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Growth of eucalyptus rooted cuttings in toxic organic waste compost of textile industry

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A B S T R A C T

Biodegradation techniques may help contaminated organic wastes to become useful for plant production. The current study aimed to evaluate the efficiency of composting in the biodegradation of toxic residues from the textile industry and its use as substrate in saplings production. Cotton cloths contaminated with oil and grease, used in loom maintenance, were composted in a mixture with cattle manure. The composted material replaced coconut fiber in the substrate for the production of eucalyptus rooted cuttings: mixture of vermiculite, carbonized rice husk and coconut fiber in the ratio of 2:1:1 (v/v) and using it as control. Thus, the amount of rice husks remained unchanged and the amount of vermiculite and compost varied. The compost proportion in the tested substrates were 0, 19, 37, 56 and 75%. The compost produced from textile wastes showed high nutrient levels and low levels of heavy metals. In general, the survival, growth and some growth indices of rooted cuttings produced on substrates with 19 and 37% compost were similar to those of rooted cuttings grown in commercial substrate. Composting is efficient and the material is useful for rooted cuttings production.

Palavras-chave:
compostagem
biodegradação
reciclagem
sustentabilidade
substratos

Crescimento de mudas de eucalipto em composto orgânico de resíduos tóxicos da indústria têxtil

R E S U M O

Técnicas de biodegradação podem ajudar a tornar resíduos orgânicos contaminados úteis à produção vegetal. Objetivou-se, neste trabalho, avaliar a eficiência da compostagem na biodegradação de resíduos tóxicos da indústria têxtil e seu uso em substrato de produção de mudas. Panos de algodão sujos de óleo e graxa usados na manutenção dos teares foram compostados em mistura com esterco bovino. O composto foi usado em substituição à fibra de coco no substrato de produção de mudas clonais de eucalipto: mistura de vermiculita, casca de arroz carbonizada e fibra de coco na proporção de 2:1:1 (v/v) e este foi usado como controle. Assim, manteve-se fixa a quantidade de casca de arroz e se variou a quantidade de vermiculita e de composto. As proporções totais de composto nos substratos avaliados foram de 0, 19, 37, 56 e 75%. O composto possuiu altos teores de nutrientes e baixos teores de metais pesados. Em geral, a sobrevivência, o crescimento e alguns índices de crescimento das mudas produzidas nos substratos com 19 e 37% de composto foram semelhantes aos das mudas crescidas no substrato comercial. A compostagem é eficiente e o composto é útil na produção de mudas.

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Introduction

Industrial waste disposal in Brazil is regulated by specific legislation and standards. Law nº 12,305, published in 2010, refers to the national solid waste policy and reinforce standards already established by CONAMA (National Council of Environment), in the normative resolutions 257/263/258 and 313. Among its guidelines is the prohibition of solid waste release to beaches, rivers and lakes, open-air garbage burning, and the allocation of recyclable materials on dumps or landfills. By contrast, this policy encourages recycling and composting among other actions.

Composting is an effective recycling process for biodegradation of different organic wastes; moreover, promoting such residue reduction, being cheaper than other treatments (Barreira et al., 2006). This procedure converts organic waste into fertilizers and soil constraints, which can be used in farming or in degraded land recovery, contributing to the closure of mineral nutrient cycle and reducing the amount of material to be grounded (Corrêa et al., 2006; Sampaio et al., 2012). Nevertheless, organic compound may have some restrictions regarding its agricultural use, one of which is related to heavy metals (Bueno et al., 2011). However, this issue varies with waste source, and in the literature results demonstrate that the amount of metals in these residues do not compromise plant growth in fertilized soils (Costa et al., 2005; Bueno et al., 2011).

Another destination of these organic compounds would be using them as substrate for sapling production. Growing plants in alternative substrates have been increasingly used in Brazil and should be low cost and available nearby consumption areas; they must provide sufficient nutrient concentration, good cation exchange capacity, allowing aeration, moisture retention and favor physiological activity of roots (Oliveira et al., 2008). The interest in using these substrates is not justified only on basis of the aforementioned aspects, but also by using materials that when discarded in the environment be polluters. As an example, organic waste, textile sludge and sewage sludge have been used to compose substrates for cultivation of fruit and forest saplings or even as fertilizers added directly to the soil, replacing cattle and chicken manure (Oliveira et al., 2008; Pelissari et al. 2009; Barros et al., 2011; Sampaio et al., 2012). Maize plants fertilized with 50 t ha^{-1} biosolid had greater shoot dry mass and macronutrient concentrations than those with manure (Barros et al., 2011).

Spinning and weaving industry generates as residue, cotton fibers from facility sweepings, coal-trashing residues from wood burning boiler and dirty cotton oakum with oil and grease used in machine maintenance. The first two are considered of low toxicity (Class II) and the latter is classified as hazardous waste (Class I), according to Brazilian standards - NBR 10.004 (ABNT, 2004). Wastes of both classes, I and II, must be treated and allocated to proper facilities for such end. For example, landfills in need of waterproof battings and several layers of protection to prevent soil and water contamination (ABNT, 2004); while in the literature, it was not found such waste recycling studies.

Therefore, this study aimed to evaluate composting efficiency to biodegrade toxic wastes from textile industry and use them as substrate for saplings production.

Material and Methods

Toxic residues, such as dirty cotton rags with oil and grease used to maintain weaving looms, came from industries located in the cities of Diamantina and Gouveia, in Minas Gerais State, Brazil. For waste biodegradation, composting was performed using 2.31 m^3 of the material with 0.78 m^3 of cattle manure. Composting pile was inverted three times per week from its installation, in cone form, up to 90 days; and twice a week up to the end of the process (176 days), when pile temperature dropped to 40 ºC, and compost was sieved in a 15-mm wire-mesh sieve.

Two samples composed of 10 subsamples were used for chemical characterization. Regarding P, K, Ca and Mg concentrations, samples were digested in hydrogen peroxide and sulfuric acid (Tedesco et al., 1995). The concentration of P was determined through spectrophotometer, K by flame photometry and Ca and Mg via atomic absorption spectrophotometer (Tedesco et al., 1995). For Cu, Zn, Cd, Pb, Ni, Cr and Fe, samples were digested in nitric and perchloric acids (Tedesco et al., 1995). The pH was measured in 0.01 M $CaCl_2$ solution (Tedesco et al., 1995). Organic carbon, humic and fulvic acids, inert material and organic matter were determined by methodology proposed by Mendonça & Matos (2005); and concentrations of C, H and N were set by CHNS-O analyzer, from which, the concentrations of C and N were used to calculate C/N ratio.

For biodegradation confirmation of toxic waste by composting, the compost was mixed to the substrate of eucalyptus rooted cuttings production, replacing coconut fiber that is commercially used in forestry companies in the Jequitinhonha Valley, with the following composition: mixture of vermiculite, rice husk and coconut fiber in the 2:1:1 ratio (v/v). This part was used as control and named here as Commercial treatment. The replacement of coconut fiber by the compost was assessed since this vegetal fiber has high cost compared to the other substrates used in eucalypt saplings production in Minas Gerais State. Table 1 shows the evaluated substrates with their respective percentages of waste compost from weaving industry.

All substrates received the following fertilizations: 1 kg m^{-3} single superphosphate (18% P_2O_5); 5 kg m^{-3} 04N-14P-08K; 0.5 kg m^{-3} Osmocote® (3N-11P-38K slow-release, 3 months) and 110 L m^{-3} of micronutrient solution used to fertilize substrates (Table 2).

Substrates were distributed on 55-cm^3 tubes by a vibrating machine aid, which provided about 77-cm^3 substrate per tube (13,000 tubes are filled with 1 m^3 of substrate). Secondly, mini-

Table 1. Evaluated substrates and percentages of each product used in the composition

Substrates	Compost	Vermiculite	Carbonized rice husk	Coconut fiber
	%			
Commercial	0	50	25	25
C-0	0	75	25	0
C-19	19	56	25	0
C-37	37.5	37.5	25	0
C-56	56	19	25	0
C-75	75	0	25	0

Table 2. Micronutrient solution composition of the substrate and fertigation of growth and hardening

Fertilizer	Micronutrient solution for substrate fertilization	Fertigation solutions	
		Growth	Hardening
	mg L^{-1}		
Ferrilene®, 6% Fe [(1)]	391	25.1	25.1
Boric acid, 17% B	182	8.5	8.5
Copper sulfate, 35% Cu	27	1.2	1.2
Manganese sulfate, 30% Mn	227	6.5	6.5
Calcium nitrate, 15.5% N and 19% Ca	---	750	375
Kristalon® - 6-12-36 NPK formula [(2)]	---	1,200	600
Ammonium sulphate, 20,0% N	---	2,650	---
Hepta-hydrated zinc sulfate, 20% Zn	---	0.7	0.7
Sodium molybdate, 39% de Mo	---	0.2	0.2
Potassium chloride, 62% K_2O	---	---	1,250

[(1)] Fe chelate to fertigation produced by ValoAgro; [(2)] manufactured by Yara Brasil Fertilizers

shoot bases of *Eucalyptus urophylla* natural hybrid were dip into indole-butyric acid (IBA) solution at 1,000 μg g^{-1} concentration and then planted. The mini-shoots were obtained from a clonal minigarden that belongs to APERAM - Bioenergia Company, in Itamarandiba, MG, Brazil. Rooted cuttings were grown under greenhouse conditions and kept under intermittent mist irrigation. Irrigation had an interval of 30 min within the first 20 days, and 50 min from the 20th day on. After 15 days, rooted cuttings were manually fertigated by a watering can, each 7 days, using 2 L m^{-2} growth solution (Table 2).

After 30 days, rooted cuttings were transferred to acclimatization platform, in which they remained for 10 days under shading; they were irrigated by sprinkling three times a day at a 20 min interval during 68 days. The rooted cuttings received two manual fertigations using a 2 L m^{-2} watering can with growth solution; and subsequently, three manual fertigations (one per week) with a hardening solution (Table 2).

The experiment was carried out in a nursery of the company in Itamarandiba - MG, Brazil (17° 51' 24" S, 42° 51' 40" W), performed in a completely randomized design with four replications of 78 rooted cuttings per plot, among which 30 were used for evaluations.

Rooted cuttings survival, shoot height (SH), coller diameter (CD) and shoot dry mass were evaluated at 90 days after planting. For survival rate, it was considered the entire plot (78 rooted cuttings). After 90 days, rooted cuttings were cut close to tube edge setting shoots apart from roots. Roots were washed under tap water to remove substrate residue; then, both roots and shoots were dried, up to constant weight, in a forced-air oven at 65 °C, to determine shoot dry mass (SDM) and root dry mass (RDM).

For rooted cuttings quality evaluation, the following indexes were calculated: SH and CD ratio (SH/CD, cm mm^{-1}), SH and SDM ratio (SH/SDM, cm g^{-1}), SDM and RDM ratio (SDM/RDM, g g^{-1}) and Dickson Quality Index (DQI), (Dickson et al., 1960): DQI = (SDM + RDM)/(SH/CD) + (SDM/RDM).

Data were subjected to variance analysis and means were compared by the Duncan test at 0.05 level of probability using SISVAR 5.3 software (Ferreira, 2010).

Results and Dicussion

The pH of compost (Table 3) was greater than what is considered adequate for most nutrients in mineral substrates (Kämpf, 2000), often observed in organic substrates (5.2 to 5.5) and the ideal range (5.5 to 6.5) of substrates for tree saplings (Valeri & Corradini, 2000).

Ca, Mg and K concentrations (Table 3) were respectively 5,275, 4,700 and 650 times higher than the critical levels recommended for eucalypt rooted cuttings production (Barros & Novais, 1999). It is also seen a P concentration well above the critical level, being 73 times higher than the recommended for sandy soils and 98 times for clayey ones (Barros & Novais, 1999). Furthermore, the P concentration (Table 3) was also higher when compared to bovine manure (4,200 mg kg^{-1}) (Costa et al., 2005). These high levels of nutrients in the compost enable its use as a nutrient source; however, their proportion within substrate should be adjusted for rooted cuttings production purpose, to avoid any nutritional imbalance.

N concentration (Table 3) was 1.5 times higher than that observed in organic waste compound (0.92%), which is considered sufficient to supply N for sapling production (Lima et al., 2011). Comparing substrates, N concentrations may vary according to its composition. For substrates composed of sewage sludge, commercial substrate and subsoil, the N concentration varied from 0.7 to 1.01% (Gomes et al., 2013); yet for substrates composed of sewage sludge and carbonized rice husk, it ranged from 1.5 to 2.5% (Rocha et al., 2013). Thus, depending on the ratio of used compounds, it could contribute to all or part of sapling N needs. N concentrations lower than 1.2% favor net immobilization of the nutrient, and concentrations above 1.8% favor net mineralization (Moreira & Siqueira, 2006). However, it was found that N concentration of the compost was not fully mineralized, by analyzing the C/N ratio of 25 (Table 3), since for a high compost maturity degree, reasons below 12 are most considered (Jiménez & Garcia, 1992). This ratio is particularly important for N release, wherein the higher the C/N ratio, the lower the N availability is (Bortolon et al., 2009; Silva et al., 2010). Nonetheless, in eucalypt rooted cuttings production at reduced substrate volumes and frequent irrigation, the N in the substrate components may not be sufficient because it is easily leached. Thus, nitrogen fertilization added to the substrate and by fertigation is required, and that is why it was not observed nitrogen deficiency symptoms in plants for any of the assessed substrates.

Heavy metal concentrations observed in the compost (Table 3), were lower than the maximum limits accepted in various countries (Grossi, 1993; Brasil, 2005). In Brazil, the maximum limits are Cd = 5; Pb = 500; Cu = 500; Cr = 300; Ni = 100; Zn = 1.500 (dag kg^{-1}) (Brasil, 2005).

The compost has an organic mass (Table 3) near to that observed in sewage sludge (43.9 kg dag^{-1}) and greater than compost of solid wastes (16.1 kg dag^{-1}) (Corrêa et al., 2010).

Table 3. Chemical characteristics of compost

pH	Ca	Mg	P	K	Fe	Zn	Cu	Pb	Ni	Cr	CO	U	AH	AF	MI	MO	C	H	N	C/N	D
	cmol$_c$ dm^{-3}		mg dm^{-3}								dag dm^{-3}										g cm^{-3}
7,3	1.055	235	5.900	6.500	2,43	364	176	41	48	47	17	12	2,8	1,6	7,2	27	21	2,8	0,8	25	0,6

OC - Organic carbon; M - Moisture 65 °C; HA - Humic acid; FA - Fulvic acid; IM - Inert material; OM - Organic matter; C = carbon; H - Hydrogen; N - Nitrogen; D - Density, Cd non-detected

For 15 composts of urban waste produced in composting plants of São Paulo city, it was observed a wide range of organic mass from 11.1 to 67.7 kg dag^{-1} (Barreira et al., 2006). Nevertheless, these authors considered that such organic matter does not necessarily guarantee a good agronomic quality to the product or its ability to change soil fertility. Actually, what determines such characteristics are the organic mass composition and stability (Corrêa et al., 2006).

Rooted cuttings survival was influenced by substrates (Figure 1A), being higher in C-0 substrate than in C-37 and C-56, but it did not differ from rooted cuttings grown on Commercial substrate, C-19 and C-75 (Figure 1A).

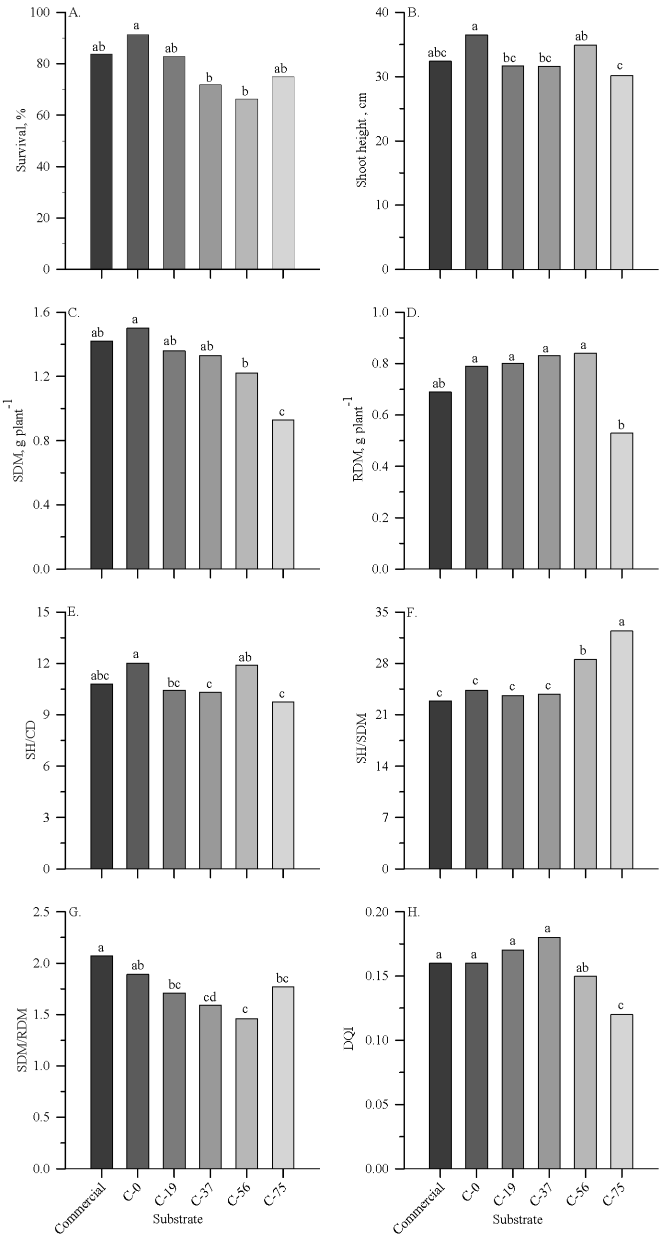
SH was influenced by substrates but CD was not ($P > 0.05$). The mean of CD was 3.0 mm. Rooted cuttings grown in C-0 were higher than those grown in C-19, C-37 and C-75, but they did not differ from rooted cuttings grown in the Commercial and C-56 (Figure 1B).

SDM, RDM, SH/CD, SH/SDM, SDM/RDM and DQI were influenced by substrates ($p < 0.05$). Overall, SDM and RDM of rooted cuttings grown in C-0, C-19, C-37 and C-56 did not differ from the Commercial treatment (Figure 1C and D). Solely, rooted cuttings grown in C-75 had lower values of SDM and RDM than Commercial ones (Figure 1C). SDM tended to decrease when compost proportion was increased in the substrate, oppositely to RDM (Figures 1C and 1D). On the other hand, RDM of rooted cuttings grown in C-75 was an exception to that trend, since it was 32% lower than the average of those grown on other substrates, which also have received the compost and all equal to the RDM of Commercial treatment (Figure 1D).

Survival for rooted cuttings grown in C-19 and C-75 (Figure 1A), SH (Figure 1B) and dry matters (Figures 1C and 1D) in C-19, C-37 and C-56 similar to rooted cuttings grown in Commercial substrate, demonstrated the feasibility of using the compost from textile industry waste in composing substrates of eucalypt rooted cuttings production. These results are consistent with that observed for other composts. In eucalypts rooted cuttings grown in substrates with 60% sewage sludge compost, survival rate was greater than those grown in commercial substrate (Rocha et al., 2013). In *Eucalyptus grandis* seedlings, using 30% bovine manure vermicompost in the substrate increased seedling height relative to the substrate without the vermicompost (Schumacher et al., 2001).

At 90 days, rooted cuttings grown in all substrate mixtures reached height and collar diameter ranges considered ideal for planting in the field, which are 15 to 40 cm height and diameters higher than 2.0 mm (Xavier et al., 2009). In practice, it is observed that not always larger heights point out for best conditions of rooted cuttings development in field, since they can be etiolated or hamper transportation due to their great height. Therefore, it is important that rooted cuttings be hardened, what was visually detected for all rooted cuttings grown in the substrates with added compost.

The trend of SDM reduction with compost proportion increase (Figure 1C), observed in this study, was contrary to that checked on eucalypt rooted cuttings grown in substrates with sewage sludge compost (Rocha et al., 2013). The authors



Substrates composed of dirty cotton cloths with oils and greases, vermiculite, carbonized rice husk and coconut fiber, respectively, Commercial: 0-50-25-25; C-0: 0-75-25-0; C-19: 19-56-25-0; C-37: 37,5-37,5-25-0; C-56: 56-19-25-0 and C-75: 75-0-25-0. Means followed by the same letter do not differ by the Duncan's test at 0.05 level of probability

Figure 1. Survival (A), shoot height - SH (B), shoot dry mass - SDM (C) and root dry mass - RDM (D) and the ratios shoot height/collar diameter - SH/CD (E), SH/SDM (F), SDM/RDM (G) and Dickson quality index - DQI (H) of eucalyptus rooted cuttings grown on different substrates composed of dirty cotton cloths with oils and greases, vermiculite, carbonized rice husk and coconut fiber

observed that both SDM (4.1 g $plant^{-1}$) and RDM (2.8 g $plant^{-1}$) were 80% higher when rooted cuttings were grown in substrates with over 40% sewage sludge compost.

The ratio SH/CD was the highest for C-0, Commercial and C-56 substrates (Figure 1E). Yet SH/SDM ratio was greater for C-75 followed by C-56 and the other substrates (Figure 1F). SDM/RDM ratio was major for rooted cuttings grown in Commercial and C-0 substrates, from which the latter has not differed from those grown in C-19 and C-75 (Figure 1G). The slightest SDM/RDM ratio was seen in rooted cuttings from C-56 substrate. Regarding DQI, the greatest values were found in Commercial, C-0, C-19, C-37 and C-56, even though it was smaller in C-75 (Figure 1H).

The rates SH/CD (Figure 1E) and SH/SDM (Figure 1F) and the Dickson index (Figure 1H) of rooted cuttings grown in substrates with compost, especially in the C-19 and C-37 substrates, such as Commercial reinforce the residue use viability for eucalypt rooted cuttings production. The equal SH/CD ratios in these rooted cuttings (Figure 1E) indicate the same probability of survival in field as those grown in Commercial substrate (Gomes et al., 2002). These authors argued that SH/CD ratio is one of the main parameters to estimate survival shortly after planting. Dickson index has been recommended in rooted cuttings quality evaluation, once within its calculation it is input plant robustness and biomass distribution balance in the rooted cutting; taking into account several important parameters used to assess the quality (Fonseca et al., 2002).

The largest ratio of SH/SDM for the rooted cuttings grown in substrates with higher proportions of compost (C-56 and C-75) (Figure 1F) suggests etiolation, which may reduce rooted cuttings survival in field; however, when using 19 to 37% compost in the substrate, the index was equal to that of Commercial treatment (Figure 1F), indicating that the proportions mentioned above are more adequate than higher ones.

Gradual reduction of SDM/RDM rate with increasing proportions of compost, up to 56% (Figure 1G), showed improved shoot and root proportionality. This characteristic can inhibit shoot water absorption problems, especially after being planted in field (Caldeira et al., 2008). These authors recommended that this ratio is best when a little over one. Thus, rooted cuttings grown in C-19, C-37 and even C-56 (Figure 1G) could also adapt to stressing conditions (nutrition and water) as the Commercial one, or even better, since they have a larger root system to meet plant needs (Pinto et al., 2011).

Although it was demonstrated the feasibility of composting dirty cotton cloths with oil and grease used in machine maintenance of textile industry; legislation would not allow this waste to undergo through a composting process. That is because such waste is considered hazardous (Class II) and should be treated and intended to appropriate facilities for this purpose (ABNT, 2004). As example of Class I wastes (non-hazardous), it can be quoted the sewage sludge, which has mainly been used in substrates for production of rooted cuttings; however, Class II wastes, mentioned above, could also be used for this end.

In this way, the use of composting could be a technique allowed by law, for disposal of dirty cotton rags with oil and grease.

Conclusions

1. Composting is effective to biodegrade dirty cotton rags with oil and grease from weaving loom maintenance.

2. The organic compound of toxic wastes from textile industry is suitable for production of eucalypts rooted cuttings.

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