GROWTH OF EUCALYPTUS SEEDLINGS IN SOIL CONTAMINATED BY HEAVY METALS

Bianca Pietsch Cunha Bendito[1], Patrícia Aparecida De Souza[2], Rubens Ribeiro da Silva[3]

[1] Mestranda em Ciências Florestais e Ambientais. Universidade Federal do Tocantins. Gurupi, Tocantins, Brasil. (biancapcb.engamb@gmail.com)
[2] Professora Doutora. Gurupi, Universidade Federal do Tocantins. Tocantins, Brasil.
[3] Professor Doutor. Gurupi, Universidade Federal do Tocantins, Tocantins, Brasil.

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ABSTRACT

One of the reasons for the disabling of dump areas is the heavy metal contents found in these areas. For the diactivation, it is necessary to choose more efficient mitigation measures. Among various techniques: the phytoremediation uses “accumulator” plants and/or tolerant of heavy metals, associated microorganisms; and uses improved agricultural practices. Among the potential phytoremediation plants, the arboreas, is the genus *Eucalyptus*. Three clones’ growth were rated (VM1, I144, 1528) in soil contaminated by heavy metals, soil originated from the landfill area in the Porto Nacional municipality, Tocantins State. The metal concentrations did not affect the clones’ natural growth, and all the VM01, I144 stood out for a better use of nutrients, despite the presence of metals. VM01 had the greatest root length and I144 the largest “increase” DAP. Possibly the standing out of these clones is associated to the best use of high Phosphorus and Potassium values found in soil samples.
KEYWORDS: landfill, remediation, eucalyptus urograndis.

CRESCIMENTO DE MUDAS DE EUCALIPTO EM SOLO CONTAMINADO COM METAIS PESADOS

RESUMO

A desativação das áreas de lixão se faz eminente, entre os motivos, devido o teor de metais pesados encontrado nessas áreas. Para a desativação, são necessárias escolhas de medidas mitigadoras que sejam mais eficientes. Entre as técnicas existentes tem-se a fitorremediação, que é o uso plantas acumuladoras e/ou tolerantes a metais pesados, sua microbiota associada, além de práticas agronômicas otimizadas. Entre as plantas com potencial fitorremediador encontram-se as espécies arbóreas do gênero *Eucalyptus*. Foi avaliado o crescimento de três clones de Eucalipto (VM1, I144, 1528) em solo contaminado por metais pesados, provenientes da área de lixão do município de Porto Nacional, TO. As concentrações de metal não afetaram o crescimento natural dos clones, contudo tudo, o VM1, I144 se destacaram por maior aproveitamento dos nutrientes apesar da presença dos

metais. VM1 apresentou maior comprimento de raiz e o I144 maior incremento de DAP. E possível que o destaque de tais clones esteja associado ao maior aproveitamento dos altos valores de fósforo e potássio também encontrados nas amostras de solo.
PALAVRAS-CHAVE: Clone, *Eucaliptus urograndis,* Lixão, Remediação.

INTRODUCTION

The heavy metals are natural soil compounds as they are part of the crystalline structure of metals that consists the rocks, main material of soil origin (SILVA, 2014). However, more and more frequently, it has been recognized the soil contamination by means of anthropic activities, such as inadequate disposal of solid waste. These contaminated soil areas, by law regulations, must be recuperated.

The inadequate disposal of urban solid waste in dump areas is one of the main causes of soil, of water courses, and of underground water contamination by heavy metals such as Nickel (Ni), Cooper (Cu), Zinc (Zn), Cadmium (Cd), Lead (Pb), Chrome (Cr). These heavy metals are found in various types of waste disposed in dump areas: lamps, batteries, paint, cans, among other toxic products (CAVALLET et al., 2013). These heavy metals can lead to various chemical reactions that are not metabolized, that stay cumulatively throughout the food chain, that increase their concentration in organisms in relation to their environment concentration, so that transformations are promoted in the ecosystems (SILVA, 2014).

In 2014, the National Panorama of Solid Waste (ABRELPE, 2014) reported that 58,4% of the daily collected waste in Brazil had adequate destination in sanitary landfills, and 41,6 % or 81.000 tons were disposed in dumps or in not very different controlled areas, for both do not have the necessary system and measures to protect the environment against damage and degradation. Among 3344 municipalities that use inadequate locals as final destination of waste, 1569 still use dump areas.

According to this reality, plans are needed for the remediation of these contaminated areas and to meet the Law n. 12.305/2010, which the regulates the National Policy for Solid Waste and the final destination of solid waste. According to this Law, the dump areas in cities, municipalities, and states in Brazil should be deactivated and recuperated (BRAZIL, 2010), in order to reintroduce these areas to the production process, and in order to avoid the slide of metals into nearby areas and into underground water, mainly the potable one, as water scarcity is being faced in many Brazilian cities nowadays.

The phytoremediation is one of the classical methods of remediation “in-situ”, presents low-cost techniques that cause less soil alteration. It uses “accumulator” plants and/or tolerant of heavy metals, associated microorganisms, and uses improved agricultural practices. The use of phytoremediation aims to remove, prevent or become harmless, stabilize and/or degrade the heavy metals that can contaminate soil, sediments and water. This method can be used in inadequate disposal areas of urban solid waste, such as the dump areas (ASSUNÇÃO, 2012).

The genus *Eucalyptus* has been used in the phytoremediation technique, for presenting quick growth features, a developed root system and easy adaptation to stressing conditions. These genera have potential to be used in recuperating programs for areas contaminated by inadequate disposal of heavy metals, and in addition to it, have potential to increase soil carbon reserves (MAGALHÃES et al.

2011).

As an example, *Eucalyptus torelliana* F. Muell, *Eucalyptus grandis* W. Hill, *Eucalyptus citriodora* Hook, and *Eucalyptus camaldulensis* Dehnh. were tested and they showed to be tolerant of heavy metal presence. However, studies have not been pursued about hybrids between Eucalyptus species, to evaluate their behavior in areas contaminated by the inadequate disposal of heavy metal. Therefore, this study aims to evaluate the growth of seedlings from *Eucalyptus urograndis* clones', in soil contaminated by heavy metals, from a dump area in Porto Nacional city, Tocantins State.

MATERIALS AND METHODS

This study was developed in the Plant Nursery at Federal University of Tocantins, in Gurupi city, TO, located at the coordinates 11°44'36.2" South and 49°02'52.7" West. In the municipality the climate is tropical. In winter, there is much less rainfalls than in summer. The annual average of rainfalls is 1483mm. According to Köppen and Geiger, the climate is classified as AW.

Three *Eucalyptus urograndis* clones, 1528, VM01, and I144, were evaluated. The seedlings, ninety (90) days old, used in this study were bought from a commercial plant nursery; they were selected according to their uniformity of size and quality, and were planted in contaminated soil in five-liter polyetilen pots.

The soil was collected from the inadequate disposal area of urban solid waste, named "Lixão de Porto Nacional", Porto Nacional city, TO, located at the coordinates 10°39'50.31" South and 48°20'57.92" West.

The soil samples were collected from a layer 0-20 cm deep. A dutch auger was used to collect these samples from three different points named soil a (Sa), soil b (Sb), and soil c (Sc). The rough fragments, such as wood, tire, metal, and other waste pieces, were collected previously. Since the collecting until the laboratory work, the conservation of samples followed regulations defined by the National Guide of Collecting and Preservation of Samples (CETESB, 2012) and the NBR 9604 (ABNT, 1986). Then, the samples were first sieved through a one-inch mesh, secondly they were sieved through a zero-point-three-inch mesh.

The areas of Sa and Sb collected points are part of the dump area that has been used for a longer period of time. The sampled locals were chosen according to their source of pollution, defined by the CETESB's Manual for the Management of Contaminated Areas (CETESB, 2012), which states about the long-term accommodation of waste piles and of solid waste that provides the soil with heavy metals: electronic devices, home appliances, electric circuits, fluorescent lamps, paints, etc. The point Sc was collected in a native area near the dump area as a control treatment. The localization of points is presented in Picture 1.

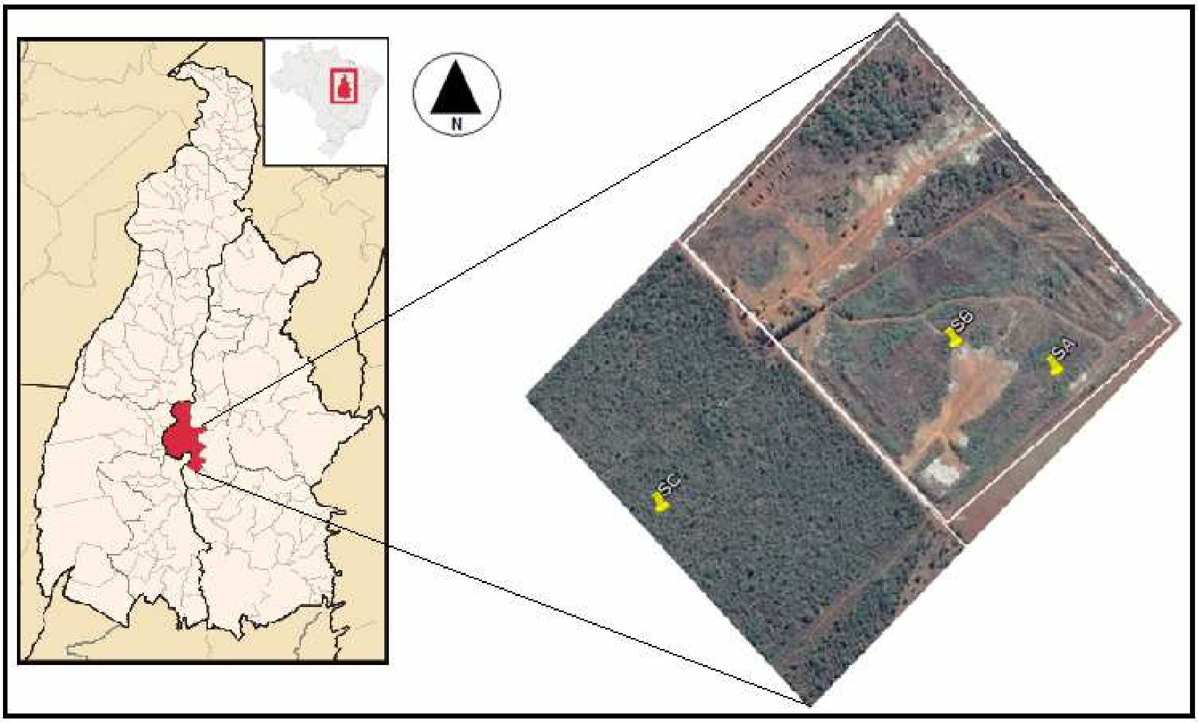

FIGURE 1. Localization of points where the soil samples were collected, in the Dump Area of Porto Nacional city, TO.

After the collecting, each soil sample was properly inserted into a plastic bag, sealed, and numbered. From each waste sample, a hundred (100) grams of the sieved material was taken to physical and chemical analyses in a private laboratory in Gurupi city, TO. Besides this, the extraction of total heavy materials was carried out at the University of Brasilia (UNB), DF, and at the laboratory of Soil Chemistry at the University of Viçosa (UFV), MG, where the reading of the extracts was also carried out (Tables 1 and 2).

TABLE 1: Physical and chemical characteristics of soil collected in the Dump Area of Porto Nacional city, TO.

	P	**K**	**Al**	**Ca**	**Mg**	**H+Al**	**CTC_T**	**SB**	**MO**	PH
	mg.dm^{-3}				**cmol.dm^{-3}**			**dag.kg^{-1}**		
V. R.*	8,1 – 12,0	71 - 120	1,01 - 2,00	2,41 – 4,00	0,91 – 1,50	5,01 – 9,00	8,61 - 15,00	3,61 - 6,00	4,01 - 7,00	5,50 - 6,50
As	162,9	342	0,0	7,0	1,5	2,80	12,17	9,37	2,5	6,0
Sb	182,1	310	0,0	7,3	1,5	1,80	11,39	9.59	3,2	5,8
Sc	14,7	66	0,0	2,4	1,0	3,10	6,67	3,57	2,1	4,9

V.R.: Reference Values of soil fertility (RIBEIRO et al.,1999). Sa and Sb soil samples: collected inside the dump area. Sc soil control treatment collected in a native area nearby the dump.

TABLE 2: Contents of heavy metals in soil samples collected in the dump area of Porto Nacional, TO.

		Hg	Pb	Zn	Cd	Mn	Ni	Cu	Cr	As
		mg.kg^{-1}								
VOQ*	VRQ	0,05	17	60	<0,5		13	35	40	3,5
	VP	0,5	72	86	1,3		30	60	75	15
Sa		0,0	60	18,3	5,0	1,2	0,0	11,6	0,0	0,0
Sb		0,0	30	13,9	2,45	1,0	0,0	14,8	0,0	0,0
Sc		0,0	3,0	4,4	0,5	1,4	0,0	1,6	0,0	0,0

VOQ: Guiding Values of Quality for heavy metals in the soil, according to the Nacional Council for the Environment (CONAMA) Resolution 420/2009, on December 28th, 2009 (BRAZIL, 2009); VRQ: Reference Values of Quality; VP: Prevention Values. Sa and Sb soil samples: collected inside the dump. Sc soil control treatment collected in a native area nearby the dump.

The experiment was carried out throughout sixty (60) days, from June to August 2016, and the seedlings were watered twice a day. The used experimental design was completely randomized, factorial diagram 3 x 3, three clones and three substrata, eight (8) repetitions, one plant per repetition, total of seventy-two (72) experimental units.

The evaluated parameters were: length of aerial part, diameter of lap, both measured with a millimeter ruler and digital calipers, respectively, in the beginning and at the end of the experiment. The initial and final values of the length and diameter based the growing tax (txc) calculation for each one of the following parameters: txc (initial and final values) and the number of analyzed months.

The statistical evaluation of collected data was carried out by the software ASSISTAT version 7.7 beta (SILVA & AZEVEDO, 2016) and the data variance analysis by the Tukey test.

RESULTS AND DISCUSSION

The factorial analysis by the Tukey test demonstrated that the relation between the factors (clone and soil) was not significant to all evaluated variables (aerial part length, lap diameter, root length, leaf number). So, these factors were analyzed separately (Tables 3 and 4).

The variance analysis demonstrated an interaction not significant for the majority of evaluations (Table 3 and 4). The comparison of species (Table 4) showed that the significant evaluations were for p < 0,01. The comparison of soil function (Table 4) showed that the significant evaluations were for p < 0,01 and 0,01 = < p < 0,05.

TABLE 3: Comparison of length of aerial part, lap diameter, root length, leaf number, growth of aerial part, growth of lap diameter, among clones in each soil sample.

CLONES	SOLOS		
	Sc	Sb	Sa
	LENGTH OF AERIAL PARTS (cm)		
1528	52,62 b	59,12 b	59,00 b
VM01	64,31 a	59,12 a	67,87 a
I144	44,55 c	49,37 c	47,94 c
	LAP DIAMETER (mm)		
1528	6,41 a	6,80 a	6,97 a
VM01	6,15 a	6,18 a	6,22 b

I144	5,16 b	6,02 a	6,12 b
	ROOT LENGTH (cm)		
1528	33,12 b	37,12 a	38,50 ab
VM01	41,50 a	37,00 a	42,87 a
I144	36,25 ab	33,50 a	35,62 b
	LEAF NUMBER		
1528	37,50 a	51,87 a	48,12 a
VM01	46,50 a	45,50 a	48,37 a
I144	37,25 a	55,87 a	48,50 a
	GROWTH OF AERIAL PART (cm)		
1528	10,81 a	15,00 a	13,87 a
VM01	12,44 a	11,97 a	13,62 a
I144	10,92 a	13,87 a	13,19 a
	GROWTH OF LAP DIAMETER (mm)		
1528	2,67 a	3,14 a	3,25 ab
VM01	2,75 a	2,63 a	2,63 b
I144	2,12 a	3,25 a	3,29 a

TABLE 4: Comparison of length of aerial part, lap diameter, root length, leaf number, growth of aerial part, growth of lap diameter, among different soils, of each clone.

SOLOS	**CLONES**		
	1528	**VM01**	**I144**
	LENGTH OF AERIAL PARTS (cm)		
Sc	52,62 b	64,31 a	44,55 b
Sb	59,12 a	65,62 a	49,37 a
Sa	59,00 a	67,87 a	47,94 ab
	LAP DIAMETER (mm)		
Sc	6,41125 b	6,14625 a	5,16 b
Sb	6,80500 ab	6,17625 a	6,02 ab
Sa	6,96750 a	6,21750 a	6,12 a
	ROOT LENGTH (cm)		
Sc	33,25 a	41,50 ab	36,12 a
Sb	37,12 a	37,00 b	33,50 a
Sa	38,50 a	42,87 a	35,62 a
	LEAF NUMBER		
Sc	37,50 a	46,50 a	37,25 b
Sb	51,87 a	45,50 a	55,87 a
Sa	48,12 a	48,37 a	48,50 a
	GROWTH OF AERIAL PART (cm)		
Sc	10,81 a	12,44 a	10,92 a
Sb	15,00 a	11,97 a	13,87 a
Sa	13,87 a	13,62 a	13,19 a
	GROWTH OF LAP DIAMETER (mm)		
Sc	2,67 a	2,74 a	2,12 b
Sb	3,14 a	2,63 a	3,25 a
As	3,25 a	2,63 a	3,29 a

The survival of the *Eucalyptus* seedlings was (100%) a hundred per cent for all evaluated treatments. The heavy metals found in the soil sample analysis were Lead, Zinc, Cadmium, Manganese, and Cooper (Table 2). The soil collected from the native area nearby the dump (Sc), according to the control treatment, presented all values below the guiding values for soil quality (Table 2), stated in CONAMA Resolution 420/2009.

The soil collected inside the dump (Sa and Sb) presented concerning values of Lead (Pb) and Cadmium (Cd) solely. The Lead values in Sa (Pb: 60 mg.kg^{-1}) and in Sb (Pb:30 mg.kg^{-1}) were superior to the reference value of quality (Pb: 17 mg.kg^{-1}) (Table 3), which demonstrates that a concerning alteration in the soil is initiating (CETESB, 2012). The Cadmium values in Sa (Cd: 5,0 mg.kg^{-1}) and in Sb (Cd: 2,45 mg.kg^{-1}) were superior to the reference value of quality (Pb: 17 mg. Cd: < 0,5 mg.kg^{-1}) (Table 2), which demonstrates that the soil has a certain metal amount superior to the amount it is capable to bear, so that these metals are not available for plant and soil absorption (BRAZIL, 2009). Besides the heavy metal presence, also the presences of high levels of macronutrients, mainly Phosphorus (P) and Potassium (K) (Table 2) were recognized, even though the toxicity traces of these nutrients in plants were not verified.

AERIAL PART LENGTH

In Table 3, a significant difference in length values among clones' aerial part in three evaluated soils, was observed. The VM01 presented larger length of aerial part (64,31 cm; 59,12 cm; 67,87 cm); the clone 1528 (52,62 cm; 59,12 cm; 59,00 cm); and the clone I144 (44,55 cm; 49,37 cm; 47,94 cm) in Sa, Sb, and Sc, respectively. This difference solely shows the VM01 presenting larger size compared to the other clones, but the growth of the aerial part (Table 4) did not present any significant difference among the clones.

Similar results were found by NALON (2008) when *E. grandis*, *E. saligna*, *E. citriodora* seedlings were evaluated in soils of 489,24 mg. kg^{-1} and 3.782 mg.kg of Pb concentration, higher than the soil collected in the dump in Porto Nacional city, TO (Sa: 60 mg. kg^{-1}, Sb: 30 mg. kg^{-1}). It was also observed that a significant effect of an interaction between clones' aerial part length and Pb doses in the first two months, did not occur (Table 3).

In Table 4, it was verified that the larger lengths of clones' aerial part were in soils where metals, such as Pb (Sa: 60 mg.kg, Sb: 30 mg. kg^{-1}) were present: the 1528 in Sb; and the VM01 and the I144 in Sa. NALON (2008) verified results similar to this study: in a fourty-day experiment, the *E. grandis* plants cultivated in Pb higher concentration soil, presented length superior to the plants cultivated in Pb lower concentration soil. The same was verified about 1528 and I144, which have the genetical basis of *E. grandis.*

The variance analysis demonstrated significant difference among the three soils evaluated for the clones 1528 and I144 (Table 4). The 1528 presented larger length of aerial part in Sb (59.12 cm) and no statistical difference from Sa (59.00 cm). The I144 also presented larger length in Sb (67,87 cm) and no statistical difference from Sa (65.62 cm). Furthermore, the growth did not present significant difference of the aerial part among the three soils, from the three clones. Therefore, the growth was similar, and it implies that the metals did not interfere in the seedling growth.

This metal non-interference is related to the Cd doses (Sa: 5.0 mg. kg^{-1}, Sb:2,45 mg. kg^{-1}) and Pb doses (Sa: 60 mg. kg^{-1}, Sb: 30 mg. kg^{-1}) found in soil which did not have sufficient concentrations to influence initial growth of the seedlings. This is confirmed by the literature: WEIRICH (2013) and ASSUNÇÃO (2012) verified that Zn an Cd values needed to initiate the aerial part length reduction of the *E. urophylla* seedlings, are respectively 1.038 mg. kg^{-1} and 16,5 mg. kg^{-1}, values superior to the values verified in Porto Nacional city.

DIAMETER

The variance analysis demonstrated a significant difference in the lap diameter growth of clones in Sa: the largest clone growth was I144 (3.29 cm), not statistically different from 1528 (3.25 cm) (Table 4). It was observed that clones I144 and 1528 had a diameter increment superior to VM01, in soil where the highest heavy metal values were (Table 3). The I144 and 1528 clones have features of *E. grandis*, which is a high diameter increment genus, according to FERREIR, SILVA and CHICHORRO (2014).

In Table 4, the variance analysis presented a significant difference in the lap diameter values among the soils for the clones 1528 and I144, where the larger values were in Sa (6.97 cm and 6.80 cm, respectively); not different from Sb (6.12 cm and 6.02 cm, respectively). The variance analysis showed a significant difference for the lap diameter growth, in lap diameter values of I144 solely, the larger value in Sa, not statistically different from Sb.

It can be inferred that the heavy metal contents (Table 3) were not sufficient to interfere with the diameter values and studies by WEIRICH (2013), NALON (2008), and ASSUNÇÃO (2012) confirm the results found. They verified that it is necessary Zn, Pb, and Cd 1.495 mg. kg^{-1}, 1.429 mg. kg^{-1} e 16.5 mg.kg doses respectively, for diameter reduction.

Furthermore, though the growth values of lap diameter of clones 1528 and I144 were larger than VM01 values (Table 4), solely the I144 clone had different growth in other soils. This shows a higher diameter increment and confirms a better performance in soil of higher metal contamination. In NALON's (2008) study, after a seventy-five-day experiment, the *E. grandis* presented a superior diameter development of stalk in treatments with Lead concentration.

These results demonstrated that I144 clone showed better response to the treatments when compared to other clones. According to ANDRADE et al. (2014), plants that have good lap diameter growth are of interest to phyto-stabilization programs in areas contaminated by heavy metals. According to BARTIERES et al. (2016), those programs are justifiable, for I144 is highly efficient in absorbing and utilizing N, P, Mg, K, has low efficiency in absorbing Ca, a nutrient which I144 utilizes very efficiently in producing biomass.

ROOT

In Table 3, the variance analysis demonstrated a significant difference of root length values among clones in Sc and in Sa. In Sc, VM01 had larger root length, statistically not different from I144. In Sa, VM01 had larger root length statistically not different from 1528. The difference of root length among soil samples (Table 4), was significant solely for clone VM01, whose larger growth was in Sa, statistically not different from the growth in Sc, or in other words, practically equal with or without the metal presence.

These results showed that metal concentrations were not sufficient to interfere in clones' root length, similar results also found by WEIRICH (2013), NALON (2008), and ASSUNÇÃO (2012). They verified that Zn, Pb, and Cd values that alter root growth are respectively: 298 mg. kg^{-1}, 1.429 mg. kg^{-1}, and 16.5 mg. kg^{-1}.

In addition to it, even though VM01 had root size similar to 1528 in Sa, it is inferred from these results that VM01 compared to its initial size, had larger growth (Table 4). Therefore, VM01 had the largest root growth in soil with high contamination. This demonstrates a better performance of the parameter "root" than the others. The root size is an important feature in order to phyto-stabilize the areas contaminated by heavy metals, for it protects the soil from erosion, reduces lixiviation, favors aggregation and microbiological activity in the soil (MADALÃO et al., 2013). PINTO et al. (2011) analyzed the nutritional efficiency of *Eucalyptus* clones. The VM01 (9.843 cm) had a significant difference in root length from I144 (8.699 cm). It was concluded that this factor conditioned the VM01 major capacity of absorption of nutrients. In Table 3, it is verified that I144 presented larger number of leaves, and the largest value was in Sb, even though the difference of leaf number statistically is not significant among the clones in the three soils.

In Table 4, it is observed that the evaluations of leaf number were significant solely for I144, which had larger number of leaves in Sb, not statistically different in Sa. These results showed that heavy metal doses did not affect the leaf number of clones. Results confirmed by WEIRICH (2013) and KABATA-PENDIAS (2010), which verified that the leaf number was solely reduced from the values of Zn 556 mg. kg^{-1} for *E. grandis*, and of Zn 2.020 mg. kg^{-1} for *E. dunnii*.

Even though the heavy metals affect the soil, their presence (Table 3) was not sufficient to cause toxicity to *Eucalyptus* genus. It was also verified that the majority of the evaluated parameters had superior values in the soil where the metal concentration was higher. This can be justified by the high Phosphorus (P) and Potassium (K) values found in these soil samples (Table 2).

The high P values (Table 2) were not harmful to the seedlings. According to BASSACO and WALCZAK (2014), the *Eucalyptus* has high need for P in the initial phase of growth, makes good use of it if in great quantity and near the root. According to PEREIRA (2016), solely 70% of P is available for absorption.

The high proportions of Potassium (k) are not considered concerning. According to MENDES et al. (2013) and NOVAIS et al. (1980), the seedling features of *Eucalyptus* are little or not affected at all by Potassium use. He states that plants presented values similar for leaf number, aerial part length, lap diameter despite any Potassium doses. In other words, it was verified that *Eucalyptus* has low initial need for Potassium.

Various study results demonstrated that genus *Eucalyptus* has great potential for use in recuperating programs of areas impacted by heavy metals in the soil, mainly for presenting features such as quick growth, well developed root system, and easy adaptation to stressing conditions (ACCIOLY et al., 2004), points also confirmed in this study here.

Among the authors which confirmed this results are WEIRICH (2013) and ASSUNÇÃO (2012). The first verified that E. grandis could tolerate until the Zn 840 mg. kg^{-1} dosage. The variables: aerial part length and lap diameter in *E. grandis* seedlings, were reduced by the use of Zn 980 mg. kg^{-1} in the soil sample. The second stated that *E. urophylla* developed well in areas contaminated by Pb (16.5 $mg.kg^{1}$), Cd (3148.4 $mg.kg^{1}$), and Zn (3612.8 $mg.kg^{1}$), stood out for concentrating higher proportions of Pb in the root and of Zn in the stalk.

CONCLUSION

- The soil samples collected in the dump area presented concerning values solely about Cd (Sa: 5.0 mg. kg^{-1}; Sb: 2,45 mg. kg^{-1}) and Pb (Sa: 60 mg. kg^{-1}; Sb: 30 mg. kg^{-1}), which demonstrates that a concerning soil quality alteration is initiating, even though the high Potassium and Phosphorus values did not damage the initial growth of the seedlings.
- The high proportions of Pb and Cd in soil samples collected from the dump area in Porto Nacional city, TO, were not sufficient to affect the initial growth of *Eucalyptus* plants. This fact demonstrates the clones' resistance and the *Eucalyptus* genera's great potential for recuperating programs in areas contaminated by such metal values.
- No clone stood out in relation to the other. However, the VM01 clones (*E. urophylla x E. camaldulensis*) stood out in their root values, and the hybrid I144 (*E. urophylla x E. grandis*) stood out for its larger diameter values in higher metal concentration soil.
- It is recommended that more studies about clones' utilization in areas contaminated by inadequate disposal of urban solid waste, the dump areas, evaluate the potential of these genera for the recuperation of areas contaminated by heavy metals.

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