SEED EMERGENCE AND DEVELOPMENT OF *Caesalpinia pulcherrima* L. SW. AND *Cassia grandis* L. F. IN ORGANIC SUBSTRATES

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ABSTRACT – The addition of adequate proportions of organic residues to formulate substrates with soil, render positive results on germination and seedling growth by providing benefits to the physical and chemical attributes of the soil. Determining an adequate proportion of such residues is essential to obtain seedlings exhibiting morphophysiological quality. This study aims to evaluate seed emergence and the development of *Caesalpinia pulcherrima* (L.) *Swartz* and *Cassia grandis* L. f. seedlings in organic substrates. The experiment was set in a completely randomized design arranged in 2 x 3 x 5 factorial scheme, consisting of two soil classes (Oxisol and Entisol), three types of organic substrate (COP (organic compost from tree pruning + cattle and goat manure), CLU (urban waste compost), RES (residue from the extraction of sisal fiber) and five percentages of organic residues (0, 20, 40, 60, 80). The percentage of emergence and emergence speed of seeds, plant height, number of leaves, root length and dry mass were determined. The species showed better results for these variables when adding organic residues to the substrate. The addition of 80% COP or CLU to the substrate provided higher mean values for percentage of emergence in seeds of *Caesalpinia pulcherrima*, and the substrate constituted by only soil provided higher dry mass in seedlings of this species. The combination of 50% COP and 50% soil (Oxisol and Entisol) resulted in higher means for the percentage of seed emergence, velocity of emergence and biomass production in *Cassia grandis* L. f. seedlings.

Keywords: *Agave sisalana* residue; Urban waste; Organic fertilization.

EMERGÊNCIA DE SEMENTES E DESENVOLVIMENTO DE MUDAS DE Caesalpinia pulcherrima *L. SW. E* Cassia grandis *L. F. EM SUBSTRATOS ORGÂNICOS*

RESUMO – Resíduos orgânicos, quando adicionados em proporções adequadas para formular substratos com solo, proporcionam resultados positivos na germinação e crescimento de mudas, proporcionando benefícios aos atributos físicos e químicos do solo. Determinar uma proporção adequada é essencial para a obtenção de mudas com qualidade morfofisiológica. Este trabalho tem como objetivo avaliar a emergência de sementes e o desenvolvimento de mudas de ***Caesalpinia pulcherrima*** *(L.)* ***Swartz*** *e* ***Cassia grandis*** *L. f. em substratos orgânicos. O experimento foi instalado em delineamento inteiramente casualizado em esquema fatorial 2 x 3 x 5, composto por duas classes de solo (Latossolo e Neossolo), três tipos de substrato orgânico (COP (composto orgânico de poda de árvores + esterco bovino e caprino), CLU (composto de lixo urbano), RES (resíduo da extração da fibra de sisal) e cinco porcentagens de resíduos orgânicos (0, 20, 40, 60, 80). A porcentagem e velocidade de emergência das sementes, além da altura de plântulas, número de folhas, comprimento de raiz e massa seca, foram determinadas. As espécies apresentaram melhores resultados para essas variáveis ao adicionar resíduos orgânicos ao substrato. A adição de 80% de COP ou CLU ao substrato proporcionou* *maiores valores médios de porcentagem de emergência em sementes de **Caesalpinia pulcherrima** e o substrato constituído apenas por solo proporcionou maior massa seca nas mudas. A combinação de 50% de COP e 50% de solo (Latossolo e Neossolo), resultou em maiores médias de porcentagem de emergência de sementes, velocidade de emergência e produção de biomassa de plântulas de **Cassia grandis**.*

*Palavras-Chave: Resíduo de **Agave sisalana**; Resíduos urbanos; Adubação orgânica.*

1. INTRODUCTION

The use of arboreal and shrubby leguminous plants in degraded areas and marginal lands has improved the success of recovery programs due to the uncomplicated management of such techniques. The advantages of leguminous species for the recovery of such areas are explained due to the carbon and nitrogen transfer between soil layers, availability of nutrients, influence on the chemical properties of the soils and increment of microbiological activity in the soil (Pereira et al., 2016; Talgre et al., 2017; Kebede, 2021).

Caesalpinia pulcherrima (L.) Swartz, commonly known as flamboyant-mirim, peacock flower or red bird of paradise, is considered a species with multiple potentials. This species is native to the tropical and sub-tropical regions of the Americas and belongs to the Fabaceae family, bein well adapted to the soil and climatic conditions in Brazil (Lorenzi et al., 2003). The specie responds to fertilization, once seedlings with better morphophysiological characetrs were obtained after organic fertilization using organic compost obtained from sisal's fiber, cattle manure or urban wastes (Moreira et al., 2018). *Cassia grandis* L. f., commonly known as pink shower tree, rose acacia, canafistula or big acacia, is considered a species with potential for timber or reforestation of marginal lands and degraded soils. It is an arboreal leguminous plant from the Fabacea family, sub-family Caesalpinioideae, a deciduous, pioneer and secondary initial native species (Lorenzi, 2008). In seedlings, organic fertilization does not influence plant growth (Anjos et al., 2018). Although further studies are required regarding the initial growth stages which may facilitate management and vegetal propagation of the species. Despite the importance of these species, the evaluation of effects from agro-industrial byproducts in the emergence of seeds and development of seedlings are still embryonic.

In order to select cultivation substrates one must consider its efficiency by supplying favorable conditions for plant growth such as water availability, aeration, balanced pH, adequate salinity, besides the capacity to supply nutrients. Organic residues, when added in adequate proportions to formulate substrates with soil, render positive results on germination and growth of seedlings by providing benefits to the physical and chemical attributes of the soil (Moreira et al., 2018; Braulio et al., 2019; Moreira et al., 2021). Among these residues are the sewage sludge (Delarmelina et al., 2013), urban waste compost (Silva et al., 2014) and cattle manure compost (Moreira et al., 2018; Braulio et al., 2019; Moreira et al., 2021).

In addition to the benefits during the seedling stage, positive responses on seed emergence and plant growth were already registered for arboreal species such as *Adenanthera pavonina* L (Andrade et al., 2013), *Enterolobium contortisiliquum* (Vell.) Morong. (Araújo e Sobrinho, 2011) and *Alibertia edulis* (LC Rich.) (Jeromini et al., 2019). In these studies, substrates which promoted the initial development of seeds were those which showed higher water retemption capacity whitin an adequate range for seed emergence, contributing to a higher homogeneity of water supply for seeds during the pre-emergence period, as well as for the emergence velocity index, being substrates with no physical impediment for seed emergence.

As organic residues used for composting may have different origins and composition, these may have show different chemical characteristics such as pH, organic matter content, nutrient availability, carbon/nitrogen ratio and physical characteristics such as texture and water retention capacity, which may influence directly on germination, emergence rates and plant biomass (Andreo-Souza et al., 2010; Brancalion et al., 2010; Alves et al., 2012).

In view of the potential for the utilization of organic residues as substrate components, the present work had the objective to evaluate the percentage of emergence and the development of *Caesalpinia pulcherrima* L. Sw. and *Cassia grandis* L. f. seedlings, under different organic substrates.

2. MATERIAL AND METHODS

The experiment was performed in greenhouse at the Center for Agrarian, Environmental and Biological Sciences from the Federal University of Recôncavo da Bahia (UFRB), located in Cruz das Almas – BA, Brazil, at 39º06'26" south latitude, 12º40'39" west longitude and 225 m altitude. According Köppen and Geiger the climate is classified as Af; with mean temperature of 23 ºC and mean annual rainfall of 1136 mm. During the experimental period the temperature in the greenhouse varied from 30.4 to 28.2 ºC, with mean temperature of 29.3 ºC.

Caesalpinia pulcherrima and *Cassia grandis* seeds were collected from twenty trees randomly distributed within the University campus during a period extended from February to March 2019. Seeds of *Cassia grandis* were immersed in sulfuric acid (95 - 97% P.A.) for 60 minutes (Silva et al., 2012) and washed in tap water to eliminate the excess of acid. This treatment is required in order to overcome the impermeability of the seed tegument (physical protection), which restrains water and oxygen and consequently prevents embryo growth (Santos et al., 2019).

Treatments were constituted by two soil classes (Oxisol- LAd) and (Entisol- RQ) and three organic residues [COP (organic compost from tree pruning + cattle and goat manure), CLU (urban waste compost) and RES (residue from the extraction of *Agave sisalana* fiber)] homogenized in five percentages (0, 20, 40, 60 and 80%) and set in a completely random design in factorial scheme 2 x 3 x 5, with eight replicates. Each replicate was constituted of three *Caesalpinia pulcherrima* and *Cassia grandis* seeds, respectively.

Soils from the sub-superficial layer (>0.40 m deep) were collected, for both soil classes: LAd collected at the UFRB Campus and RQ collected in the county of Entre Rios, Bahia. Physical characterization of Lad showed the following results: 535 g kg^{-1} sand, 281 g kg^{-1} silt and 181 g kg^{-1} clay; humidity of 0.114 m^3 m^{-3} at -10kPa and 0.111 m^3 m^{-3} at -33kPa. Chemical characterization indicated: pH_{H2O} of 5.2, contents of

Table 1 – Chemical and physical characterization of residues: COP (organic compostfrom pruning), CLU (urban waste compost) and RES (residue from the extraction of *Agave sisalana* fibers), used to compose organic substrates.
Tabela 1 *– Caracterização química e física dos resíduos: COP (composto orgânico de poda de árvores), CLU (composto de lixo urbano) e RES (resíduo da extração das fibras de* ***Agave sisalana****), utilizados para compor os substratos orgânicos.*

Chemical attribute	COP		CLU		RES	
	Dry	Humid	Dry	Humid	Dry	Humid
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
Humidity at 60 - 65°C (%)	-	12.03	-	16.55	-	41.53
Humidity 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 (%)	87.12	76.64	74.92	62.52	39.75	23.24
Mineral residue (%)	6.55	5.76	7.29	6.08	34.67	20.27
Insoluble mineral residue (%)	80.57	70.88	67.63	56.44	5.08	2.97
Nitrogen, total (NT) (%)	0.70	0.62	2.12	1.77	2.51	1.47
Phosphorus, total (P_2O_5) (%)	0.23	0.20	0.86	0.72	3.51	2.05
Potassium, total (K_2O) (%)	0.25	0.22	0.32	0.27	1.27	0.74
Calcium, total (Ca) (%)	0.57	0.50	1.76	1.47	8.50	4.97
Magnesium, total (Mg) (%)	0.13	0.11	0.14	0.12	1.68	0.98
Sulfur, total (S) (%)	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]Values for pH($CaCl_2$) were estimated by the equation of Novais et al., (2007) apud Souza et al. (1989): pH($CaCl_2$) = 0.12+0.89 pH(H_2O).
[1] Valores de pH($CaCl_2$) foram estimados pela equação de Novais et al., (2007) apud Souza et al. (1989): pH($CaCl_2$).= 0.12+0.89 pH(H_2O).

Table 2 – Humidity (m^3 m^{-3}) of substrates formed by the homogeneization of soil classes [LAd (Oxisol) and RQ (Entisol] and types of organic residue [COP (organic compost from pruning), CLU (urban waste compost), RES (residue from the extraction of *Agave sisalana* fibers)], at percentages of 0, 20 and 80%, submitted to pressures of -10 kPa and -33 kPa.
***Tabela 2** – Umidade (m^3 m^{-3}) dos substratos formulados pela homogeneização de classes de solo [LAd (Latossolo Amarelo Distrófico) e RQ (Neossolo Quartzarênico] e tipos de resíduos orgânicos [COP (composto orgânico de poda de árvores), CLU (composto de lixo urbano) e RES (resíduo da extração das fibras de **Agave sisalana**)], nas porcentagens de 0, 20 e 80%, submetidos às pressões de -10 kPa e -33 kPa.*

Soil	Organis residues	Percentage of Residue					
		---------- 0% --------		-------- 20% --------		--------- 80% -------	
		Humidity (m^3m^{-3})					
		-10 kPa	-33 kPa	-10 kPa	-33 kPa	-10 kPa	-33 kPa
LAd	COP	0.1144	0.1114	0.1141	0.1128	0.1368	0.1270
	CLU	0.1144	0.1114	0.1382	0.1333	0.2529	0.2283
	RES	0.1144	0.1114	0.1266	0.1279	0.2037	0.1962
RQ	COP	0.0187	0.0198	0.0282	0.0276	0.0851	0.0745
	CLU	0.0187	0.0198	0.0410	0.0455	0.1935	0.1847
	RES	0.0187	0.0198	0.0266	0.0249	0.1361	0.0858

available P of 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 of 14.4 g dm^{-3}. The results for RQ showed: 922 g kg^{-1} sand, 47 g kg^{-1} sand and 31 g kg^{-1} clay, humidity of 0.018 m^3 m^{-3} at -10kPa and 0.019 m^3 m^{-3}at -33kPa; pH_{H2O} of 5.5, contents of available P of 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} and organic matter of <3.5 g dm^{-3}.

COP and CLU residues were originated from a compost pile established with 15 cm tree pruning residues and 5 cm of cattle and goat manure + correctives (limestone) and fertilizers (simple superphosphate and potasium chloride) (3:1 ratio) made at the UFRB, and from tree pruning residues and organic household waste (3:1 ratio) from the county of Entre Rios – BA, Brazil, respectively. RES was originated from pure waste compost piles where *in loco* fermentation was predominant, without any specific management, at the county of Valente – Bahia. The chemical and phisycal characterization of the residues are showed in Table 1.

Regarding the potential risks to the environment, according the Brazilian regulation NBR 10.004 – Solid Residues of 2004 from ABNT, the residues used (COP, CLU and RES), are classified as agricultural, household and industrial, belonging to the Class of Residues II A – Not inert.

Both, residues and soil, were air dried before sieved through a 5 mm mesh, homogenized acording to the treatments and distributed in 0.12 x 0.23 m polyethilene bags with 1.2 dm^{-3} capacity. Part of the treatments were reserved to determine the humidiy at field capacity (Table 2). Irrigation was performed manually every day, simulating comercial nurseries conditions.

The variables analyzed in *Caesalpinia pulcherrima* and *Cassia grandis* sown in different substrates were: percentage of emergence (%E), velocity of emergence index (IVE) (Maguire, 1962) and the first count of emergence (PCE) (Laboriau e Valadares, 1976). Emergence counting was accomplished every day, considering as emerged all plants showing totally free cotyledons.

Thirty days after sowing, plants were divided in aerial portion (shoots) and roots, at that time, plant height (H), root length (CR) and the number of leaves per plant (NF) were evaluated. Then, the aerial portion and roots were dried in a circulating forced air oven at 65 ºC and the dry mass of the aerial portion (MSPA) and roots (MSR) were determined.

Data was submitted to a variance analysis through the F test and multiple means compared by the Tukey test and polynomial regression analysis at 5% probability for the studied variables according to the percentages of residues, with statistical software SISVAR (Ferreira, 2014). Emergence data were transformed to arc sin $(x/100)^{1/2}$.

3. RESULTS

Treatments influenced ($p<0.05$) the initial development of both species, *Caesalpinia*

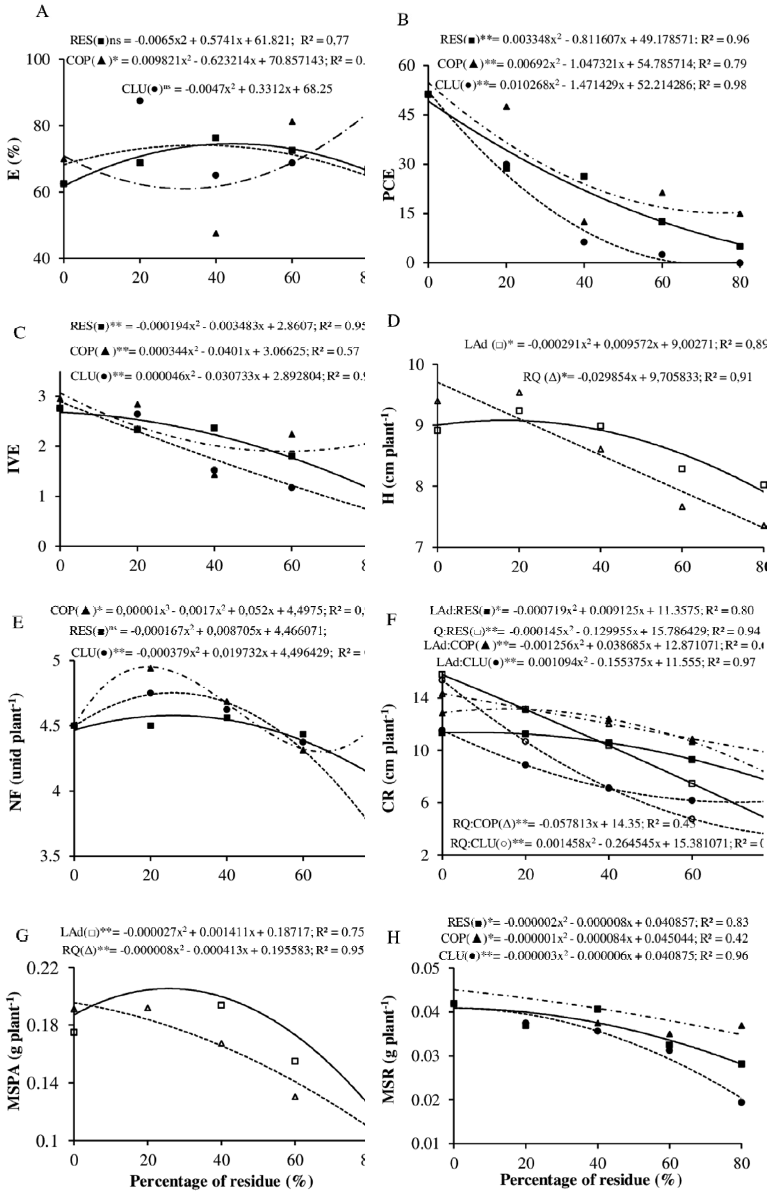

Figure 1 – Percentage of emergence (%E) (A), first emergence count (PCE) (B), velocity of emergence index (IVE) (C), height (H) (D), number of leaves (NF) (E), root length (CR) (F), dry weight of the aerial portion (MSPA) (G) and dry weight of roots (MSR) (H) in *Caesalpinia pulcherrima* seedlings, according to soil class (Oxisol- LAD and Entisol-RQ), types of organic residue [COP (organic compost from pruning), CLU (urban waste compost), RES (residue from the extraction of Agave sisalana fibers)] and percentages of organic waste (0, 20, 40, 60, 80). ** - p<0,05; * - p<0,01; ns – not significant by the Tukey's test.

***Figura 1** – Porcentagem de emergência (%E) (A), primeira contagem de emergência (PCE) (B), índice de velocidade de emergência de semente (IVE) (C), altura (H) (D), número de folhas (NF) (E), comprimento radicular (CR) (F), massa seca da parte aérea (MSPA) (G) e massa seca de raízes (MSR) (H) em mudas de **Caesalpinia pulcherrima**, de acordo às classes de solo [LAd (Latossolo Amarelo Distrófico) e RQ (Neossolo Quartzarênico], tipos de resíduos orgânicos [COP (composto orgânico de poda de árvores), CLU (composto de lixo urbano) e RES (resíduo da extração das fibras de Agave sisalana)] e percentagens de composto orgânico (0, 20, 40, 60, 80). ** - p<0.05; * - p<0.01; ns – não difere significativamente pelo teste Tukey.*

Table 3 – Percentage of emergence (%E), first emergence count (PCE) of seeds and plant height (H) of *Caesalpinia pulcherrima* and *Cassia grandis* seedlings, according to soil class LAd (Oxisol) and RQ (entisol) and types of organic residue [COP (organic compost from pruning), CLU (urban waste compost), RES (residue from the extraction of *Agave sisalana* fibers)].

***Tabela 3** – Porcentagem de emergência (%E), primeira contagem de emergência (PCE) de sementes e altura (H) de mudas de **Caesalpinia pulcherrima** and Cassia grandis, de acordo às classes de solo [LAd (Latossolo Amarelo Distrófico) e RQ (Neossolo Quartzarênico] e tipos de resíduos orgânicos [COP (composto orgânico de poda de árvores), CLU (composto de lixo urbano) e RES (resíduo da extração das fibras de **Agave sisalana**)].*

Soil	*C. pulcherrima*				*C. grandis*			
	%E							
	Organic Residue							
	COP	CLU	RES	Mean	COP	CLU	RES	Mean
LAd	68.00^{ns}	70.5^{ns}	70.50^{ns}	69.67^{ns}	81.67aA	75.00aA	74.17aA	76.95a
RQ	78.50^{ns}	68.00^{ns}	68.00^{ns}	71.50^{ns}	88.33aA	60.83bB	77.50aA	75.56a
Mean	73.25^{ns}	69.25^{ns}	69.25^{ns}		85.00A	67.92B	75.83B	
CV	36.09%				20%			
Soil	**PCE**							
	COP	CLU	RES	Mean	COP	CLU	RES	Mean
LAd	38.00aA	22.00aB	24.00aB	28.00a	2.14^{ns}	0.78^{ns}	2.08^{ns}	1.69a
RQ	21.00bA	14.00bB	25.00aA	20.16b	0.41^{ns}	0.41^{ns}	0.70^{ns}	0.50b
Mean	29.50A	18.00B	24.75A		1.28^{ns}	0.60^{ns}	1.38^{ns}	
CV	23%				27.34%			
Soil	**H**							
	COP	CLU	RES	Mean	COP	CLU	RES	Mean
LAd	8.83aA	8.32aA	8.93aA	8.69a	11.93^{ns}	11.26^{ns}	11.70^{ns}	11.63^{ns}
RQ	9.03aA	8.22bA	8.29bB	8.51a	11.58^{ns}	9.39^{ns}	10.32^{ns}	10.43^{ns}
Mean	8.93A	8.27B	8.61AB		11.76^{ns}	10.33^{ns}	11.01^{ns}	
CV	14.43%				19.51%			

Means followed by the same lowercase letter in the column and same capital letter in the line, for each species, do not differ by the Tukey's test ($p<0,05$). ^{ns} – not significant.

Médias seguidas de letras minúsculas na coluna e de letras maiúsculas na linha, para cada espécie, não difere peloteste Tukey (p<0.05). ns – não significativo.

pulcherrima and *Cassia grandis*. Seedling emergence of *Caesalpinia pulcherrima* and *Cassia grandis* started six and nine days after sowing, ending after 14 and 20 days, with mean values of 70.9% and 76.3%, respectively. Double interaction between types and percentages of organic residues ($p<0.01$) occurred for the percentage of emergence in *Caesalpinia pulcherrima* (Figure 1A). The addition of COP caused decrease of percentage of emergence in *Caesalpinia pulcherrima* seeds at percentages between 0 and 38%. The maximum seed %E mean values were of 78.9% and 66.6%, at 16% and 56% of CLU and RES residues applied, respectively. These mean values were 21% and 6% higher than the percentage of emergence from seeds sown in only soil (Figure 1A).

Double interaction ($p<0.05$) was verified between soil classes and types of residues for the percentage of emergence in *Cassia grandis* (Table 3). When organic residues were mixed with Lad a similar result occurred for E%. When these residues were mixed with RQ, COP and RES they provided higher E% values when compared to CLU (Table 3).

Double interaction was verified between soil classes and the type of residue ($p<0.01$) for PCE (Table 3) and between types and percentages of organic residues ($p<0.05$) in *C. pulcherrima* (Figure 1B), as well as double interaction ($p<0.01$) between soil classes and percentage of residues in *Cassia grandis* (Figure 2D). The first count of *Caesalpinia pulcherrima* and *Cassia grandis* emerged seedling was performed with six and nine days after seeding, respectively. In the first count, a higher number of *Caesalpinia pulcherrima* seeds emerged (51%) in the substrate constituted only by soil (Figure 1B) and 23% *Cassia grandis* seeds emerged in the substrate constituted by LAd + 18% organic residue (Figure 2D). Among the evaluated soil classes, higher mean values for plant emergence were observed in LAd, with higher PCE means when compared to RQ, for both plant species (Table 3, Figure 2D).

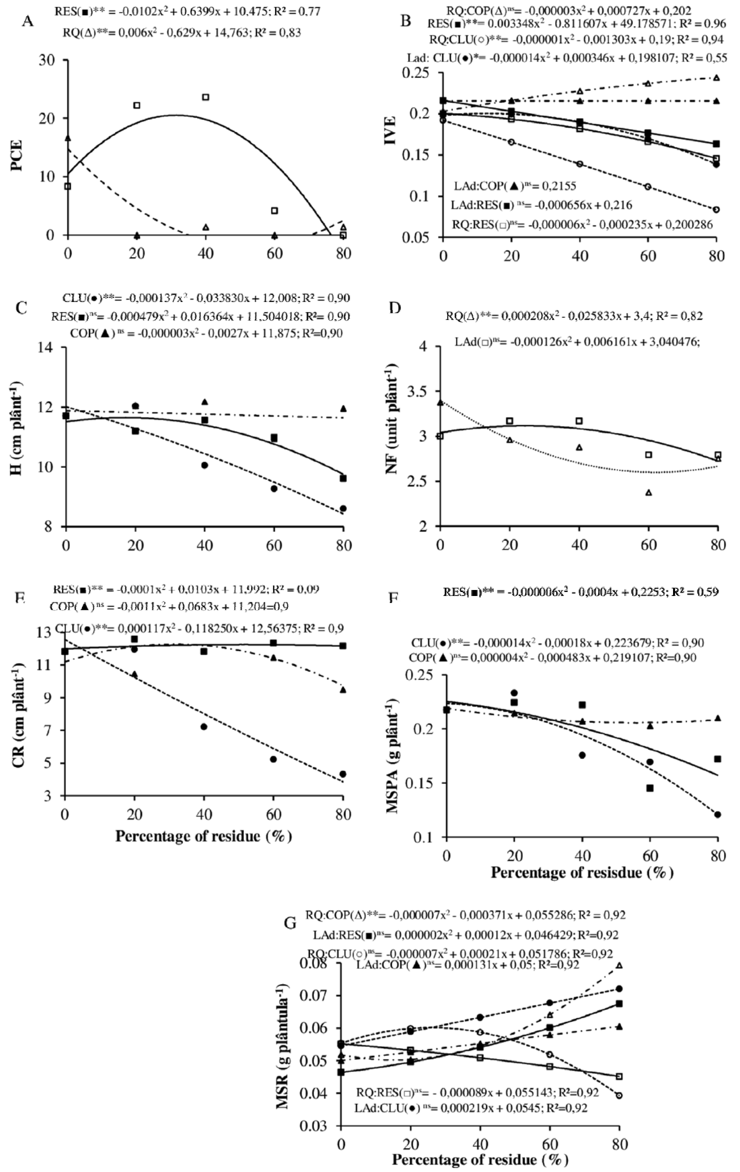

Figure 2 – First emergence count (PCE) (A), velocity of seed emergence index (IVE) (B), height (H) (C), number of leaves (NF) (D), root length (CR) (E), dry mass of the aerial portion (MSPA) (F) and dry mass of roots (MSR) (G) in *Cassia grandis* L. f. seedlings, according to soil class (Oxisol- LAD and Entisol-RQ), types of organic residue [COP (organic compost from pruning), CLU (urban waste compost), RES (residue from the extraction of *Agave sisalana* fibers)] and percentages of organic waste (0, 20, 40, 60, 80). ** - p<0,05; * - p<0,01; ns – not significant by Tukey's.

Figura 2 *– Primeira contagem de emergência (PCE) (A), índice de velocidade de emergência de semente (IVE) (B), altura (H) (C), número de folhas (NF) (D), comprimento radicular (CR) (E), massa seca da parte aérea (MSPA) (F) e massa seca de raízes (MSR) (G) em mudas de* ***Cassia grandis*** *L. f., de acordo às classes de solo [LAd (Latossolo Amarelo Distrófico) e RQ (Neossolo Quartzarênico], tipos de resíduos orgânicos [COP (composto orgânico de poda de árvores), CLU (composto de lixo urbano) e RES (resíduo da extração das fibras de* ***Agave sisalana****)] e percentagens de composto orgânico (0, 20, 40, 60, 80). ** - p<0.05; * - p<0.01; ns – não difere significativamente pelo teste Tukey.*

Double interaction ($p<0.01$) between types and percentages of organic residues were observed for the IVE in *Caesalpinia pulcherrima* (Figure 1C). The substrate constituted of only soil promoted higher IVE (3.05) (Figure 1C). In *Cassia grandis* there was a triple interaction ($p<0.05$) between soil classes, types and percentages of organic residues (Figure 2B). The addition of COP to the soil, independently from the soil class, favored in a linear increasing manner, the IVE. This residue promoted a maximum index of 0.24 in *Cassia grandis* with the addition of 80% COP in RQ soil (Figure 2B).

Double interaction between soil classes and type of residues ($p<0.05$) (Table 3), and between soil classes and percentage of organic residues ($p<0.01$) were observed for H in *Caesalpinia pulcherrima* (Figure 1D). Among the organic residues, COP and RES promoted higher H mean values (Table 3). The addition of residue resulted in decrease of H in RQ soil. In LAd soil, it was estimated that the addition of 16.5% of organic residue resulted in maximum H growth (9.08 cm $plant^{-1}$) in *Caesalpinia pulcherrima* (Figure 1D). In *Cassia grandis*, there was double interaction ($p<0.05$) between types and percentages of residue (Figure 2C). The highest mean value (12.21 cm $plant^{-1}$) of H was obtained in the substrate constituted of 14% COP, followed by 17% RES with 11.64 cm $plant^{-1}$ (Figure 2C).

There was double interaction ($p<0.01$) between the type and percentages of organic residue for NF in *Caesalpinia pulcherrima* (Figure 1E). In a general way, all residues were favorable for NF, with a maximum number of leaves of 4.9, 4.8 and 4.6 for the estimated percentages of 15.3, 26 and 26% of COP, CLU and RES, respectively (Figure 1E). Thirty days after sowing *Caesalpinia pulcherrima* L. f. plants cultivated in substrate containing 40, 60 and 80% of organic residue showed visible symptoms of anomalies, such as symmetric yellowing veins in younger leaves, reduction of vegetative growth and continuous leaf drop. In *Cassia grandis*, double interaction was observed ($p<0.05$) between soil classes and percentages of organic residue (Figure 2D). The addition of residue promoted reduction of NF in RQ, while in LAd the addition of residue increased NF, with maximum of 3.05 (units $plant^{-1}$) at an estimated residue percentage of 24.4% (Figure 2D). No visible symptoms of anomalies were observed in this species while using organic residue.

A triple interaction was observed ($p<0.05$) between soil classes, types and percentages of residues for CR in *Caesalpinia pulcherrima* (Figure 1F). In a general manner the addition of organic residues COP, CLU and RES, interfered in a negative way for CR, with a maximum of 15.78 cm $plant^{-1}$ observed in plants cultivated in substrate containing only soil (Figure 1F). Double interaction ($p<0.05$) was verified in *Cassia grandis* between types and percentages of organic residues (Figure 2E). Plants showed higher CR (12.03 cm $plant^{-1}$) when cultivated in substrate containing 46.5% COP, followed by 10% RES (11.2 cm $plant^{-1}$). When using CLU, a CR decrease in *Cassia grandis* was observed with the increment of percentages of the organic residue (Figure 2E).

Double quadratic interaction ($p<0.05$) was verified between soil classes and percentages of organic residues for MSPA in *Caesalpinia pulcherrima* (Figure 1G). When using LAd, the maximum MSPA was of 0.21 g $plant^{-1}$, obtained at an estimated percentage of 26% organic residue. In RQ, the highest mean was observed without the use of the residue (Figure 1G). In *Cassia grandis* there was double interaction ($p<0.05$) between types and percentages of residues (Figure 2F). The addition of 18.5% RES resulted in a maximum estimated MSPA of 0.25 g $plant^{-1}$. The use of COP and CLU did not increase MSPA in *Cassia grandis* (Figure 2F).

In *Caesalpinia pulcherrima* a double and quadratic interaction ($p<0.05$) between the types and percentages of organic residues was verified for MSR (Figure 1H). Similar to what occurred in CR, the MSR was reduced with the addition of residues to the substrate (Figure 1H). In *Cassia grandis* a triple interaction was verified ($p<0.05$) between soil classes, types and percentages of residues (Figure 2G). Highest production of MSR (0.079 g $plant^{-1}$) was observed when the substrate was constituted of RQ and 80% COP, a MSR value that is 35% higher than in plants cultivated with only soil. Other substrate formulations also enhanced the production of MSR, such as LAd with 80% COP, CLU or RES, as well as RQ with 15% CLU (Figure 2G).

4. DISCUSION

Mean values for the percentage of emergence in *Caesalpinia pulcherrima* and *Cassia grandis* were similar to previous results obtained by Oliveira et al. (2010) and Melo and Rodolfo Júnior (2006), where seeds had 72% and 77% emergence, respectively, when cultivated in plastic boxes containing washed sand.

Depending on the chemical and physical characteristics of the organic residues used to constitute a substrate, these may increase the contents of available macro and micro nutrients (Moreira et al., 2018; Braulio et al., 2019; Moreira et al., 2021), increase the values of pH in the substrate, reduce aluminum saturation, reduce substrate density, increase aeration (Delarmina et al., 2013), increase macro-porosity and total volume of pores (Delarmina et al., 2014), and promote the increase of water retention in the substrate, as verified. A substrate with such factors in equilibrium, supplies ideal conditions for the emergence and establishment of a vigorous plant.

Water availability depends on the texture, structure, porosity, density (Amaro Filho et al., 2008), and organic matter content (Novais et al., 2007), which define the uniformity of water supply to the soil solution, and consequently to the seeds, that is to say, all factors performing concomitantly. In such context, substrates containing higher percentages of organic residues, depending on the mixture used, showed higher retention capacity in the present study (Table 1), as well as uniform distribution of water for longer periods of time, increasing the emergence of *Caesalpinia pulcherrima* and *Cassia grandis* seeds.

The fact of the substrate constituted of only soil promoting higher velocity of seed emergence in *Caesalpinia pulcherrima* may be related with the pH. LAd and RQ soils are considered acidic. According Oliveira et al. (2010), seeds of *Caesalpinia pulcherrima* when immersed in sulfuric acid for five minutes have their velocity of emergence doubled when compared to those without physical or chemical treatment. In the present study, the treatment for breaking dormancy was used in seeds of these species, therefore, the acidity of the substrate composed by only soil may have accelerated seedling emergence.

The addition of organic substrates promoted positive responses for velocity of emergence in *Cassia grandis*, a fact related with a lesser physical impediment, that is to say, higher substrate porosity (Saidelles et al., 2009). Mixture of organic compost (made from animal cattle and other materials) also increased the velocity of emergence in plants of *Myracrodruon urundeuva* Allemão LC and *Caesalpinia ferrea* Mart. ex Tul cultivated with sugarcane bagasse + cattle manure (Andrade et al., 2013) and Dystrophic Ferric Yellow Latosol (Oxisol) + sand + organic fertilizer (Scalon et al., 2011), respectively.

The condition of "better substrate" varies for each species and developmental stage. Asimilar behavior in *Caesalpinia pulcherrima* with reduction of mean values for CR and MSR, as the proportion of organic residues increased in the cultivation substrate, was verified. This fact may be explained by the lower water retention in the substrate constituted by only soil. Lower water availability in the soil triggers a series of morfophysiological responses in plant, one of them is the stimuli of root growth and development of lateral roots (Taiz e Zeiger, 2004). Andrade et al. (2013) verified similar results for H and dry mass in *Myracrodruon urundeuva* 28 days after sowing.

In seedlings of *Cassia grandis*, the addition of organic residue to the substrate was significant for CR and MSR, that is to say, in the radicular system. Increments in MSR, resulting from the addition of percentages of organic residues were observed previously by some authors. Alves et al. (2015) observed higher CR and MSR in plantlets of *Adenanthera pavonina*, 21 days after sowing, when cultivated in fine vermiculite + cattle manure (1:1). Araújo e Sobrinho (2011) verified higher gathering of dry mass in the radicular system of *Enterolobium contortisiliquum* in substrate containing soil + cattle manure + carbonized rice husk (1:1:1, v:v).

The substrate must provide enough porosity to allow good aeration, have a high water retention capacity and still provide good drainage for root growth. Among the studied residues, RES provided higher CR and MSR in *Cassia grandis* seedlings. This residue is originated from fiber residues from leaves and contains different size fragments of leaves and fibers. Despite sifting through a 5 mm mesh, the sisal residue contains coarser particles than COP and CLU residues. In that manner, the RES texture may increase the porous volume of the substrate, allowing good aeration and water drainage for radicular growth (Lacerda et al., 2006), as observed in the present study.

5. CONCLUSIONS

Substrate composition changes the germination behavior of the species evaluated. The addition of

80% COP or CLU to the substrate provided higher mean values for percentage of emergence in seeds of *Caesalpinia pulcherrima* and the substrate constituted by only soil provided higher production of dry mass, a soil characterized by its acidity and low nutrient concentrations. In *Cassia grandis*, the estimated combination of 50% COP and 50% soil, independently form the soil class, resulted in higher means for percentage of seed emergence, velocity of emergence and biomass production of seedlings.

AUTHOR CONTRIBUTIONS

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