CULTIVATION OF *Caesalpinia pulcherrima* L. SW. IN REGIONAL SUBSTRATES[1]

Flávia Mélo Moreira[2], Rafaela Simão Abrahão Nóbrega[3*], Ronaldo Pedreira dos Santos[4], Caeline Castor da Silva[5] and Júlio César Azevedo Nóbrega[3]

[1] Received on 19.03.2018 accepted for publication on 28.05.2018.
[2] Universidade Estadual do Sudoeste da Bahia, Programa de Pós-Graduação em Agronomia, Cruz das Alma, BA-Brasil. E-mail: <fmmoreira_ef@yahoo.com.br>.
[3] Universidade Federal do Recôncavo da Bahia, Centro de Ciências Agrárias, Cruz das Almas, BA-Brasil. E-mail: <rafaela.nobrega@gmail.com> and <jcanobrega@gmail.com> .
[4] Instituto Federal de Educação, Ciência e Tecnologia Baiano, Catu, BA-Brasil. E-mail: <ronaldopedreira@gmail.com>.
[5] Universidade Federal do Recôncavo da Bahia, Graduanda em Agronomia, Cruz das Alma, BA-Brasil. E-mail: <kaeline01@hotmail.com>.
*Corresponding author.

ABSTRACT – The objective of the present research was to evaluate different types and proportions of organic wates and soil classes for substrate formulation for *Caesalpinia pulcherrima* cultivation. The experiment was performed in a greenhouse, and treatments were composed by two soil classes (Oxisol and Entisols), three types of residues (organic compound from pruning + manure, urban waste compost and residue from the extraction of *Agave sisalana* fibers) and five residue:soil proportions (0:100, 20:80, 40:60, 60:40, 80:20, v/v). Plant height, stem diameter, number of leaves, rates of a, b and total chlorophyll, leaf area, root length, shoots and roots dry weight and the Dickson Quality Index were evaluated 90 days after sowing. All three types of residues evaluated showed potential to be used in the elaboration of growth substrates for the production of *C. pulcherrima* L. Sw. seedlings. The substrates formulated with 33%, 23% or 5% of organic tree pruning + animal manure, urban waste compost and residue of the *Agave sisalana* fiber extraction, respectively, promoted better quality of seedlings 90 days after sowing, regardless of the soil class.

Keywords: Seedling quality, Agave sisalana fiber extraction residue, Chlorophyll index.

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RESUMO –Objetivou-se avaliar tipos e proporções de resíduos orgânicos e classes de solo para formulação de substrato para cultivo de ***Caesalpinia pulcherrima****. O experimento foi conduzido em casa de vegetação, sendo os tratamentos arranjados e constituídos por duas classes de solo (Latossolo e Neossolo), três tipos de resíduos (composto orgânico de poda + esterco animal, composto de lixo urbano e resíduo da extração de fibras de* ***Agave sisalana****) e cinco proporções resíduo:solo (0:100, 20:80, 40:60, 60:40, 80:20, v/v). Após 90 dias da semeadura, foram realizadas as seguintes avaliações: altura, diâmetro, número de folhas, índices de clorofila a, b e total, área foliar, comprimento radicular, massa seca das partes aérea e raiz e suas relações, e o Índice de Qualidade de Dickson. Os resíduos orgânicos, composto orgânico de poda de árvores + esterco animal, composto de lixo urbano e resíduo da extração de fibras de* ***Agave sisalana*** *apresentaram potencial para serem utilizados na elaboração de substratos de cultivo para a produção de mudas de* ***C. pulcherrima*** *L. Sw. Os substratos formulados com 33%, 23% ou 5% de composto orgânico de poda de árvores + esterco animal ou composto de lixo urbano ou resíduo da extração de fibras de* ***Agave sisalana****, respectivamente, promoveram melhor qualidade das mudas aos 90 dias após a semeadura, independente da classe de solo.*

Palavras-Chave: Qualidade de mudas, Resíduo da extração de fibras de ***Agave sisalana****, Índice de clorofila.*

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1.INTRODUCTION

Quality of seedlings is a key issue in the establishment of plant stands for conservation or commercial purposes, whose success depends on prior knowledge on the species to be implanted, its self-ecology, habitat, nutritional and water requirements, among others. The *Caesalpinia pulcherrima* L. Swartz, for example, is a legume widely used in urban afforestation (Pires et al., 2010); however, there are few studies on its growth in the nursery. In the early stages of its development, it is important to notice that this species is very responsive to some types of substrates, such as sand, vermiculite (Alves et al., 2017), subsoil (Moreira, 2016), pure humus and humus + sand (Sousa et al., 2014).

The morpho-physiological quality of the seedlings is related to water, air and nutrients availability on the substrates, in order to guarantee survival and growth in the field (Atta et al., 2015). The use of natural soil, sand or a mixture of these as substrate components are often used because they are cheap and easy to acquire. However, these materials may have insufficient properties for seedling development. In general, looking for low-cost components, available near the consumption area, easy to transport, rich in nutrients, well structured, to provide conditions for plant germination and root development, reducing the cultivation time, input consumption, which may reduce the dependence of forest activity on commercial substrates.

In some areas of the Semiarid and of the Recôncavo Bahiano, large quantities of agricultural and urban wastes are produced. With the objective to reduce such wastes, it is proposed that manure + tree pruning, urban waste compost and residues from the extraction of sisal (*Agave sisalana*) fibers, may be used for growing forest seedlings, adding value to these materials with low commercial value. Some authors have already emphasized the benefits of organic compost from bovine or goat manure in the production of *Tabebuia aurea* (Manso) seedlings (Freire et al., 2015), *Spondias tuberosa* rootstocks (Medeiros et al., 2015), *Anadenanthera macrocarpa* (Benth.) (Silva do Ó et al., 2015). Silva et al. (2014) while evaluating the initial growth of *Eucalyptus grandis* in different alternative substrates concluded that the urban waste compost, whether pure or in mixture with commercial substrate, has great potential for seedling production of this species, as well as in a proportion of 54.7:45.3 (urban waste compost:Distroferric Red Oxisol) for *Trema micrantha* (L.) Blumes (Nóbrega et al., 2010). Studies concerning the use of residues of the extraction of sisal fiber to produce tree seedlings substrates are unusual, and most of them focus only on vegetal growing subjects (Silva et al., 2015). The benefits of growing tree seedlings on substrates formulated with organic residues depend on the quality of the residues and the nutritional requirements of the species. Thus, we aimed to evaluate different types and proportions of organic wastes and soil classes for substrate formulation for *Caesalpinia pulcherrima* cultivation.

2.MATERIALAND METHODS

The experiment performed in a greenhouse at the Center for Agrarian, Environmental and Biological Sciences of the Federal University of Recôncavo da Bahia (UFRB), located in the municipality of Cruz das Almas - BA, at 39º06'26" south latitude and 12º40'39' west longitude coordinates and 225m of altitude. According to Köoppen and Geiger the climate corresponds to the Af type; with average temperature of 23ºC and average of 1.136 mm annual rainfall. During the experiment, the greenhouse temperature varied from 25.2ºC to 30.4°C with mean temperature of 28.0°C.

The treatments were set in a completely random design in a factorial scheme (2 x 3 x 5), with eight replicates. These were composed of two classes of soil [Dystrophic Yellow Oxisol (LAd) and Entisols Quartzipsamments (RQ)] and three organic residues [COP (organic compound of tree pruning + bovine an goat manure), CLU (organic urban waste compost), RES (*Agave sisalana* fiber extraction residue)], combined in five residue: soil proportions (0:100, 20:80, 40:60, 60:40, 80:20, v/v).

To formulate the respective cultivation substrates, the organic compound of tree pruning + bovine an goat manure (COP) was derived of the compost pile contain 15 cm of trees and grasses pruning residue and five centimeters of bovine and porcine manure and goat + correctives and fertilizers. The piles were irrigated on alternate days and turned over every 15 days for three months in the field. The organic urban waste compost (CLU) was derived of the compost pile contain three handcarts of residues from pruned trees and grasses and one of organic household wastes. The piles were irrigated every day with slurry from the decomposition of other piles, and turned over every seven days for three months in the field. The sisal fiber extraction residue (RES) was accumulated in piles without any management.

Soils from the sub-superficial horizon (> 40 cm of depth) were collected in two soil classes, the LAd collected in UFRB and the RQ collected in Entre Rios-BA. Lad contains 535, 281 and 181 g kg^{-1} of sand, silt and clay, respectively; moisture at -10kPa, 0.114 m^3 m^{-3}, and -33kPa 0.111 m^3 m^{-3}. Concerning soil nutrition, LAd contains pH_{H2O} 5.2 and pH_{CaCl2} 4.5, contents P available - 11.2 mg dm^{-3}, K^+ - 0.19 $cmol_c$ dm^{-3}, Ca^{2+} - 0.8 $cmol_c$ dm^{-3}; Mg^{2+} - 0.4 $cmol_c$ dm^{-3}; Al^{3+} - 0.3 $cmol_c$ dm^{-3}; H+Al – 2.6 $cmol_c$ dm^{-3} and organic matter 14.4 g kg^{-1}. RQ contains 922, 47 and 31 g kg^{-1} of sand, silt and clay, respectively; moisture at -10kPa, 0.018 m^3 m^{-3}, e a -33kPa 0.019 m^3 m^{-3}; pH_{H2O} - 5.5 and pH_{CaCl2} - 4.8, contents of P available 12.1 mg dm^{-3}, K^+ - 0.0 $cmol_c$ dm^{-3}, Ca^{2+} - 0.0 $cmol_c$ dm^{-3}; Mg^{2+} - 0.0 $cmol_c$ dm^{-3}; Al^{3+} 0.2 $cmol_c$ dm^{-3}; H+Al 0.7 $cmol_c$ dm^{-3} e organic matter <3.5 g kg^{-1}. The characterization of the soil and the residues were accomplished at the Soil Science Laboratory of the University of São Paulo - ESALQ (Table 1) and the physical characterization was completed at the Laboratory of Soil Physics at the Federal University of Recôncavo da Bahia.

The soil and the residues were air dried under natural conditions before being sieved trough a 5 mm mesh sieve, homogenized according to the treatments and distributed in polyethylene bags with 0.12 x 0.23 m and 1.2 dm^{-3} capacity. Regarding the potential risks to the environment, the wastes used are classified under Class II A - Non inert waste, according to NBR 10.004 – 2004 Solid Residues Standards from ABNT. Plants of *C. pulcherrima* were grown on the described substrates by sowing. The seeds were collected from matrices found in the UFRB *Campus* in Cruz das Almas, immersed in 2% sodium hypochlorite solution for 10 minutes (Souza et al., 2013), washed in water; five seeds were sowed into each polyethylene bag. Manual irrigation was performed on alternate days simulating conditions of commercial nurseries.

Thinning was completed, leaving only the most vigorous plant occupying the central position on the bag 30 days after sowing. Ninethy days after sowing the following variables were evaluated: plant height (cm $plant^{-1}$) from the base to the apical bud (H), stem diameter (mm $plant^{-1}$) at 1.0 cm from the soil (D), total

Table 1 – Chemical and physical characterization of residues COP (organic compound of tree pruning + bovine an goat manure), CLU (organic urban waste compost) and RES (*Agave sisalana* fiber extraction residue), used in the production of organic substrates.

Tabela 1 – *Caracterização química e física dos resíduos COP (composto orgânico de poda + esterco bovino), CLU (composto de lixo urbano) e RES (resíduo da extração de fibras de* ***Agave sisalana****), utilizados na composição de substratos orgânicos.*

Chemical and physical attributes	COP		CLU		RES	
	Dry	Moist	Dry	Moist	Dry	Moist
pH (H_2O)[1]	-	7.0	-	7.4	-	9.6
pH ($CaCl_2$ 0.01 M)	-	6.4	-	6.7	-	8.7
Density (g cm^{-3})	-	1.00	-	0.74	-	0.20
Moisture at 60 - 65°C (%)	-	12.03	-	16.55	-	41.53
Moisture at 110°C (%)	-	0.69	-	2.36	-	3.53
Organic Matter (combustion) (%)	12.10	10.64	22.25	18.57	54.23	31.71
Organic Carbon (%)	5.99	5.27	11.05	9.22	28.34	16.57
Total mineral residue (T.M.R.) (%)	87.12	76.64	74.92	62.52	39.75	23.24
Nitrogen total (NT) (%)	0.70	0.62	2.12	1.77	2.51	1.47
Phosphorus (P_2O_5) total (%)	0.23	0.20	0.86	0.72	3.51	2.05
Potassium (K_2O) total (%)	0.25	0.22	0.32	0.27	1.27	0.74
Calcium (Ca) total (%)	0.57	0.50	1.76	1.47	8.50	4.97
Magnesium (Mg) total (%)	0.13	0.11	0.14	0.12	1.68	0.98
Sulfur (S) total (%)	0.02	0.02	0.25	0.21	0.19	0.11
C/N ratio	-	9	-	5	-	11
Copper (Cu) (mg kg^{-1})	15	13	20	17	92	54
Manganese (Mn) (mg kg^{-1})	127	112	97	81	137	80
Zinc (Zn) (mg kg^{-1})	35	31	53	44	109	64
Boron (B) (mg kg^{-1})	234	206	14	12	17	10
Sodium (Na) (mg kg^{-1})	824	725	2214	1848	414	242

[1]The values of $pH_{(CACl2)}$ were estimated by the equation: $pH_{(CaCl2)} = 0.12+0.89\ pH_{(H2O)}$.

number of leaves (leaves plant^{-1}) (NL), *a* (CLA), *b* (CLB) and total (*a* + *b*) (CLT) chlorophyll indexes in leaves from the lower, medium and upper third portion of the plant, leaf area (cm^2 plant^{-1}) (LA) and root length (cm plant^{-1}) (RL). The quantification of chlorophyll index was expressed in dimensionless units (Falker, 2008). Subsequently, the plants were washed and sectioned in aerial portion and roots, dried in forced air circulating oven at a temperature of 60°C to determine biomass distribution over the plant part, such as dry weight of the aerial part (DMAP) and of the roots (DMR) and their ratios, H/DMAP, DMR/DMAP, DQI (Dickson Quality Index) (Dickson et al., 1960).

Data were subjected to variance analysis and multiple mean comparisons using the Tukey test at the 5% probability and polynomial regression analysis of the variables, depending on the proportions of organic residue:soil, using the statistical software SISVAR (Ferreira, 2014).

3.RESULTS

Seedlings of *Caesalpinia pulcherrima* were influenced ($p<0.05$) by treatments with different soil classes, types and organic residues proportions at 90 days after sowing (Table 2).

We observed a double interaction ($p<0.01$) between the proportions of residue:soil (Table 2) and between residue type and proportions of residue:soil for plant height (H) (Figure 1B). As regards to soil classes, the seedlings cultivated in Lad and RQ obtained the maximum estimated averages of 11.2 and 10.5 cm plant^{-1} for proportions of 0:100 and 22:88 (residue:soil), respectively (Figure 1A). Regarding the residue types, the maximum values observed were 11 cm plant^{-1} for H of the seedlings in substrate with COP in the ratio 20.4:79.6 (residue:soil). However, the substrates containing RES and CLU, the higher values for H was recorded in the ratio 0:100 (residue: soil) (Figure 1B).

Table 2 – Mean square for height (H). diameter (D), height/diameter ratio (H/D), number of leaves (NL), leaf area (LA), chlorophyll *a* (CLA), chlorophyll *b* (CLB), total chlorophyll (CLT), root length (RL), dry weight of the aerial part (DMAP), dry weight of roots (DMR), ratio of dry weight of roots/dry weight of the aerial part (DMR/DMAP), height/dry weight of the aerial part ratio (H/DMAP), Dickson Quality Index (DQI) of *Caesalpinia pulcherrima* L. Sw. seedlings 90 days after sowing, grown on substrates composed by different soil classes, types of organic residues and residue:soil proportions.

Table 2 – *Quadrado médio para a altura (H), diâmetro (D), relação altura/diâmetro (H/D), número de folhas (NL), área foliar (LA), clorofila a (CLA), clorofila b (CLB), total de clorofila total (CLT), comprimento da raiz (RL), massa seca da parte aérea (DMAP), massa seca das raízes (DMR), massa seca das raízes/massa seca da parte aérea (DMR/DMAP), altura/massa seca da parte aérea (H/DMAP), Índice de Qualidade de Dickson (DQI) de mudas de* ***Caesalpinia pulcherrima*** *L. Sw. aos 90 dias após a semeadura, cultivadas em substratos compostos por diferentes classes de solo, tipos de resíduos orgânicos e proporções de resíduo:solo.*

S.V.	D.F	Mean squares						
		H	D	H/D	NL	LA	CLA	CLB
Soil (S)	1	15.03**	0.00^{ns}	292.65**	21.85**	7.91*	465.43**	137.79**
Residue (R)	2	19.14**	0.01**	465.79**	10.19**	13.39**	351.17**	28.09**
Proportion(P)	4	35.22**	0.03**	610.66**	19.81**	13.72**	282.03**	27.58**
S x R	2	1.79^{ns}	0.00^{ns}	19.71^{ns}	0.26^{ns}	1.22^{ns}	161.34**	39.70**
S x P	4	4.01**	0.00^{ns}	41.42^{ns}	1.40*	4.16*	64.62**	21.06**
R x P	8	3.23**	0.00**	84.65**	2.27**	5.05**	51.79**	9.356**
S x R x P	8	1.85^{ns}	0.00^{ns}	43.57^{ns}	0.54^{ns}	0.77^{ns}	19.17^{ns}	5.91*
CV (%)		10.80	13.02	14.79	21.03	27.51	22.97	33.15
S.V.	D.F.	Mean squares						
		CLT	RL	DMAP	DMR	DMR/DMAP	H/DMAP	DQI
Soil (S)	1	1109.92**	36.54^{ns}	0.01^{ns}	0.05*	0.06^{ns}	0.53^{ns}	0.00^{ns}
Residue (R)	2	577.57**	1259.48**	0.12**	0.44**	0.63**	1.92*	0.03**
Proportion(P)	4	485.81**	2327.84**	0.52**	0.76**	1.36**	14.14**	0.12**
S x R	2	348.38**	24.84^{ns}	0.01^{ns}	0.03*	0.03^{ns}	0.23^{ns}	0.01^{ns}
S x P	4	153.80**	168.92**	0.01^{ns}	0.02^{ns}	0.04*	0.19^{ns}	0.00^{ns}
R x P	8	100.55**	136.07**	0.06**	0.08**	0.10**	1.30**	0.01**
S x R x P	8	42.97^{ns}	51.51**	0.00^{ns}	0.01^{ns}	0.01^{ns}	0.10^{ns}	0.00^{ns}
CV (%)		21.88	22.15	14.25	19.01	16.07	10.77	11.84

S.V.: Source of Variation; D.F.: Degree of freedom; CV: Coefficient of variation; ^{ns}non-significant; *. ** Significant at 0.05 and 0.01 probability levels, respectively, by the F test.

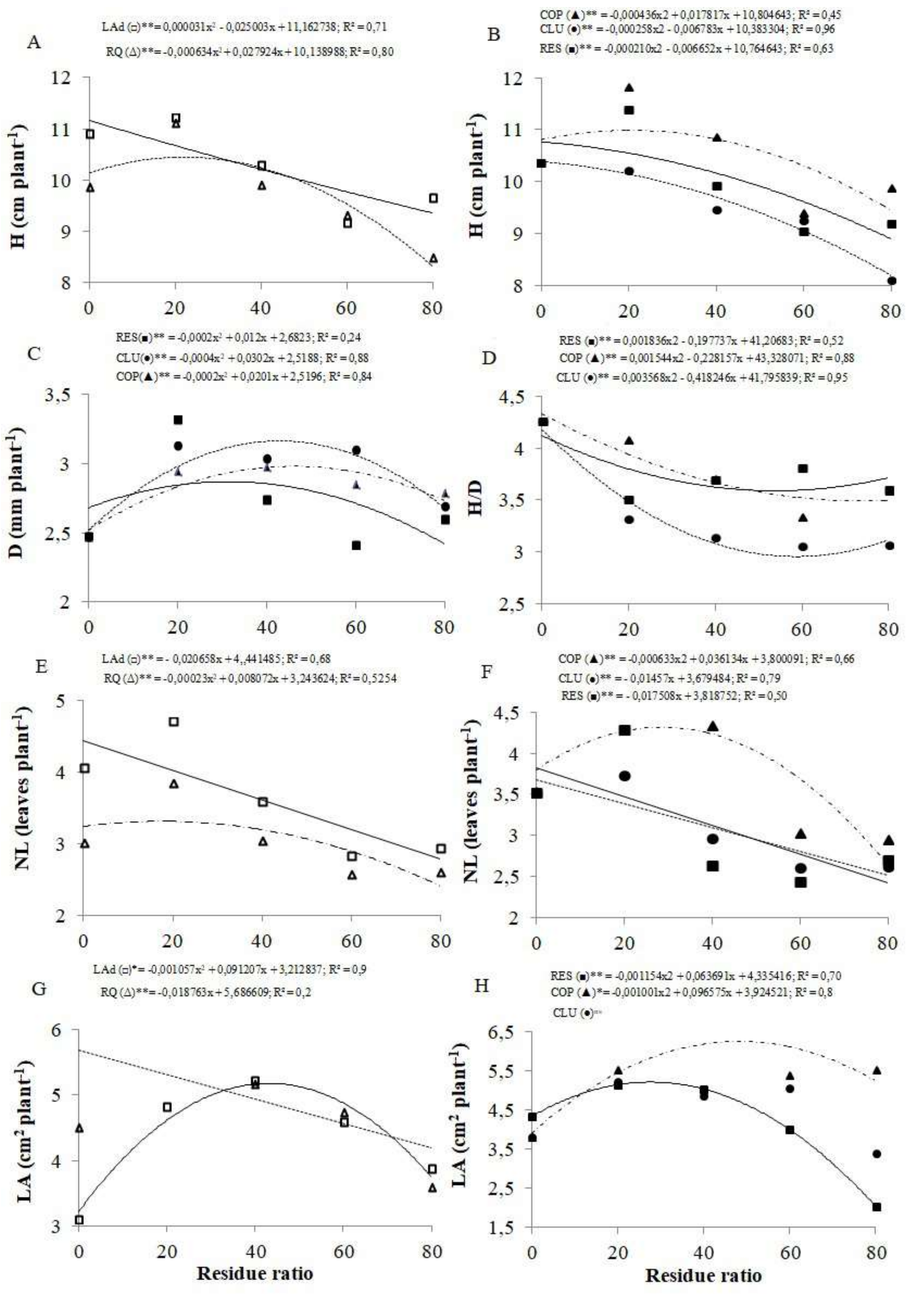

Figure 1 – Height (H) (A, B), diameter (D) (C), height/diameter ratio (H/D) (D) number of leaves (NL), (E. F) and leaf area (LA) (G. H) of *Caesalpinia pulcherrima* L. Sw. seedlings, 90 days after sowing, according to the soil classes [LAd (Yellow Oxisol) and RQ (Entisols)] and types of organic waste: [COP (organic compound of tree pruning + bovine an goat manure), CLU (organic urban waste compost), RES (sisal fiber extraction residue)] and ratios of residue:soil (0:100, 20:80, 40:60, 60:40, 80:20; v/v).

Figura 1 *– Altura (H) (A,B), diâmetro (D) (C), altura/diâmetro (H/D) (D), número de folhas (NF) (E,F) e área foliar (LA) (G, H) de mudas de **Caesalpinia pulcherrima** L. Sw., aos 90 dias pós semeadura, em função de classes de classes de solo [LAd (Latossolo Amarelo Distrófico) e RQ (Neossolo Quartzarênico], tipos de resíduos orgânicos [COP (composto orgânico de poda), CLU (composto de lixo urbano), RES (resíduo da extração de fibra de sisal)] e proporção resíduo:solo (0:100, 20:80, 40:60, 60:40, 80:20, v/v).*

Double and linear interaction ($p<0.01$) between types of organic residues and proportions was verified for plants' stem diameter (Table 2). All organic residues (CLU, COP and RES) increase the stem diameter of plants (3.08, 3.02, 2.86 mm plant^{-1}) at proportions of 37.75:62.25, 50.25:49.75, 30:70 (residue:soil; v/v), respectively (Figure 1C). For H/D, there was a double and quadratic interaction ($p<0.01$) between the type of organic residues and residue:soil proportions (Table 2). All organic residues (CLU, COP and RES) reduced the mean values H/D (2.97, 3.5 and 3.7) at proportions of 62:38, 80:20, 39:61 (residue:soil), respectively (Figure 1D).

Double interactions ($p<0.05$) between soil class and residue:soil proportions and ($p<0.01$) between type of organic waste and residue:soil proportions were significant for NL (Table 2). Among the soil classes, plants grown in LAd (0:100, v/v) showed 26% more NL (4.3 leaves plant^{-1}) than those grown in RQ (3.2 leaves plant^{-1}) with organic residue (18:82; v/v) (Figure 1E). The seedlings cultivated with substrates composed of COP produced the maximum estimated NL of 4.3 leaves plant^{-1} at proportion of 29:71 (v/v) residue:soil. Plants cultivated in the presence of residues CLU and RES showed similar behavior, linear and decreasing when adding residue (Figure 1F).

There were double interactions ($p<0.05$) between soil class and residue:soil proportion and ($p<0.01$) between type of organic residues and residue:soil proportion for seedlings' LA (Table 2). Considering the soil classes, the RQ resulted higher LA (5.68 cm^2 plant^{-1}) at a proportion of 0:100 (residue:soil; v/v), while in plants cultivated in LAd with organic residue the maximum estimated LA was of 5.18 cm^2 plant^{-1} in the substrate composed of 43:57 (residue:soil; v/v) (Figure 1G). With the addition of COP, estimated proportion of 48:52 (residue:soil; v/v), the maximum LA of the plants was 6.05 cm^2 plant^{-1}. When applying RES, in an estimated proportion of 28:72 (residue: soil; v/v) there was a maximum LA of 5.21 cm^2 plant^{-1} (Figure 1H).

There was a double interaction between soil class and type of organic residue ($p<0.01$), between soil class and residue: soil proportion ($p<0.01$) and between the type of organic residue and residue:soil proportion ($p<0.01$) for the contents of CLA (Table 2). Plants cultivated on soil substrates, 0:100 (residue:soil; v/v) showed higher CLA, with LAd (18.83) being the most important (Figure 2A). While the addition of organic residue to the cultivation substrate negatively influenced the CLA in plants (Figure 2B).

For CLB there was triple interaction ($p<0.05$) between soil class, organic residue type and residue:soil proportion (Table 2). Plants grown on substrate prepared with COP and LAd had maximum CLB (8.45) for an estimated proportion of 15:85 (residue:soil; v/v). On the other hand, those grown on substrates made with CLU and RQ shad a maximum estimated CLB of 4.62, in the proportion 80:20 (residue:soil; v/v). The other substrate formulations reduced CLB averages (Figure 2C). Double interactions between soil class and type of organic residue ($p<0.01$) and between soil class and soil:residue proportions ($p<0.01$) and between residue type and residue:soil proportion ($p<0.01$) (Table 2) were determined for CLT. In general, the CLT indexes showed a behavior similar to that of CLA. Plants cultivated in substrate consisting of soil only, 0:100 (residue: soil; v/v) showed higher CLT indexes than those grown on substrate with organic residue, with LAd of 24.49 CLT in leaves (Figure 2D, E).

Triple interaction ($p<0.01$) between soil class, type of organic residue and residue:soil proportion was evidenced for seedling's CR (Table 2). Seedlings grown on substrates elaborated with COP and LAd showed maximum RL of 28 cm plant^{-1}, for the estimated proportion of 12:88 (residue:soil; v/v). The other substrate formulations with addition of residue did not show positive responses for RL. The highest averages were observed on substrates consisting only of soil, 0:100 (residue:soil, v/v) (Figure 2F).

Double interactions ($p<0.01$) between the type of organic residue and residue:soil proportion were assessed for DMAP, DMR, DMR/DMAP, H/DMAP and DCI (Table 2). The addition of RES at an estimated ratio of 27:73 (residue:soil; v/v) resulted in maximum DMAP of 0.54 g plant^{-1}, this represents an increment of 15% in weight compared to seedlings grown in substrate with 0:100 (residue:soil; v/v). All other substrates showed a decrease of DMAP, proportional to the residue's implementation to the soil (Figure 3A). Regarding DMR, plants grown in substrate elaborated with the COP at a ratio of 21:79 (residue:soil; v/v) showed higher yield (0.49 g plant^{-1}), 10% more than those grown in only soil (0,44 g plant^{-1}). Concerning to all other residues, its application resulted in a decrease of DMR (Figure 3B). As regards the DMR/DMAP ratio, the addition of organic residue to the cultivation substrate reduced this ratio in the seedlings, both in LAd and in RQ (Figure 3C). The substrate constituted by soil only, 0:100 (residue:soil; v/v) provided a better balance between DMR/DMAP weights near 1 (Figure 3D).

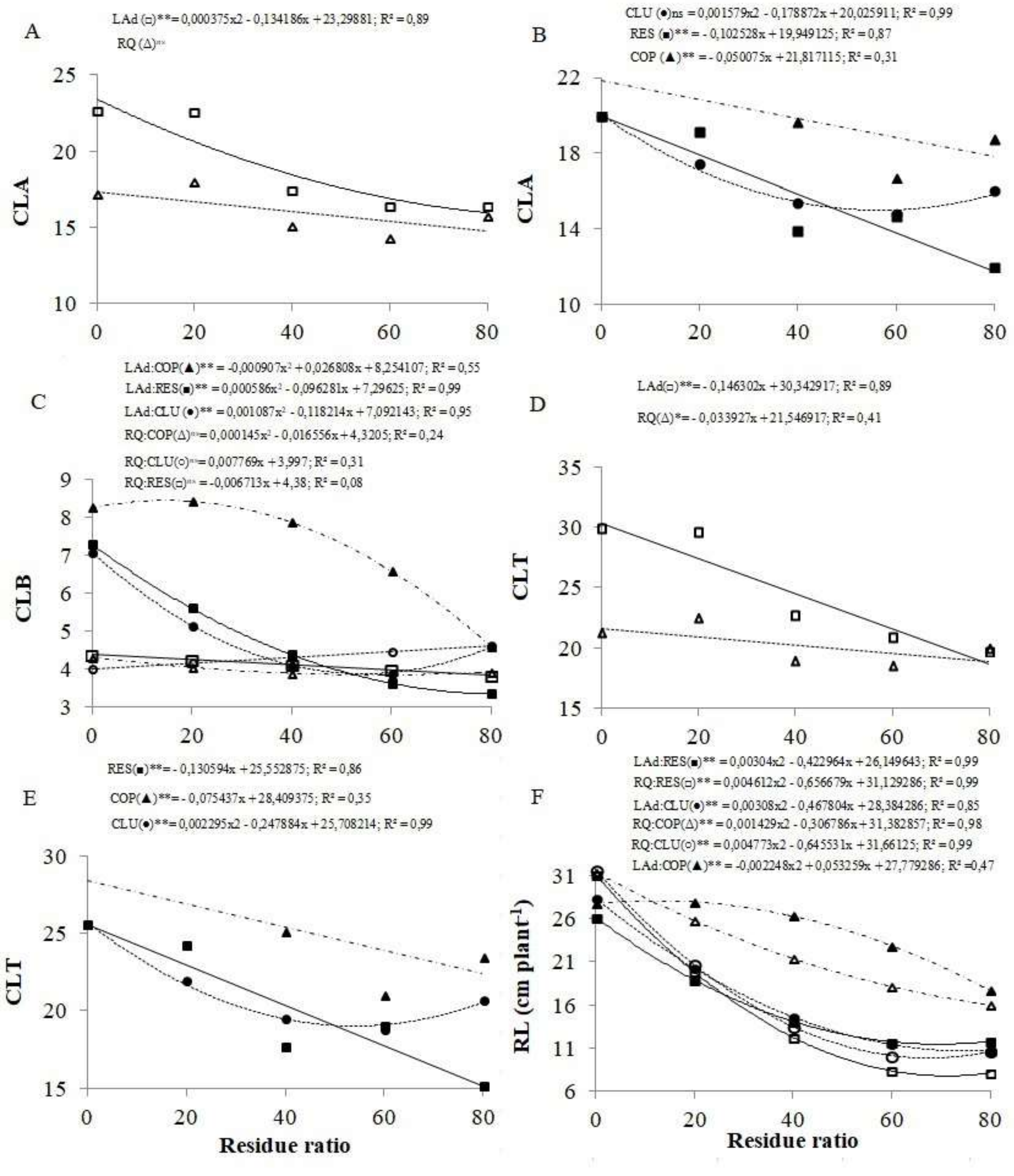

Figure 2 – Chlorophyll *a* index (CLA) (A. B), chlorophyll *b* index (CLB) (C) and chlorophyll total (CLT) index (D, E) and root length (RL) (F) of *Caesalpinia pulcherrima* L. Sw. seedlings, 90 days after sowing, according to the soil classes [LAd (Yellow Oxisol) and RQ (Entisols)] and types of organic waste: [COP (organic compound of tree pruning + bovine an goat manure). CLU (organic urban waste compost). RES (sisal fiber extraction residue)] and ratios of residue:soil (0:100. 20:80. 40:60. 60:40. 80:20. v/v).

Figura 2 – *Índice de clorofila a (CLA) (A, B), índice de clorofila b (CLB) (C) e total (CLT) (D, E) e comprimento radicular (RL) (F) em mudas de* ***Caesalpinia pulcherrima*** *L. Sw., aos 90 dias pós semeadura, em função de classes de classes de solo [LAd (Latossolo Amarelo Distrófico) e RQ (Neossolo Quartzarênico], tipos [COP (composto orgânico de poda), CLU (composto de lixo urbano), RES (resíduo da extração de fibra de sisal)] e proporção resíduo:solo (0:100, 20:80, 40:60, 60:40, 80:20, v/v).*

Another relationship influenced by the use of organic residue was H/DMAP. The addition of COP, RES and CLU resulted in decreases of H/DMAP, of 2.1, 2.4 and 2.5 for estimated ratios of 42:58, 31:69, 38:62 (residue:soil; v/v), respectively (Figure 3E). In relation to DQI, the plants showed higher values when grown in substrate prepared with organic residue (Figure 3F). All organic residues COP, CLU and RES provided maximum DQI of seedlings, 12% (0.44), 3% (0.38) and 1% (0.4) for the estimated proportions of 33:67, 23:77, 5:95 (residue:soil; v/v), respectively, when compared to the substrate constituted by soil only, 0:100 (residue:soil; v/v) (Figure 3F).

4.DISCUSSION

Good quality forest seedlings can be obtained using growth substrates fromulated with soil and organic residues. In legumes the response for plants has been varied ranging for substrates formulated with ratios of approximately 50:50 soil:residue. Species such as *Leucaena leucocephala* (Lam.) and *Sesbania virgata* showed better quality seedlings when grown on substrates composed by organic compost from tree prunings and animal manure, in proportions of 50:50 and 80:20 (organic compound:soil), respectively (Sousa et al., 2015; Amaral et al., 2016). As well as *Enterolobium contortisiliquum* grown on substrates made by urban waste compost at proportions of 80:20 (compound: soil) (Nóbrega et al., 2008). Thus, the types and proportions of organic residues used in the cultivation substrate formulation should be evaluated to meet the nutritional requirements of a determined species to simplify the cultivation of such species, especially to meet production demands from municipalities, schools and rural associations.

The addition of organic residues to the culture substrate promoted an increase of the growth variables evaluated and specially of the Dickson Quality Index, when compared to the substrate consisting of soil only in *Caesalpinia pulcherrima* L. Sw. Plant responses varied according to the type and proportion of organic residue and also to the soil class used for the preparation of the cultivation substrate. The highest averages were obtained with the substrates made with COP among all evaluated residues. This material made from tree pruning is promising for urban afforestation programs in municipalities that use composting as a method for production of organic fertilizers and also as bioremediation of organic wastes.

The organic pruning compound, which has the appearance of coffee powder, shows neutral pH, higher density, lower humidity, contains organic matter, as well as macronutrients such as nitrogen, phosphorus, potassium, calcium, magnesium and sulfur and micronutrients such as copper and higher concentration of manganese and boron. According to the chemical and physical characterization of the residues (Table 1), the *Agave sisalana* fiber extraction residue is essentially fibrous, presenting alkaline pH, lower density, higher humidity, higher organic matter content, macronutrients such as phosphorus, potassium, calcium; micronutrients such as copper, zinc, and lower sodium content compared to other residues. The urban waste compost has intermediate chemical and physical attributes when compared to the organic pruning compound and to the residue of *Agave sisalana* fiber extraction. According to the legislation (Brasil, 2009), organic fertilizers must contain a nutrient content of at least N+P+K > 10% and Ca+Mg+S > 5%, all residues evaluated in the present work have low levels of macronutrients. However, they contain satisfactory levels of micronutrients (B>0.03; Cu>0.05; Mn>0.05; Zn>0.1%) and organic carbon (TOC>3%) (Table 1).

Organic materials have the potential to improve the physical and chemical attributes of substrates, these being the main factors that directly interfere in the development of the root and aerial system of the seedlings and, consequently, seedling quality (Delarmelina et al., 2013). The organic pruning compound mixed with the Oxisol proportioned plants a higher root length. This residue excels among the others regarding the effect of treatments on plant growth. It provided increase in plant height, diameter, number of leaves, leaf area, chlorophyll indices, dry mass of roots and DQI. The benefits of the organic pruning compound + animal manure are associated with the balanced nutrient increment provided by this residue to the growing substrate to a maximum ratio of 40:60 (residue: soil; v/v). As well as to the potential for water retention and distribution over a longer period, since in the seed germination of this species'seeds such behavior was already verified (Moreira, 2016).

Different authors have reported the positive effect of organic compost from tree pruning and bovine manure on *Sesbania virgata* (Souza et al., 2015), *Tabebuia aurea* (Freire et al., 2015), under controlled conditions. The organic residues, from urban waste and residue from *Agave sisalana* fiber extraction, when mixed with the soil, also provided an increase in growth of *C.*

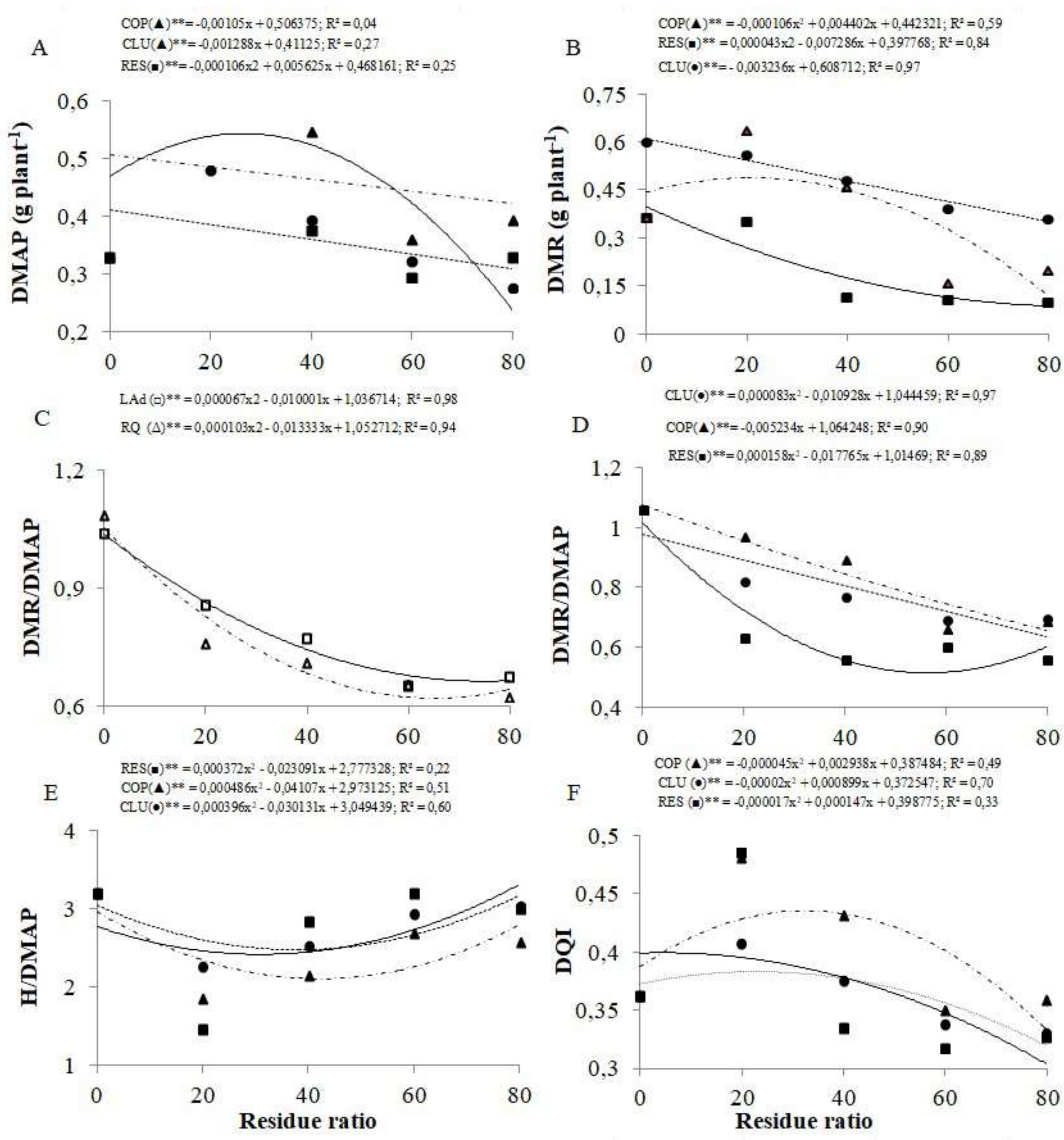

Figure 3 – Dry weight of the aerial part (DMAP) (A), dry weight of the roots (DMR) (B), dry weight of the roots/dry weight of the aerial part ratio (DMR/DMAP) (C. D), height/dry weight of the aerial part ratio (H/DMAP) (E) and Dickson Quality Index (DQI) (F) of *Caesalpinia pulcherrima* L. Sw. seedlings, 90 days after sowing, according to the soil classes [LAd (Yellow Oxisol) and RQ (Entisols)] and types of organic waste: [COP (organic compound of tree pruning + bovine an goat manure), CLU (organic urban waste compost). RES (sisal fiber extraction residue)] and residue:soil ratios (0:100. 20:80. 40:60. 60:40. 80:20; v/v).

Figura 3 *– Massa seca da parte aérea (MSPA) (A), de raízes (MSR) (B), relação entre massa seca de raízes e massa seca da parte aérea (MSR/MSPA) (C, D), relação entre altura e massa seca da parte (H/MSPA) (E) e Índice de Qualidade de Dickson (IQD) (F) de mudas de* ***Caesalpinia pulcherrima*** *L. Sw., aos 90 dias pós semeadura, em função de classes de classes de solo [LAd (Latossolo Amarelo Distrófico) e RQ (Neossolo Quartzarênico], tipos de resíduos orgânicos [COP (composto orgânico de poda), CLU (composto de lixo urbano), RES (resíduo da extração de fibra de sisal)] e proporção resíduo:solo (0:100, 20:80, 40:60, 60:40, 80:20, v/v).*

pulcherrima plants, however, in lower rates. This fact is related to the characteristics of each residue, as previously described. Other tree species responsive to the urban waste compost are *Eucalyptus grandis* and *Trema micrantha* (L.), cultivated in a mixture of compost and commercial substrate in a ratio of 1:1 (v/v) and 55% of composts and 45% of Dystrophic Red Oxisol (Nóbrega et al., 2010; Silva et al., 2014).

Silva and Stein (2008) recommends 150g of N, 700 g of P_2O_5, 100 g of K_2O and 200 g of "fries" (micronutrient cocktail in the form of silicate oxides) per cubic meter of subsurface soil, as base fertilization for production of *Eucalyptus* sp. seedlings. Converting these values to 1.2 dm^{-3} of soil, volume used in the present study, the base fertilization would be 0.18, 0.84 and 0.12 g of N, P and K, respectively. Based on this information, only the urban waste compost and the fiber extraction residue of *Agave sisalana* would be able to provide the N amount suggested by these authors in the maximum proportion evaluated, 80:20 (residue:soil; v/v). None of the residues would provide this amount for the other nutrients, even if applied in high proportions (Table 1). Despite the low and medium contents of some nutrients in the residues used, this fact was not a limiting factor for the seedling growth.

Despite the low contents of some macronutrients, based on a base fertilization, the residues show high levels of micronutrients (Table 1), which in certain residue:soil proportions, above 40:60, caused nutritional imbalance in the plants. Organic materials are rich in most nutrients, however, they may present marked lack or excess of at least one nutrient. Micronutrients are required in low quantities by the plant and the limit between nutritional requirement and toxicity is very narrow, ie, high availability in the substrate results in negative effects on plant development (Abreu Junior et al., 2005). This effect was described by Nóbrega et al. (2008), who verified an increased of micronutrient availability proportional to the addition of biosolids in Red Yellow Oxiosol and Entisol Quartzipsamments. A reduction on growth of *C. pulcherrima* seedlings was also verified with reduction of chlorophyll index, number of leaves and leaf area in plants cultivated on substrates formulated with 40:60, 60:40, 80:20 (residue:soil; v/v).

Substrates elaborated with lower proportions of organic residue, regardless of type, provided better quality seedlings, compared to the substrate elaborated with 0:100 (residue: soil; v/v). In this case, the elevation of the macro and micronutrients contents in relation to the substrate constituted by soil alone, resulted in an increase of the plant growth until a certain proportion, indicating that *C. pulcherrima* is responsive to the addition of nutrients in the substrate. There are no reports in the literature about the responsiveness of this species to fertilization during the nursery stage. However, other species from the same genus Caesalpinia as *C. piramidalis* Tul. (Dantas et al., 2011) and *C. ferrea* Mart. (Scalon et al., 2011), were responsive to organic fertilization under controlled conditions.

Regarding soil classes' water retention, Oxisol is superior to that of the Entisol, mainly due to the nature of the colloidal material, soil with a fine texture compared to the coarse texture. The granulometric fraction is directly related to the storage and release of water in the soil (Amaro Filho et al., 2008). The Oxisol physical characteristics such as texture, organic matter, and water retention capacity favor the gradual supply of water to the plants for a longer period when compared to the Entisol that retains less water and abruptly releases it. Both soil classes show slightly acidic pH, but the Oxisol shows a greater sortative complex than Entisol. Both required fertilization due to the low nutritional contents. The difference in physical and chemical attributes between Oxisol and Entisol is expressed in the growth of *C. pulcherrima* seedlings, as was verified while evaluating plant height. Nóbrega et al. (2008) also verified differences in the attributes of these soil classes while growing *Anadenanthera peregrina* (L.).

5.CONCLUSION

Organic residues, tree organic pruning + animal manure, urban waste compost and *Agave sisalana* extraction residue can be used in the elaboration of cultivation substrates for the production of *Caesalpinia pulcherrima* L. Sw seedlings.

The substrates formulated with 33%, 23% or 5% of tree organic pruning + animal manure or urban waste compost or *Agave sisalana* fiber extraction residue, respectively, promoted better quality of *Caesalpinia pulcherrima* L. Sw. seedlings, 90 days after sowing, regardless of the soil class.

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