 a	1.0 a	11.8 b	35.3 a	23.5 a	6.3 a
D15	6.8 a	19.3 a	9.0 a	1.1 a	10.3 b	39.7 a	29.4 a	6.3 a
D20	6.8 a	18.3 a	8.3 a	1.1 a	10.5 b	38.1 a	27.6 a	6.8 a
DAM	5.6 b	7.5 b	7.0 a	0.7 b	14.3 a	29.5 b	15.2 b	4.8 a

Electronic ISSN 1982-4688
DOI: 10.5380/rf.v49 i2.58256

Means followed by distinct letters (in the comparison between fertilization treatments, within the same species), differed by the Skott-Knott test ($p < 0.05$). SB: sum of bases; CEC: cation exchange capacity.

The monitoring of seedling growth was carried out quarterly over two consecutive years: from planting of seedlings in February / 2010 to February / 2011 (year 1), and from February / 2011 to February / 2012 (year 2). The total height (TH, m) was measured with the aid of a graduated ruler, crown diameter (CD, m) with the aid of a scalem, and stem diameter at ground level (DGL, mm) with the support of a digital caliper. In addition, it was evaluated the survival rate (SUR, %) of the seedlings. Data were presented as an average for the years 1 and 2.

On November 04, 2010, nine months after the planting of the seedlings, a large infestation of the defoliant beetle *Costalimaia ferruginea fulgata* Lef. occurred in the eucalyptus planting, whose control was carried out the following day (05 / november 2010) with the application of agricultural detergent based on Deltrametrin (concentration of 200 mL 100 L^{-1} ha^{-1}). Despite this, many plants presented perforated and / or laced leaves and there were losses of some seedlings, regardless of the fertilization treatment. The treatment D0 of the fourth block was totally decimated and, therefore, for this treatment, three replications were worked out in the eucalyptus planting. In the planting of *Mabea fistulifera*, flooding of the first block in the D0 treatment has occurred at the same season, which caused the death of plants present there. For this treatment, we also worked with three replicates.

The results were analyzed by analysis of variance and Skott-Knott's test for the comparisons of averages ($p < 0.05$) with the SISVAR program (FERREIRA, 2011). The hierarchical grouping analysis, in which the Bray-Curtis distance was considered by the single linkage method, was carried out with the purpose of evaluating the similarity between treatments within each species individually. In addition, it was also carried out the analysis of the principal components, in order to evaluate the correlation between the attributes analyzed and the treatments within each individual forest species. Both multivariate analyzes were performed using the PAST program version 2.17c, in which the average values of the attributes, calculated between years 1 and 2, were considered.

RESULTS

According to the data set, it was not corroborated the hypothesis that the steady increase of the dose of fertilization with the industrial residue of cellulose production favors the growth and the survival of seedlings of both species *Mabea fistulifera* and *Eucalyptus urograndis* compared to conventional mineral fertilization in an area degraded by the soil loan. In relation to the seedlings of *Mabea fistulifera*, in year 1, the average values of survival (SUR), total height (TH), crown diameter (CD), and stem diameter at ground level (DGL) ranged from 84.72% (DAM) to 97.22% (D20); from 1.15 m (D20) to 1.68 m (DAM); from 0.95 m (D20) to 1.60 m (DAM); and from 16.96 mm (D20) to 29.71 mm (DAM), respectively (Table 4). In the year 2, this same species presented average values of SUR, TH, CD, and DGL that varied between 74,30% (D10) and 93.05% (D20); between 1,97 m (D20) and 2,55 m (D10); between 1,81 m (D20) and 2,53 m (DAM); between 32,58 mm (D20) and 48,58 mm (DAM), respectively.

In the case of *Eucalyptus* urograndis, in year 1, the average values of SUR varied from 73.61% (D20) to 100.00% (DAM); TH, from 0.89 m (D0) to 2.01 m (DAM); CD, from 0.77 m (D20) to 1.43 m (DAM); DGL, from 13.24 mm (D0) to 34.69 mm (DAM) (Table 4). In year 2, the range of variation of SUR values was between 56.25% (D20) and 96.53% (DAM); TH, between 1.79 m (D0) and 3.11 m (DAM); CD, between 1.58 m (D0) and 2.34 m (DAM); DGL, between 34.92 mm (D0) and 57.48 mm (DAM).

When comparing the treatments of fertilization for the seedlings of *Mabea fistulifera* in year 1, there were significant differences in the following attributes: TH ($p = 0.0063$), CD ($p = 0.0019$), and DGL ($p = 0.0004$), (Table 4). In year 2, the treatments did not differ among themselves in relation to their effect on TH ($p = 0.4403$) and DGL ($p = 0.1799$), but there was a significant difference between treatments for CD ($p = 0.0403$).

Table 4. Average values of survival (SUR), total height (TH), crown diameter (CD), and stem diameter at ground level (DGL) of seedlings of *Mabea fistulifera* and *Eucalyptus urograndis*, in years 1 and 2, in treatments D0 (without fertilization), DAM (mineral fertilizer), D10, D15 and D20 (fertilization with the industrial production of pulp residue in doses 10, 15, and 20 Mg ha $^{-1}$, respectively), in monospecific plantations in Selvíria, MS.

Tabela 4. Valores médios de sobsobrevivência (SUR), altura total (TH), diâmetro da copa (CD) e diâmetro do tronco ao nível do solo (DGL) de mudas de *Mabea fistulifera* e *Eucalyptus urograndis*, nos anos 1 e 2, nos tratamentos D0 (sem adubação), DAM (adubação mineral), D10, D15 e D20 (adubação com o resíduo industrial da produção de celulose nas doses 10, 15 e 20 Mg ha^{-1}, respectivamente), em plantios monoespecíficos em Selvíria, MS.

	Year 1 (February 2010-February 2011)							
	Mabea fistulifera				*Eucalyptus urograndis*			
	SUR	**TH**	**CD**	**DGL**	**SUR**	**TH**	**CD**	**DGL**
Treatment	**%**	**-----m-----**		**mm**	**%**	**-----m-----**		**mm**
D0	87.50 a	1.17 b	1.08 b	16.99 b	79.63 b	0.89 c	0.78 c	13.24 b
D10	88.89 a	1.23 b	1.11 b	18.35 b	90.27 a	1.45 b	1.15 b	21.00 b
D15	88.89 a	1.30 b	1.10 b	18.39 b	80.55 b	1.29 b	0.94 c	19.49 b
D20	97.22 a	1.15 b	0.95 b	16.96 b	73.61 b	1.25 b	0.77 c	18.75 b
DAM	84.72 a	1.68 a	1.60 a	29.71 a	100.00 a	2.01 a	1.43 a	34.69 a
	Year 2 (February 2011-February 2012)							
	Mabea fistulifera				*Eucalyptus urograndis*			
	SUR	**TH**	**CD**	**DGL**	**SUR**	**TH**	**CD**	**DGL**
Treatment	**%**	**-----m-----**		**mm**	**%**	**-----m-----**		**mm**
D0	81.95 a	2.20 a	2.22 a	37.12 a	73.15 b	1.79 b	1.58 b	34.92 b
D10	74.30 a	2.55 a	2.00 b	39.02 a	69.45 b	2.60 a	1.94 b	47.46 b
D15	80.55 a	2.29 a	2.16 a	39.77 a	69.44 b	2.27 b	1.81 b	44.36 b
D20	93.05 a	1.97 a	1.81 b	32.58 a	56.25 b	2.15 b	1.72 b	40.04 b
DAM	83.33 a	2.39 a	2.53 a	48.58 a	96.53 a	3.11 a	2.34 a	57.48 a

Means followed by distinct letters (in the comparison between fertilization treatments, within the same species and the same year), differ among themselves by the Skott-Knott test ($p < 0.05$).

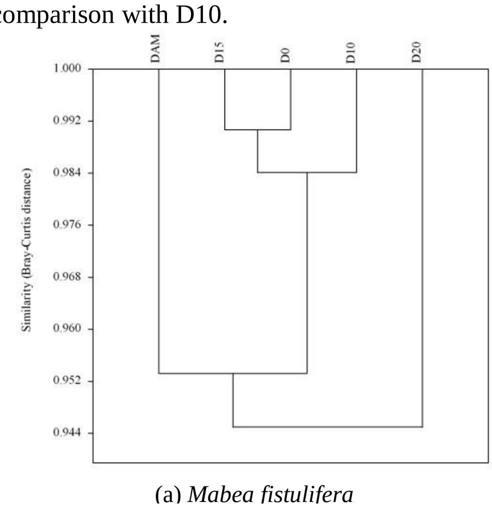
Regarding to the seedlings of *Eucalyptus urograndis*, in both years, we observed significant differences in the effect of treatments for TH attributes($p = 0.0000$, year 1, $p = 0.0062$, year 2), CD ($p = 0.0000$, year 1, $p = 0.0028$, year 2), and DGL ($p = 0.0000$, year 1; $p = 0.0010$, year 2) (Table 4).

As for the SUR variable of *Mabea fistulifera* seedlings, there were no significant differences between treatments ($p = 0.0523$, year 1, $p = 0.5053$, year 2) (Table 4). However, the treatments varied among each other with respect to the effect on the SUR of *Eucalyptus urograndis* seedlings ($p = 0.0001$, year 1; $p = 0.0005$, year 2).

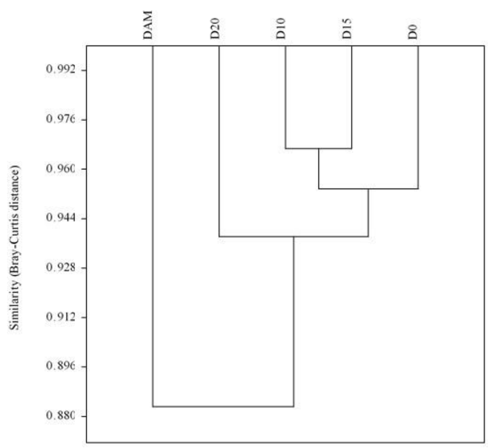
In general, DAM influenced higher values of survival and growth attributes than the other treatments, for seedlings of both forest species (Table 4). This pattern of response to DAM treatment was identified for seedlings of *Mabea fistulifera* (highest mean values of TH, CD, and DGL) in year 1, and for seedlings of *Eucalyptus urograndis* (highest average values of SUR, TH, CD and DGL) in both years 1 and 2. The D0 treatment resulted in lower averages of TH and DGL in seedlings of *Eucalyptus urograndis* in year 1, in relation to the other treatments.

When comparing the effect of the different doses of industrial pulp residue among themselves, the lowest dose (D10) influenced more expressive increases for SUR and CD (both in year 1), and also TH (year 2), for seedlings of *Eucalyptus urograndis* (Table 4). With respect to the seedlings of *Mabea fistulifera*, the intermediate dose (D15) influenced higher increases of CD (year 1), in relation to the other doses of the industrial residue (D10 and D20), which did not differentiate from each other.

The Figure 1a, which was constructed according to the survival and growth attributes of seedlings of *Mabea fistulifera*, showed the individualization of the treatments tested in two large groups: one represented only by D20, and another one formed by the union of D0, D10, D15, and DAM. However, the latter group was subdivided into two subgroups: the individualization of DAM from the another subgroup formed by the union of D0, D10, and D15. Within this subgroup, there was a high similarity between D0 and D15 (lower binding distance) in comparison with D10.



(a) *Mabea fistulifera*



(b) *Eucalyptus urogradis*

Figure 1. Dendrogram of hierarchical clustering for the average values of survival and growth attributes of the seedling of *Mabea fistulifera* (a) and *Eucalyptus urograndis* (b)calculated between the years 1 and 2, in treatments such as D0 (without fertilization), DAM (mineral fertilizer), D10, D15, and D20 (fertilization with the industrial production of pulp residue in doses 10, 15, and 20 Mg ha^{-1}, respectively), in monospecific plantations in Selvíria, MS.

Figura 1. Dendrograma de agrupamento hierárquico para os valores médios dos atributos de sobrevivência e crescimento de mudas de *Mabea fistulifera* (a) e *Eucalyptus urograndis* (b), calculados entre os anos 1 e 2, nos tratamentos D0 (sem adubação), DAM (adubação mineral), D10, D15 e D20 (adubação com o resíduo industrial da produção de celulose nas doses 10, 15 e 20 Mg ha^{-1}, respectivamente), em plantios monoespecíficos em Selvíria, MS.

Regarding the influence of the treatments on the seedlings of *Eucalyptus urograndis*, Figure 1b indicated the formation of two large groups: one represented only by DAM, while the other was formed by the D0, D10, D15, and D20 (Figure 1b). The latter group, in turn, was separated into two subgroups, in which the individualization of D20 was verified, while the other subgroup was represented by the D0, D10, and D15 reunion. And, within this subgroup, the similarity between D10 and D15 (lower binding distance) was higher, in comparison with D0.

In Figure 2, the eigenvectors, or arrows, represent the attributes analyzed within each monospecific planting and the points represent the treatments. The analysis of the main components explained 95.05% of the variability of the data, and showed the separation among the treatments, through the relation between the main component 1 (axis 1) and the main component 2 (axis 2). Regarding the axis 1, whose eigenvalue corresponded to 82.95%, D10 and DAM were located in the right portion (positive values). The eigenvalue of each axis consists of its relative contribution to explain the total variance of the data. However, the other three presented a contrasting pattern, since they were grouped in the left portion of axis 1 (negative values), in comparison with D0, D15, and D20.

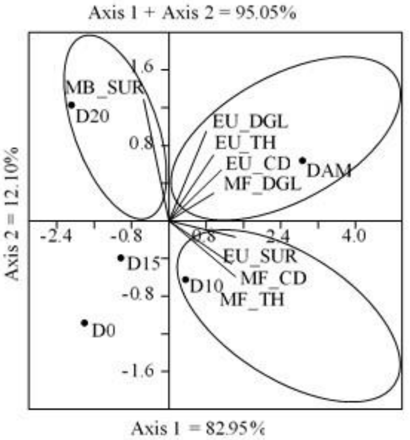


Figure 2. Principal components analyses of survival (SUR), total height (TH), canopy diameter (CD), and stem diameter at ground level (DGL) of *Mabea fistulifera* and *Eucalyptus urograndis* seedlings, in monospecific plantations in Selvíria, MS.

Figura 2. Análise de componentes principais dos atributos sobrevivência (SOB), altura total (HT), diâmetro de copa (DC) e diâmetro do fuste à altura do solo (DAS) de mudas de *Mabea fistulifera* (MF) e *Eucalyptus urograndis* (EU), em plantios monoespecíficos em Selvíria, MS.

In relation to axis 2, which explained 12.10% (eigenvalue of the axis) of the data variability, there was a separation of DAM and D20, which were located in the upper portion (positive values), from D0, D15, and D20, which were grouped in the lower portion (negative values) (Figure 2). Practically all eigenvectors pointed to the right side, considering axis 1. This demonstrated that the attributes studied for the two forest species correlated with DAM (DGL for *Mabea fistulifera*, and TT, CD, and DGL for *Eucalyptus urograndis*) or D10 (HT and CD for *Mabea fistulifera*, and SUR for *Eucalyptus urograndis*). Only the eigenvector for SUR for *Mabea fistulifera* pointed to the left side, on axis 1, in the direction of D20. Thus, this variable showed correlation with the treatment. No attributes evaluated for the seedlings of forest species correlated with D0 or D15.

According to Table 5, all the attributes of the two forest species presented high values of eigenvector (≥ 0.70) in one of the components (main axisaxis 1 or 2), which were positive. The eigenvector, that varies from -1 to +1, is the value that corresponds to the weight of each variable in each of the axisaxis, which is considered as a correlation coefficient. Thus, based on axis 1, which is the one that represents the direction of greatest possible variation, the DGL and TH attributes were the most representative (highest values of eigenvectors) for the seedlings of *Mabea fistulifera*. In the case of the seedlings of *Eucalyptus urograndis*, the most representative attributes were CD and SUR.

Table 5. The values of the coefficient of correlation between the mean values (calculated between years 1 and 2) of survival (SUR), total height (TH), crown diameter (CD), and stem diameter at ground level (DGL) of the seedlings of *Mabea fistulifera* and *Eucalyptus urograndis*, and the principal axis 1 and 2 of principal component analysis, in monospecific plantations in Selvíria, MS.

Tabela 5. Valores do coeficiente de correlação entre os valores médios (calculados entre os anos 1 e 2) de sobrevivência (SUR), altura total (TH), diâmetro de copa (CD) e diâmetro do fuste à altura do solo (DGL) de mudas de *Mabea fistulifera* e *Eucalyptus urograndis*, e os eixos principais 1 e 2 da análise de componentes principais, em plantios monoespecíficos em Selvíria, MS.

Forestry species	**Variable**	**Correlation Coefficient with the main axis 1**	**Correlation Coefficient with the main axis 2**
Mabea fistulifera	SUR	-0.5847	0.7832
	TH	0.9661	-0.2030
	CD	0.9124	-0.1135
	DGL	0.9757	0.06715
Eucalyptus urograndis	SUR	0.9700	-0.1132
	TH	0.9085	0.3561
	CD	0.9703	0.1840
	DGL	0.9319	0.3426

DISCUSSION

The DAM treatment was considered superior in relation to the treatments in which the cellulose residue was applied, since it provided an increase in the survival and growth attributes of the seedlings of *Mabea fistulifera* and *Eucalyptus urograndis*. However, in the DAM treatment, the availability of the macronutrients Ca, Mg, K, and P were lower in the soil solution. It is believed that the elevation of soil pH to near neutrality or alkaline values in the treatments where the cellulose residue was applied also has reduced the availability of micronutrients, such as Fe, Mn, Cu and Zn (SOUZA *et al.*, 2007). This, in turn, negatively affected the growth of the seedlings of both species in the treatments D10, D15, and D20 when compared to AMD. The residue of the pulp and paper industry is naturally alkaline, as reported in this study. Therefore, this residue, which presents a high concentration of NaOH and CaOH in its composition, is considered to be more efficient than limestone, in the increasing of the pH of the soil solution (MEDEIROS *et al*., 2009).

In the present study, we verified that the lower dose (D10) provided an increase in the survival and growth of the seedlings of *Eucalyptus urograndis*, among the other doses of industrial pulp residue. Therefore, such a practice should be encouraged, even because it is economically advantageous. Arruda *et al*. (2011) indicated that the use of 10 Mg ha $^{-1}$ of the industrial pulp residue presented the lowest total cost (R$ 4,267.86 ha $^{-1}$), considering the costs of obtaining and applying this dose in a planting of *Eucalyptus urograndis*, when compared to the doses of 15 and 20 Mg ha $^{-1}$ (the costs were of R$ 4,879.90 ha $^{-1}$ and R$ 5,472.33 ha $^{-1}$, respectively).

In the production of seedlings of *Eucalyptus urograndis* in tubers under nursery conditions, Toledo *et al*. (2015) observed that the intermediate doses of the industrial waste of cellulose (60% and 80%) used in the substrate formulation, promoted higher increases in the growth of the plants (height, diameter of the colon, dry matter of both shoot and root), in relation to the absence of residue (0%), the lowest doses (20% and 40%) and the highest dose (100%).

Silva *et al.* (2008) applied several fertilizer treatments in the planting line of *Eucalyptus grandis* seedlings in Itatinga, SP, Brazil, and verified that after 36 months there were no significant differences between conventional mineral fertilization and the different doses (5, 10, 20 or 30 t) of sewage sludge (wet or dry), supplemented with the addition of potassium and boron, in relation to plant height. However, the effect of these treatments was higher than the control, which was statistically equal to the effect of application of 10 t of moist sewage sludge and without the addition of potassium and boron. In this way, the authors verified that these nutrients have to be complemented when the sewage sludge is applied, since this fertilizer presents low contents of them, in order to guarantee the greater growth of the plants, independently of the dose of sludge, no matter if it is applied wet or dry.

The multivariate analysis of hierarchical grouping emphasized that the DAM treatment promoted the best performance of the seedlings for both species studied, followed by the D10 treatment. All the analyzed attributes were important for the multivariate principal component analysis, which demonstrated that the DAM and D10 treatments influenced similar responses for the seedlings of both species.

The survival rate and seedling growth of *Eucalyptus urograndis* was considered adequate. This demonstrated that the tested hybrid had a good adaptation to the edaphoclimatic conditions of the study area, although the eucalyptus seedlings had undergone severe attack of the leafhopper beetle *Costalimaita ferrugineavulgata*, as previously informed. In degraded areas of Cerrado, due to the occurrence of soil erosion processes in Uberlândia / MG, Silva *et al* (2011) verified that the survival and growth of different forest species occurs independently of the fact of being exotic or native when planted under the same soil and climatic conditions.

CONCLUSIONS

- The conventional mineral fertilization with NPK (DAM treatment) provided higher values of survival and growth attributes for seedlings of the forest native species *Mabea fistulifera* and the exotic hybrid *Eucalyptus urograndis* in monospecific plantations in an area degraded by the loan of soil in Cerrado, when compared to the different doses of industrial waste obtained from the production of cellulose (organic compound). This result was probably influenced by the lower availability of micronutrients in the soil solution due to the alkaline pH in the treatments in which the cellulose residue was applied, regardless of the dose.
- When comparing the different doses of the industrial waste from the cellulose production, the dose of 10 Mg ha $^{-1}$ was the most adequate for the acquisition of higher survival and growth of seedlings of the forest native species *Mabea fistulifera* and the exotic hybrid *Eucalyptus urograndis*, in monospecific plantations under the studied field conditions.

ACKNOWLEDGMENTS

To FAPESP and CAPES, for the provision of scholarship (doctorate) of the first author, in Brazil and abroad.

To the group Ambitec, for the donation of the organic compound.

To Fibria and Energetic Company of São Paulo (CESP), for the donation of seedlings of *Mabea fistulifera* and *Eucalyptus urograndis*, respectively.

REFERENCES

ALVARES, C. A.; STAPE, J. L.; SENTELHAS, P. C.; GONÇALVES, J. L. M.; SPAROVEK, G. Köppen's climate classification map for Brazil. **Meteorologische Zeitschrift**, Stuttgart, v. 22, n. 6, p. 711-728, 2013.

ALVES, M. C.; SOUZA, Z. M. Recuperação do subsolo em área de empréstimo usada para construção de hidrelétrica. **Revista Ciência Agronômica**, Fortaleza, v. 42, n. 2, p. 301-309, 2011.

ARRUDA, O. G.; TARSITANO, M. A. A.; ALVES, M. C.; GIÁCOMO, R. G. Comparação de custos de implantação de eucalipto com resíduo celulósico em substituição ao fertilizante mineral. **Revista Ceres**, Viçosa, v. 58, n. 5, p. 576-583, 2011.

CALDEIRA, M. V. W.; DELARMELINA, W. M.; FARIA, J. C. T.; JUVANHOL, R. S. Substratos alternativos na produção de mudas de *Chamaecrista desvauxii*. **Revista Árvore**, Viçosa, v. 37, n. 1, p. 31-39, 2013.

CHRISTO, A. G.; GUEDES-BRUNI, R. R.; PINTO SOBRINHO, F. A.; SILVA, A. G.; PEIXOTO, A. L. Structure of the shrub-arboreal component of an Atlantic Forest fragment on a hillock in the central lowland of Rio de Janeiro, Brazil. **Interciencia**, Caracas, v. 34, p. 232-239, 2009.

ENGEL, V. L.; PARROTA, J. A. Definindo a restauração ecológica: tendências e perspectivas mundiais. In: KAGEYAMA, P. Y.; OLIVEIRA, R. E.; MORAES, L. F. D.; ENGEL, V. L.; GANDARA, F. B. **Restauração ecológica de ecossistemas naturais**. Botucatu: Fundação de Estudos e Pesquisas Agrícolas e Florestais, 2003. p. 3-25.

EVARISTO, V. T.; BRAGA, J. M. A.; NASCIMENTO, M. T. Atlantic Forest regeneration in abandoned plantations of eucalypt (*Corymbia citriodora* (Hook.) K. D. Hill and L. A. S. Johnson) in Rio de Janeiro, Brazil. **Interciencia**, Caracas, v. 36, n. 6, p. 431-436, 2011.

FERREIRA, D. F. Sisvar: a computer statistical analysis system. **Ciência e Agrotecnologia**, Lavras, v. 35, n. 6, p. 1039-1042, 2011.

FERREIRA, W. C.; BOTELHO, S. A.; DAVIDE, A. C.; FARIA, J. M. R.; FERREIRA, D. F. Regeneração natural como indicador de recuperação de área degradada a jusante da usina hidrelétrica de Camargos, MG. **Revista Árvore**, Viçosa, v. 34, n. 4, p. 651-660, 2010.

HÜLLER, A.; COELHO, G. C.; LUCCHESE, O. A.; SCHIRMER, J. A comparative study of four tree species used in riparian forest restoration along Uruguay river, Brazil. **Revista Árvore**, Viçosa, v. 33, n. 2, p. 297-304, 2009.

INSTITUTO BRASILEIRO DO MEIO AMBIENTE E DOS RECURSOS NATURAIS RENOVÁVEIS - IBAMA. **Manual de recuperação de áreas degradadas pela mineração**. Brasília: IBAMA, 1990. 96 p.

KUNZ, S. H.; IVANAUSKAS, N. M.; MARTINS, S. V. Estrutura fitossociológica de uma área de cerradão em Canarana, Estado do Mato Grosso, Brasil. **Acta Scientiarum Biological Sciences**, Maringá, v. 31, p. 255-261, 2009.

LI, X.; NIU, J.; XIE, B. The effect of leaf litter cover on surface runoff and soil erosion in Northern China. **PLoS ONE**, Cambridge, v. 9, n. 9, p. 1-15, 2014.

MARQUES, T. E. D; BAÊTA, H. E.; LEITE, M. G. P.; MARTINS, S. V.; KOZOVITS, A. R. Crescimento de espécies nativas de cerrado e de *Vetiveria zizanioides* em processos de revegetação de voçorocas. **Ciência Florestal**, Santa Maria, v. 24, n. 4, p. 843-856, 2014.

MEDEIROS, J. C.; ALBUQUERQUE, J. A.; MAFRA, A. L.; BATISTELLA, F.; GRAH. Calagem superficial com resíduo alcalino da indústria de papel e celulose em um solo altamente tamponado. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 33, n. 6, p. 1657-1665, 2009.

MELO, A. C. G.; DARONCO, C.; RÉ, D. S.; DURIGAN, G. Atributos de espécies arbóreas e a facilitação da regeneração natural em plantio heterogêneo de mata ciliar. **Scientia Forestalis**, Piracicaba, v. 43, n. 106, p. 333-344, 2015.

MENDONÇA, R. C.; FELFILI, J. M.; WALTER, B. M. T.; SILVA-JÚNIOR, M. C.; REZENDE, A. V.; FILGUEIRAS, T. S.; NOGUEIRA, P. E.; FAGG, C. W. Flora vascular do bioma Cerrado: checklist com 12.356 espécies. In: SANO, S. M.; ALMEIDA, S. D. P.; RIBEIRO, J. F. (Eds.). **Cerrado**: ecologia e flora. v. 2. Brasília: Embrapa Cerrados/Embrapa Informação Tecnológica, 2008. p. 421-1279.

MYERS, N.; MITTERMEIER, R. A.; MITTERMEIER, C. G.; FONSECA, G. A. B.; KENT, J. Biodiversity hotspots for conservation priorities. **Nature**, London, v. 403, p. 853-858, 2000.

ROCHA, J. H. T.; SANTOS, A. J. M.; DIOGO, F. A.; BACKES, C.; MELO, A. G. C.; BORELLI, K.; GODINHO, T. O. Reflorestamento e recuperação de atributos químicos e físicos do solo. **Floresta e Ambiente**, Seropédica, v. 22, n. 3, p.299-306, 2015.

SANO, E. E.; ROSA, R.; BRITO, J. L. S.; FERREIRA, L. G. Mapeamento semidetalhado do uso da terra do Bioma Cerrado. **Pesquisa Agropecuária Brasileira**, Brasília, v. 43, n. 1, p. 153-156, 2008.

SILVA, A. H.; PEREIRA, J. S.; RODRIGUES, S. S. Desenvolvimento inicial de espécies exóticas e nativas e necessidade de calagem em área degradada do Cerrado no triângulo mineiro (Minas Gerais, Brasil). **Agronomía Colombiana**, Bogotá, v. 29, n. 2, p. 287-292, 2011.

SILVA, A. M.; CANUTO, D. S. O.; MORAES, M. L. T.; BUZETTI, S. Avaliação das propriedades químicas em solo de Cerrado sob reflorestamento ciliar. **Floresta**, Curitiba, v. 42, n. 1, p. 49-58, 2012.

SILVA, P. H. M.; POGGIANI, F.; GONÇALVES, J. L. M.; STAPE, J. L.; MOREIRA, R. M. Crescimento de *Eucalyptus grandis* tratado com diferentes doses de lodos de esgoto úmido e seco, condicionados com polímeros. **Scientia Forestalis**, Piracicaba, v. 36, n. 77, p. 79-88, 2008.

SOARES, M. P.; NUNES, Y. R. F. Regeneração natural de cerrado sob plantio de *Eucalyptus camaldulensis* Dehn. no norte de Minas Gerais, Brasil. **Revista Ceres**, Viçosa, v. 60, n. 2, p. 205-214, 2013.

SOUZA, D. M. G.; MIRANDA, L. N.; OLIVEIRA, S. A. Acidez do solo e sua correção. In: NOVAIS, R. F.; ALVAREZ, V. H.; BARROS, N. F.; FONTES, R. L. F.; CANTARUTTI, R. B.; NEVES, J. C. L.. **Fertilidade do solo**. Viçosa: Sociedade Brasileira de Ciência do Solo, 2007. p. 205-274.

TOLEDO, F. H. S. F.; VENTURIN, N.; CARLOS, L.; DIAS, B. A. S.; VENTURIN, R. P.; MACEDO, R. L. G. Composto de resíduos da fabricação de papel e celulose na produção de mudas de eucalipto. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande, v. 19, n. 7, p. 711-716, 2015.

VIANI, R A. G.; DURIGAN, G.; MELO, A. C. G. A regeneração natural sob plantações florestais: desertos verdes ou redutos de biodiversidade? **Ciência Florestal**, Santa Maria, v. 20, n. 3, p. 533-552, 2010.