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Substrates and cultivation environments in the production of seedlings of *Genipa americana L. (Rubiaceae)* seedlings

Ambiente de cultivo e substrato para produção de mudas de *Genipa americana L. (Rubiaceae)*

Sustratos y ambientes de cultivo en la producción de plántulas de *Genipa americana L. (Rubiaceae)*

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Abstract

This study aimed to evaluate genipap seedling formation in different protected environments using different substrates. Five protected cultivation environments (E) were used: E1 - greenhouse without aluminized shade cover under polyethylene film; E2 - greenhouse with aluminized shade cover under polyethylene film; E3 - screened with black shade cover; E4 - screened with aluminized shade cover; and E5 - nursery covered with bacuri coconut straw. In each protected cultivation environment, substrates containing different percentages of earthworm humus (H), vermiculite (V), bovine manure (M) and shredded cassava stems (C) were tested. Seedlings emerged best in environments E2, E3 and E4. Mixtures ¾ H + ¼ V and ¾ H + ¼ C favored growth and yielded high quality seedlings. Environments E3 and E4 provided superior growth, with better- quality and high-quality seedlings. Environments E1 and E5 did not provide adequate seedling growth. Therefore, were not recommended for genipap seedling production using the substrates tested.

Keywords: *Genipa americana*; Protected environments; Substrates.

Resumo

O presente trabalho teve como objetivo avaliar a formação de mudas de jenipapo em diferentes ambientes protegidos utilizando diferentes substratos. Foram utilizados cinco ambientes de cultivo protegidos (E): E1 - estufa sem cobertura de sombra aluminizada sob filme de polietileno; E2 - estufa com cobertura de sombra aluminizada sob filme de polietileno; E3 – ambiente telado com cobertura de sombra preta; E4 – ambiente telado com cobertura de sombra aluminizada; e E5 - estufa coberta com palha de coco bacuri. Em cada ambiente de cultivo protegido foram testados diferentes substratos contendo diferentes porcentagens de húmus de minhoca (H), vermiculita (V), esterco bovino (M) e caule de mandioca desfiado (C). As mudas surgiram melhor nos ambientes E2, E3 e E4. As misturas ¾ H + ¼ V e ¾ H + ¼ C favoreceram o crescimento e produziram mudas de alta qualidade. Os ambientes E3 e E4 proporcionaram crescimento superior, com mudas de alta qualidade. Os ambientes E1 e E5 não proporcionaram crescimento adequado das mudas, por isso não são recomendados para produção de mudas de jenipapo em função dos substratos testados.

Palavras-chave: Ambiente protegido; *Genipa americana*; Substrato.

Resumen

Este estudio tuvo como objetivo evaluar la formación de plántulas de genipap en diferentes ambientes protegidos utilizando diferentes sustratos. Se utilizaron cinco ambientes de cultivo protegidos (E): E1 - invernadero sin sombra aluminizada bajo película de polietileno; E2 - invernadero con cubierta de sombra aluminizada bajo película de polietileno; E3 - apantallado con cubierta de sombra negra; E4 - apantallado con cubierta de sombra aluminizada; y E5 - vivero cubierto con paja de coco bacuri. En cada ambiente de cultivo protegido, se probaron sustratos que contenían diferentes porcentajes de humus de lombriz (H), vermiculita (V), estiércol bovino (M) y tallos de yuca desmenuzada (C). Las plántulas emergieron mejor en los ambientes E2, E3 y E4. Las mezclas ¾ H + ¼ V y ¾ H + ¼ C favorecieron el crecimiento y produjeron plántulas de alta calidad. Los ambientes E3 y E4 proporcionaron un crecimiento superior, con plántulas de mejor calidad y alta calidad. Los ambientes E1 y E5 no proporcionaron un crecimiento adecuado de las plántulas. Por lo tanto, no se recomendaron para la producción de plántulas de genipap utilizando los sustratos probados.

Palabras clave: Ambientes protegidos; *Genipa americana*; Sustratos.

1. Introduction

Genipap (Genipa americana L.), of the Rubiaceae family, is found throughout Brazil in forests located in humid lowlands, typical of the Atlantic Forest and the cerrado vegetation. The genipap fruits are indehiscent, globular and aromatic used in the production of wines, juice, liquor, sweets and jellies (LORENZI, 2002). The plant has an environmental, social and economic appeal, as it is widely used in the afforestation of cities, helping in the microclimate and environment, and also a good option for economic exploitation by small farmers due to the production and commercialization of fruits and wood (COSTA et al., 2007). In addition, genipap is an option for recovering areas of forests degraded by flood, fruit generation and consequently community jobs.

This plants species is easily propagated through the use of seeds, with up to 92% of emergence (OLIVEIRA et al., 2011). Vieira and Gusmão (2006) state that Percentage of Emergence (PE) and Emergence Speed Index (ESI) are important parameters in the production of seedlings, since these are directly related to obtaining adult plant uniformity.

According to Mesquita et al. (2009), genipap seedlings can be produced satisfactorily in polyethylene bags, using substrate composed of soil + manure + carbonized rice hull in first place; and soil + manure + vermiculite in the second place. However, the authors do not recommend the use of soil + manure alone, which do not meet the nutrient requirements of plants grown in nurseries. Moreover, for better management and results in reducing the time of permanence of these seedlings in the nursery, further studies are necessary to test other combinations of materials in substrate composition. Costa et al. (2007) relate that high-quality seedlings were obtained using substrates made with black soil and bovine manure (1:1) and that combination supplemented with carbonized rice husk (1:1:1).

The chemical fertilization under 40% shade cover using substrates rich in organic compounds favored the formation of high-quality seedlings, showing higher values of root collar diameter, plant height and shoot and root biomass accumulation (MORAES NETO; GONÇALVES, 2000). According Silva et al. (2018) the substrates fertilized soil, fertilized soil + coconut fiber, fertilized soil + sand and bovine manure + sand promoted better genipap seedlings production. Sassaqui, Terena and Costa (2013) reported that substrates composed of “50% bovine manure + 50% cassava stem” and “50% bovine manure + 50% Vida Verde®” used in agricultural greenhouses, and those of “50% bovine manure + 50% vermiculite” and “25% bovine manure + 25% cassava stems + 25% Vida Verde® + 25% vermiculite” under black shade cover, formed high-quality genipap seedlings, although a more in-depth study on different combinations of greenhouses and substrates will help in the seedling cultivation of changing genipap more efficiently. The search for new cultivation techniques to grow native species are tools that will allow obtaining healthy plants, avoiding limitations in commercial production (FRANZON, 2009). Under this premise, this study sought to evaluate the effect of different cultivation environments and the use of substrates on the emergence, initial growth, biomass, and on biometric relations of genipap seedlings.

2. Materials and Methods

The experiments on genipap seedling formation using substrates and in protected environments were carried out in State University of Mato Grosso do Sul (UEMS), in the Aquidauana county, State of Mato Grosso do Sul (MS), Brazil (latitude 20º27'00"South , longitude 55º40'12" West, altitude of 210 meters over sea level - transition region between cerrado and Pantanal biomes), from January to May 2012.

The fruits were collected from trees located in the region of Aquidauana and Anastácio, MS, Brazil, on January 6, 2012. The seeds were removed from the fruits,

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separated, washed in running water and then dried in the shade by 10 days. Subsequently, the seeds were selected by size and shape, discarding those with some type of damage, and were sowed in polyethylene bags of 0.15 by 0.22 m (1.6 liters), filled with substrates composed of earthworm humus (H), bovine manure (M), vermiculite (V) and cassava stems (C), totaling 14 substrates of different proportions (Table 1).

Table 1 - Substrates composed of various proportions of earthworm humus (H), bovine manure (M), vermiculite (V) and cassava stems (C). Aquidauana, MS, Brazil, 2012.

Humus (H) + Vermiculite (V)	Humus (H) + Cassava Stems (C)
S1 = 25% de H + 75% de V;	S4 = 25% de H + 75% de C;
S2 = 50% de H + 50% de V;	S5 = 50% de H + 50% de C;
S3 = 75% de H + 25% de V.	S6 = 75% de H + 25% de C.
Bovine Manure (M) + Vermiculite (V)	Bovine Manure (M) + Cassava Stems (C)
S7 = 25% de M + 75% de V;	S10 = 25% de M + 75% de C;
S8 = 50% de M + 50% de V;	S11 = 50% de M + 50% de C;
S9 = 75% de M + 25% de V.	S12 = 75% de M + 25% de C.
Humus (H) + Bovine Manure (M) + Vermiculite (V)	
S13 = 33.3% de H + 33.3% de M + 33.3% de V	
Humus (H) + Bovine Manure (M) + Cassava Stems (C)	
S14 = 33.3% de H + 33.3% de M + 33.3% de C	

Source: Authors.

Bovine manure was obtained in the region of Aquidauana-MS, composted for 30 days (November 26 to December 26, 2011), revolved and irrigated every two days. Earthworm humus was purchased from a slaughterhouse/cold store located in the municipality of Dois Irmãos do Buriti, MS, Brazil, where the earthworms were fed organic residue containing remains of rumen, viscera, blood, fats, among other things. Cassava stems were shredded in a hammermill, with an 8 mm sieve, then composted from October 21 to December 21, 2011 (60 days), revolved and irrigated every two days. Medium vermiculite was also used.

The organic materials were characterized chemically and shown in Table 2.

Table 2 - Chemical analysis of the organic materials in the substrates used for the experiments. Aquidauana, MS, Brazil, 2012.

	----------	----------	----------	---------- g kg^{-1}	----------	----------	----------	----------
	N	P	K	Ca	Mg	S	C	OM
M	10.60	3.66	1.00	9.80	1.65	1.81	96.50	166.00
H	14.80	4.46	1.00	26.70	12.50	3.53	163.00	281.00
C	19.50	2.89	7.00	18.80	6.15	2.42	376.00	647.00
	-	-	-	----------	----------	---------- mg kg^{-1}	----------	----------
	pH	RH	C/N	Cu	Zn	Fe	Mn	B
M	6.50	2.86	9.10	17.50	75.00	7800.00	310.00	11.47
H	6.90	13.46	11.01	30.00	130.00	14800.00	370.00	14.40
C	7.20	11.23	19.28	20.50	87.50	3440.00	520.00	20.70

* Solanalise Laboratory of Soil Analysis, Cascavel, PR, Brazil. OM = organic matter; RH = relative humidity (%) at 65 °C; M = bovine manure; H = earthworm humus; C = cassava stems; C/N = carbon and nitrogen ratio.

The Table 2 shows the chemical analysis of the organic materials in the substrates such as N, P, K, Ca, Mg, S, C, OM, pH, RH, C/N, Cu, Zn, Fe, Mn and B.

The organic materials were characterized and physically by the wet and dry density of the substrates shown in Table 3.

Table 3 - Wet (W) and dry (D) density of the substrates. Aquidauana, MS, Brazil, 2012.

				Density ($kg.m^{-3}$)			
	S1**	S2	S3	S4	S5	S6	S7
W*	791,11	958,74	1104,50	931,50	1146,2	1229,1	648,14
D	279,83	479,71	500,62	273,65	502,11	648,2	209,47
	S8	S9	S10	S11	S12	S13	S14
W	741,17	838,14	652,16	700,27	816,03	956,67	766,94
D	270,36	399,47	216,58	244,08	376,33	442,97	289,88

*W = Wet density; D = Dry density **S1 = 25% H + 75% V; S2 = 50% H + 50% V; S3 = 75% H + 25% V; S4 = 25% H + 75% C; S5 = 50% H + 50% C; S6 = 75% H + 25% C; S7 = 25% M + 75% V; S8 = 50% M + 50% V; S9 = 75% M + 25% V; S10 = 25% M + 75% C; S11 = 50% M + 50% C; S12 = 75% M + 25% C; S13 = 33,3% H + 33,3% M + 33,3% V; S14 = 33,3% H + 33,3% M + 33,3% C. Source: Authors.

Table 3 shows that the densest wet substrate was S3 and the least dense dry was S7.

Five protected cultivation environments (E) were used: E1: greenhouse, arched-roof galvanized steel frame of 8.0 m wide by 18.0 m long and 4.0 m in height to gutter, covered with 150µm-thick light-diffuser low-density polyethylene film (LDPE), zenithal ventilation along the ridge, and sidewalls and front covered with monofilament 50% shade cover; E2: greenhouse (same dimensions and materials as E1), with additional coverage of thermo-reflective 50% shade cover under LDPE; E3: screened, agricultural galvanized-steel structure of 8.00 m wide by 18.00 m long and 3.50 m in height to gutter, 45º sloped roof, covered with black monofilament 50% shade cover (Sombrite®) in all its extension; E4: screened, agricultural structure (same dimensions as E3), covered with thermo-reflective 50% aluminized shade cover (Aluminet®); and A5: nursery covered with coconut straw (popularly known as bacuri) native to the region, wood frame of 1.20 m wide, 3.0m long and 1.70m in height.

Seeds were sowed on January 27, 2012, including two units per container. Emergence was observed at 15 days after sowing (DAS), and thinning was performed at 47 DAS upon emergence stability. Irrigation was done manually with the use of watering cans, twice a day (morning and afternoon, when necessary), in order to supply the water needs of the seedlings, but taking care not to soak the substrates, keeping them in good condition for root development.

Initially, the Emergence Speed Index (ESI) proposed by Maguire (1962), the Percentage of Emergence (PE) and the Mean Time-to-Emergence (MTE) proposed by Labouriau (1983) were evaluated. Data were collected daily until emergence stability, that is, when the number of emerged plants repeats for three consecutive days, remaining stable, in at least one of the treatments. Plant heights were measured at 60 (PH1) and 120 (PH2) DAS with a ruler in millimeters, and root collar diameter (CD) at 120 DAS with a digital caliper.

Shoot dry mass (SDM) and root dry mass (RDM) of the genipap seedlings were evaluated at 120 DAS. By summing SDM and RDM, total dry mass (TDM) was calculated. In order to measure SDM and RDM, the shoot and root parts of the plants were placed individually in paper sacks and submitted to air drying at 65°C until constant weight.

Shoot/root dry mass ratio (SRR), plant height/shoot dry mass ratio (HSR) and Dickson Quality Index (DQI) (DICKSON et al., 1960) were calculated.

During the experiment, dry bulb and wet bulb temperatures were measured daily at 9 a.m., 12 p.m. and 3 p.m. inside each cultivation environment, in addition to the external temperature. Subsequently, relative humidity was determined and shown in Table 4. Data were collected daily from January 27 to May 26, 2012.

Table 4 - Air temperature (°C) and relative air humidity (%) at 9 a.m., 12 p.m. and 3 p.m. outside and inside the cultivation environments, from January 27 to May 26, 2012, in Aquidauana, Brazil, 2012.

	Air Temperature (ºC)			Air Relative Humidity (%)		
	9 a.m.	12 p.m.	3 p.m.	9 a.m.	12 p.m.	3 p.m.
Greenhouse without cover under film	29.41	32.13	31.82	67.03	57.50	58.40
Greenhouse with cover under film	27.78	31.56	31.59	70.34	58.64	58.61
Screened with black shade cover	28.79	32.60	32.72	66.58	55.08	55.32
Screened with aluminized shade cover	27.26	31.21	31.16	74.15	61.58	62.67
Bacuri coconut straw	26.80	30.36	30.70	77.56	65.02	64.54
Outside	27.25	31.61	31.33	72.24	60.26	62.06

Source: Authors.

It is possible to observe in Table 4 that the highest temperatures occurred in the production system Greenhouse without cover under film, and the lowest in the production system Bacuri coconut straw.

As there were no replicates of the cultivation environments, each one of them was considered an experiment. For each environment, the experimental design was completely randomized, with 4 replicates of 5 seedlings each. Afterwards, the data were submitted to analysis of variance for each substrate, followed by evaluation of the mean residual sum of squares (BANZATTO; KRONKA, 2013) and a joint analysis of the experiments in order to verify the best cultivation environment. Statistical software program Sisvar 5.3 was used, and the means were compared by the Scott-Knott test at 5% probability. The percentage of emergence (PE) results were transformed into arcsin [(x + 0.5) ½].

3. Results and Discussion

According to the analysis of variance, for the evaluated parameters the ratio of the mean residual sum of squares was lower than 7:1 (Banzatto; Kronka, 2013), which allowed performing a joint analysis of the experiments and comparisons between the cultivation environments shown in Table 5.

Table 5 - Analysis of variance with F calculated for emergence speed index (ESI), percentage of emergence (PE), mean time-to-emergence (MTE), plant height (PH) at 60 (PH1) and 120 (PH2) DAS, root collar diameter (CD), shoot dry mass (SDM), root dry mass (RDM), total dry mass (TDM), shoot/root dry mass ratio (SRR), plant height/shoot dry mass ratio (HSR) and Dickson quality index (DQI) of the genipap seedlings. Aquidauana, MS, Brazil, 2012.

	Speed Emergence Index	Percentage Of Emergence	Mean Time-to-Emergence
Environments	35.10**	8.03**	70.48**
Substrates	2.49**	1.44^{NS}	6.61**
Interaction	1.82**	1.35^{NS}	1.45*
CV (%)	16.74	14.51	2.02
MRSR	1.87	2.85	3.49
	Root Collar Diameter	**Plant Height at 60 DAS**	**Plant Height at 120 DAS**
Environments	50.58**	112.50**	48.08**
Substrates	60.82**	72.48**	65.17**
Interaction	3.92**	4.72**	5.64**
CV (%)	13.36	8.46	15.35
MRSR	4.39	1.72	3.06
	Shoot Dry Mass	**Root Dry Mass**	**Total Dry Mass**
Environments	30.09**	56.28**	42.21**
Substrates	75.05**	76.65**	80.34**
Interaction	6.23**	6.80**	6.63**
CV (%)	26.83	29.82	27.11
MRSR	3.20	4.46	3.84
	Shoot/Root Dry Mass Ratio	**Plant Height/Shoot Dry Mass Ratio**	**Dickson Quality Index**
Environments	51.64**	2.37^{NS}	51.95**
Substrates	12.12**	79.95**	75.29**

Interaction	3.5**	7.5**	6.23**
CV (%)	14.27	27.29	28.71
MRSR	2.43	2.91	3.91

[NS] = Not significant; ** = Significant at 1%; * = Significant at 5%; CV = Coefficient of Variation; MRSR= ratio of the highest/lowest mean residual sum of squares. Source: Authors.

From the statistical analysis presented in Table 5, it was possible to observe that there was an interaction between the substrate and the environment. Except for the Percentage of Emergence and Plant Height/ Shoot Dry Mass Ratio.

Table 6 presents the interaction between cultivation environments and substrates (E x S) regarding emergence speed index (ESI) and percentage of emergence (PE) of the genipap seedlings

Table 6 - Interaction between cultivation environments and substrates (E x S) regarding emergence speed index (ESI) and percentage of emergence (PE) of the genipap seedlings. Aquidauana, MS, Brazil, 2012.

**	Emergence Speed Index (ESI)				
	Greenhouses		Screened		Nursery
	Without cover under film	With cover under film	Black cover	Aluminized cover	Bacuri straw
¼ H + ¾ V	4.95bA	8.43 aA	6.92 aA	7.43 aA	5.82 bA
½ H + ½ V	5.04 bA	7.07 aA	8.03 aA	7.05 aA	5.97 bA
¾ H + ¼ V	5.28 bA	5.54 bB	7.99 aA	5.81 bA	5.35 bA
¼ H + ¾ C	5.47 aA	7.12 aA	7.04 aA	6.62 aA	6.09 aA
½ H + ½ C	5.48 aA	6.54 aB	6.79 aA	6.71 aA	6.32 aA
¾ H + ¼ C	5.86 aA	5.74 aB	6.85 aA	6.09 aA	5.48 aA
¼ M + ¾ V	5.36 bA	5.86 bB	7.49 aA	6.91 aA	7.12 aA
½ M + ½ V	4.51 bA	6.53 aB	7.54 aA	6.95 aA	6.81 aA
¾ M + ¼ V	4.82 bA	6.20 aB	7.27 aA	6.68 aA	5.73 bA
¼ M + ¾ C	3.57 bB	6.74 aB	6.07 aB	6.25 aA	5.54 aA
½ M + ½ C	2.76 bB	6.39 aB	6.15 aB	7.08 aA	5.91 aA
¾ M + ¼ C	3.76 bB	7.35 aA	5.87 aB	6.85 aA	6.48 aA
⅓ H + ⅓ M + ⅓ V	4.99 bA	7.53 aA	6.14 bB	6.46 bA	5.71 bA
⅓ H + ⅓ M + ⅓ C	5.72 aA	5.89 aB	5.44 aB	5.70 aA	5.62 aA

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	Percentage of Emergence (PE)				
¼ H + ¾ V	70.00 bA	95.00 aA	80.00 bA	95.00 aA	80.00 aA
½ H + ½ V	75.00 aA	85.00 aA	92.50 aA	87.50 aA	82.50 aA
¾ H + ¼ V	75.00 aA	72.50 aB	87.50 aA	70.00 aA	80.00 aA
¼ H + ¾ C	82.50 aA	90.00 aA	100.00 aA	87.50 aA	87.50 aA
½ H + ½ C	85.00 aA	80.00 aB	90.00 aA	87.50 aA	90.00 aA
¾ H + ¼ C	90.00 aA	70.00 aB	85.00 aA	85.00 aA	82.50 aA
¼ M + ¾ V	82.50 aA	70.00 bB	92.50 aA	90.00 aA	90.00 aA
½ M + ½ V	77.50 aA	85.00 aA	97.50 aA	92.50 aA	92.50 aA
¾ M + ¼ V	72.50 aA	80.00 aB	92.50 aA	82.50 aA	80.00 aA
¼ M + ¾ C	70.00 aA	87.50 aA	90.00 aA	87.50 aA	80.00 aA
½ M + ½ C	55.00 bA	87.50 aA	87.50 aA	95.00 aA	85.00 aA
¾ M + ¼ C	75.00 aA	95.00 aA	82.50 aA	92.50 aA	90.00 aA
⅓ H + ⅓ M + ⅓ V	77.50 aA	92.50 aA	85.00 aA	85.00 aA	87.50 aA
⅓ H + ⅓ M + ⅓ C	87.50 aA	75.00 aB	80.00 aA	80.00 aA	87.50 aA

* The same uppercase letters within a column and same lowercase letters within a row do not differ from one another by the Scott-Knott test at 5% probability; ** H = earthworm humus; V = vermiculite; M = bovine manure; C = shredded cassava stems. Source: Authors.

In general, the lowest emergence speed indices were observed for the environment without thermo-reflective cover under LDPE film (E1) and for the environment covered with bacuri coconut straw (E5), respectively (Table 6).

Emergence occurred at 15 DAS, extending over 47 DAS, a result lower than that observed by Andrade et al. (2000), who noted that cotyledons emerge and expand between day 17 and day 34, extending over 70 days. Vieira and Gusmão (2006) observed that seedling emergence occurred between 19 and 29 DAS. ESI reached the value of 8.43 plants per day, which is higher than the result observed by Sassaqui et al. (2013) of 2.06.

It is known that the amount of water influences the emergence of seedlings (TAIZ; ZEIGER, 2004). During the period from January 27 to February 14, 2012 it rained a total of 44.8 mm (Automatic Weather Station of AQUIDAUANA-A719, National Institute of Meteorology - INMET), which provided more favorable conditions for emergence of the seedlings that were in the environments with less solar radiation. Environment E1 received water only by irrigation, as the LDPE film did not let rainwater inside, besides allowing greater solar radiation over the seedlings, directly hindering greater emergence.

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The ESI for environment A2 (environment covered with LDPE and thermo-reflective cloth under the film) did not differ from that for environment E3 (black shade cloth), differently from that observed by Sassaqui et al. (2013), who found higher values for seedlings grown in a greenhouse and sowed on September 27, 2010 – the season with the least amount of rainfall in the region.

The smallest ESI values were observed for environments A1 and A3 in substrates S10 to S12, (Table 6). These substrates had shredded cassava stems in its constitution - a material that may have caused delayed emergence, as observed by Costa et al. (2012) for baru (Dipteryx alata Vog). Cassava stems, besides allowing less water retention than the organic matter of earthworm humus and bovine manure, may have released some chemical compound that interfered in emergence, causing an allelopathic effect.

The percentage of emergence was above 70%, reaching 100% in plants cultivated in environment A3 with the substrate containing 25% humus + 75% cassava stems (S4); however, there was low variation in the environments and substrates (Table 4). Sassaqui et al. (2013) observed emergence percentages ranging from 75 to 86.5%, lower than those obtained in the present study, while Oliveira et al. (2011) reported values of 83 to 92%. Figliolia and Silva (1998) obtained 94% germination in humid substrate (60 mL water/ 30 g vermiculite) and very humid substrate (90 mL water/ 30 g vermiculite) at 25ºC under white light. In contrast, Vieira and Gusmão (2006) verified maximum value of 49% of emergence.

The Table 7 presents the interaction between environments and substrates regarding MTE and Cd at 120 DAS.

Table 7 - Interaction between environments and substrates (E x S) regarding mean time-to-emergence (MTE) and root collar diameter (CD) at 120 DAS of the genipap seedlings. Aquidauana, MS, Brazil, 2012.

**	Mean Time-to-Emergence (MTE)				
	Greenhouses		Screened		Nursery
	Without cover under film	With cover under film	Black cover	Aluminized cover	Bacuri straw
¼ H + ¾ V	32.20 aB	30.63 bA	30.84 bB	31.50 aA	32.17 aA
½ H + ½ V	32.70 aB	31.19 bA	30.77 bB	31.29 bA	32.21 aA
¾ H + ¼ V	32.61aB	31.80 aA	30.62 bB	31.20 bA	32.66 aA
¼ H + ¾ C	32.72 aB	31.54 aA	32.27 aA	31.95 aA	32.48 aA

½ H + ½ C	32.82 aB	31.28 bA	31.69 bB	31.74 bA	32.37 aA
¾ H + ¼ C	33.00 aB	31.31 bA	31.17 bB	32.08 aA	32.68 aA
¼ M + ¾ V	32.96 aB	31.14 bA	31.39 bB	31.50 bA	31.45 bA
½ M + ½ V	33.86 aA	31.38 bA	31.54 bB	31.70 bA	32.05 bA
¾ M + ¼ V	32.93 aB	31.36 bA	31.46 bB	31.37 bA	32.32 aA
¼ M + ¾ C	34.31 aA	31.71 bA	32.43 bA	32.22 bA	32.64 bA
½ M + ½ C	34.60 aA	31.92 bA	32.29 bA	31.96 bA	32.54 bA
¾ M + ¼ C	33.96 aA	31.47 bA	32.19 bA	31.97 bA	32.23 bA
⅓ H + ⅓ M + ⅓ V	33.08 aB	31.12 bA	32.11 bA	31.73 bA	32.91 bA
⅓ H + ⅓ M + ⅓ C	32.93 aB	31.54 bA	32.50 aA	32.23 bA	33.20 aA
	Root Collar Diameter (CD) at 120 DAS				
¼ H + ¾ V	3.69 aA	3.55 aB	3.31 aE	3.14 aD	3.01 aB
½ H + ½ V	3.23 bB	4.36 aA	4.18 aC	4.88 aB	3.53 bA
¾ H + ¼ V	3.72 cA	4.08 cA	4.71 bB	5.52 aA	3.84 cA
¼ H + ¾ C	2.60 cC	3.39 bB	3.06 bE	4.25 aC	2.61 cB
½ H + ½ C	2.81 bC	4.21 aA	4.67 aB	4.24 aC	3.80 a
¾ H + ¼ C	3.98 cA	4.85 bA	5.48 aA	5.55 aA	3.67 cA
¼ M + ¾ V	2.08 bD	2.49 bC	2.66 bF	3.46 aD	2.67 bB
½ M + ½ V	1.98 cD	2.90 bC	3.58 aD	3.47 aD	2.96 bB
¾ M + ¼ V	2.79 bC	3.40 aB	3.61 aD	3.74 aD	3.24 aA
¼ M + ¾ C	1.90 aD	1.96 aD	1.81 aG	2.14 aE	2.24 aC
½ M + ½ C	2.36 aC	2.77 aC	2.52 aF	2.05 aE	1.92 aC
¾ M + ¼ C	2.46 bC	2.92 aC	1.97 bG	3.17 aD	3.55 aA
⅓ H + ⅓ M + ⅓ V	2.90 cC	4.31 bA	4.19 bC	5.15 aA	3.54 cA
⅓ H + ⅓ M + ⅓ C	3.09 bB	3.62 bB	4.32 aC	4.76 aB	3.60 bA

* The same uppercase letters within a column and same lowercase letters within a row do not differ from one another by the Scott-Knott test at 5% probability; ** H = earthworm humus; V = vermiculite; M = bovine manure; C = shredded cassava stems. Source: Authors.

The mean time-to-emergence (MTE) values for the plants grown with substrates S10, S11 and S12 in the greenhouse without shade cloth under the film (E1) and the one covered with black shade cloth (E3) were high because there were cassava stems in their composition, consequently presenting lower ESI, as this variable is the inverse of the MTE shown in Table 7. In another experiment with baru (Dipteryx alata Vog) carried out by Costa et al. (2012), it was found that cassava stems delay seedling emergence, probably due to some chemical compound or substance such as tannin, which may cause some allelopathic effect.

In the greenhouse without shade cover under the film (E1), higher MTE values were observed for most of the substrates, resulting in a lower ESI (Table 7). In the environment covered with coconut straw (E5), in comparison to the cloth-covered structures (E3 and E4), the seedlings presented greater MTE values, which are in line with the results obtained by Sassaqui et al. (2013).

The environment covered with bacuri straw (E5) had no side protection against winds, directly exposing the seedlings, so more time was required until emergence stability. The overall MTE was 32.08 days, very similar to that found by Sassaqui et al. (2013), which was 32.27 days.

Regarding root collar diameter (CD) at 120 DAS, it was observed that, in the environment covered with monofilament cover (E3) and the one with thermo-reflective cover (E4), substrates S3 and S6 yielded better seedling development, with emphasis to the fact that these substrates were composed of 75% earthworm humus (Table 7). Root collar diameter of 5.55 mm was observed for seedlings cultivated in the aluminized shade cover (E4). This result was superior (4.30 cm) to that observed by Costa et al. (2007) using black soil and bovine manure (2:1) at 150 days after deflasking, which occurred at 21 days after emergence (DAE), in a total of 171 DAE, without counting the days required for onset. Sabonaro (2006) points out that earthworm humus has been requested in substrate composition, since it has high rates of bacteria that facilitate the assimilation of nutrients.

Using substrate S10, with 25% bovine manure + 75% cassava stems, the plants showed the lowest mean root collar diameter, since it contains a very large amount of cassava stems (75%). It is worth mentioning that cassava stems have a high C/N ratio, which may have hampered the availability of nutrients to the plant and negatively influenced the development of the genipap seedlings (Table 2).

The Table 8 presents the interaction between environments and substrates.

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Table 8 - Interaction between environments and substrates (E x S) regarding plant height at 60 (PH1) and 120 (PH2) DAS. Aquidauana, MS, Brazil, 2012.

**	Plant Height at 60 DAS (PH1)				
	Greenhouses		Screened		Nursery
	Without cover under film	With cover under film	Black cover	Aluminized cover	Bacuri straw
¼ H + ¾ V	2.47 bA	3.05 aC	3.21 aB	2.53 bC	2.50 bC
½ H + ½ V	2.50 bA	3.37 aB	3.50 aB	3.26 aB	2.78 bB
¾ H + ¼ V	2.57 dA	3.47 bB	4.06 aA	3.90 aA	3.06 cB
¼ H + ¾ C	2.51 bA	2.84 aC	2.95 aC	3.22 aB	2.52 bC
½ H + ½ C	2.56 cA	3.62 bB	3.93 aA	3.27 bB	3.46 bA
¾ H + ¼ C	2.76 dA	4.23 aA	4.19 aA	3.73 bA	3.33 cA
¼ M + ¾ V	2.04 bB	2.60 aD	2.68 aC	2.78 aC	2.85 aB
½ M + ½ V	2.14 bB	2.77 aC	2.78 aC	2.71 aC	3.05 aB
¾ M + ¼ V	2.23 bB	2.98 aC	2.74 aC	3.06 aB	2.52 bC
¼ M + ¾ C	1.75 bB	2.27 aD	2.11 aD	2.16 aD	2.21 aD
½ M + ½ C	1.94 bB	2.49 aD	2.41 aD	2.27 aD	2.14 bD
¾ M + ¼ C	2.01 bB	2.50 aD	2.21 bD	2.52 aC	2.76 aB
⅓ H + ⅓ M + ⅓ V	2.32 cA	3.62 aB	3.52 aB	3.87 aA	2.96 bB
⅓ H + ⅓ M + ⅓ C	2.40 cA	3.18 bB	3.39 bB	3.81 aA	3.05 bB
	Plant Height at 120 DAS (PH2)				
¼ H + ¾ V	5.65 aA	5.87 aB	5.82 aD	4.47 bC	4.30 bB
½ H + ½ V	5.00 cB	6.48 bB	7.11 bC	8.24 aA	5.10 cB
¾ H + ¼ V	5.61 bA	6.19 bB	8.93 aB	9.07 aA	6.05 bA
¼ H + ¾ C	4.55 bB	5.13 bC	5.75 aD	6.75 aB	4.53 bB
½ H + ½ C	4.73 cB	6.66 bB	8.72 aB	7.07 bB	6.65 bA
¾ H + ¼ C	6.25 dA	8.09 cA	10.88 aA	9.41 bA	6.11 dA
¼ M + ¾ V	3.27 aC	3.93 aD	3.72 aE	4.69 aC	4.56 aB
½ M + ½ V	3.19 bC	4.78 aC	5.13 aD	4.44 aC	4.86 aB
¾ M + ¼ V	4.07 aC	5.35 aC	5.34 aD	5.46 aC	4.90 aB
¼ M + ¾ C	2.70 aC	3.27 aD	2.48 aE	2.35 aD	3.43 aC
½ M + ½ C	3.41 aC	4.08 aD	3.74 aE	3.11 aD	3.11 aC
¾ M + ¼ C	3.59 bC	4.27 bD	3.16 bE	4.95 aC	6.03 aA
⅓ H + ⅓ M + ⅓ V	4.32 cC	6.58 bB	6.88 bC	8.77 aA	5.86 bA
⅓ H + ⅓ M + ⅓ C	4.18 dC	5.01Dc	7.27 bC	8.60 aA	6.07 cA

* The same uppercase letters within a column and same lowercase letters within a row do not differ from one another by the Scott-Knott test at 5% probability; ** H = earthworm humus; V = vermiculite; M = bovine manure; C = shredded cassava stems. Source: Authors.

Evaluating the substrates in terms of plant height, higher mean heights were observed for the seedlings grown with substrate S6 (75% humus + 25% cassava stems), both at 60 and 120 DAS (Table 8), reaching 10.88 cm at 120 DAS under black shade cover (E3). Similar results were obtained by Costa et al. (2007) using black soil and bovine manure (11.00 cm) at 171 DAE, without counting the days required for onset. It can be noticed that this substrate again stood out in relation to the other substrates tested, providing the best averages of root collar diameter and plant height. With reference to plant height, the highest values were obtained in environment E3 using substrate S6 (Table 8). This result is probably related to the greater influence that the external environment exerts on this cultivation environment (E3), for instance greater accumulation of thermal energy and lower relative humidity during the day, rainfall interference, greater acceleration and degradation of organic matter and air circulation, among other things, thus providing better climatic conditions for plant growth.

It is worth noting that all the evaluations showed that the plants cultivated with substrate S6 (75% earthworm humus + 25% cassava stems), regardless of the cultivation environment, achieved better development compared to those using the other substrates (Table 8). Mixing different components in substrate formulations favors seedling growth by improving aeration and providing better arrangement of the organic compounds, greater macroporosity and availability of nutrients, as highlighted by Fernandes and Corá (2001). Additionally, it was noted that at 120 DAS the seedlings were double the height they were at 60 DAS, that is, in 60 days the plants grew and doubled in size (Table 8).

The Table 9 presents the interaction between environments and substrates regarding shoot dry mass and root dry mass of the genipap seedlings.

Table 9 - Interaction between environments and substrates (E x S) regarding shoot dry mass (SDM) and root dry mass (RDM) of the genipap seedlings. Aquidauana, MS, Brazil, 2012.

**	Shoot Dry Mass (SDM)				
	Greenhouses		Screened		Nursery
	Without cover under film	With cover under film	Black cover	Aluminized cover	Bacuri straw
¼ H + ¾ V	1.5644 aA	1.1962 bA	0.9220 cD	0.5669 cE	0.7775 cA
½ H + ½ V	0.8533 cC	1.4118 bA	1.5254 bC	1.8847 aB	0.9249 cA
¾ H + ¼ V	1.7323 aA	1.5092 bA	2.0504 aB	2.1273 aB	1.2297 bA
¼ H + ¾ C	0.4718 bD	0.8587 aB	0.7472 aD	1.1179 aD	0.4720 bB
½ H + ½ C	0.6863 cC	1.4541 bA	1.8824 aB	1.3149 bC	0.9816 cA
¾ H + ¼ C	1.1864 cB	1.7376 bA	2.5614 aA	2.4201 aA	0.9729 cA
¼ M + ¾ V	0.3384 aD	0.3988 aC	0.4095 aE	0.7174 aE	0.5557 aB
½ M + ½ V	0.2387 bD	0.6855 aB	0.9428 aD	0.6077 aE	0.6437 aB
¾ M + ¼ V	0.6926 aC	0.9203 aB	0.8651 aD	0.9507 aD	0.9801 aA
¼ M + ¾ C	0.1736 aD	0.1489 aC	0.0892 aE	0.1008 aF	0.2816 aC

½ M + ½ C	0.3153 aD	0.4399 aC	0.4116 aE	0.2269 aF	0.1783 aC
¾ M + ¼ C	0.5614 bC	0.6044 bB	0.1810 cE	0.7434 bE	1.0253 aA
⅓ H + ⅓ M + ⅓ V	0.7213 cC	1.2714 bA	1.4112 bC	1.8773 aB	1.0588 cA
⅓ H + ⅓ M + ⅓ C	0.7176 bC	0.8448 bB	1.4414 aC	1.5829 aC	1.0161 bA
			Root Dry Mass (RDM)		
¼ H + ¾ V	1.0015 aA	0.8976 aB	0.6508 bD	0.5566 bD	0.4522 bA
½ H + ½ V	0.4112 cC	0.9367 bB	1.1092 bC	1.2956 aB	0.5742 cA
¾ H + ¼ V	1.0133 cA	0.8994 cB	1.3451 bB	1.6352 aA	0.6814 dA
¼ H + ¾ C	0.2084 bD	0.6714 aC	0.4155 aD	0.5008 aD	0.2112 bB
½ H + ½ C	0.3379 cC	1.1242 bB	1.3354 aB	0.9439 bC	0.4991 cA
¾ H + ¼ C	0.6288 bB	1.5346 aA	1.6941 aA	1.7810 aA	0.4811 bA
¼ M + ¾ V	0.1721 aD	0.2747 aD	0.3040 aE	0.4845 aD	0.2869 aB
½ M + ½ V	0.0950 bD	0.4220 aC	0.6071 aD	0.4313 aD	0.3259 aB
¾ M + ¼ V	0.3303 aC	0.5238 aC	0.6163 aD	0.5943 aD	0.4619 aA
¼ M + ¾ C	0.0730 aD	0.0795 aD	0.0580 aE	0.0698 aE	0.1477 a B
½ M + ½ C	0.1582 aD	0.2161 aD	0.2126 aE	0.1200 aE	0.1197 aB
¾ M + ¼ C	0.2178 bD	0.2966 bD	0.0987 bE	0.3607 bD	0.5593 aA
⅓ H + ⅓ M + ⅓ V	0.4729 cC	0.9609 bB	1.1078 bC	1.3277 aB	0.7120 cA
⅓ H + ⅓ M + ⅓ C	0.3442 bC	0.6661 aC	0.8680 aC	0.8432 aC	0.5703 bA

* The same uppercase letters within a column and same lowercase letters within a row do not differ from one another by the Scott-Knott test at 5% probability; ** H = earthworm humus; V = vermiculite; M = bovine manure; C = shredded cassava stems. Source: Authors.

In all cultivation environments, it was verified that substrates ¾ H + ¼ V and ¾ H + ¼ C yielded plants with high shoot, root and total development, as expressed by their shoot, root and total dry masses, with values superior to those of plants grown using other substrates. For these substrates, the plants cultivated under black shade cover and aluminized shade cover had greater biomasses than those grown in the other environments tested (Table 9).

The highest shoot and root biomasses at 120 DAS were 2.5614 and 1.7810 (Table 9), respectively, higher than the results observed by Costa et al. (2007) of 2.19 and 1.73 g at 171 DAE, without counting the days required for onset, even using 3.0 kg single superphosphate per cubic meter of substrate. However, these biomass values were lower than those found by Sassaqui et al. (2013), who obtained 4.7 and 2.0 g, respectively, at 108 DAS.

The substrates containing ¼ M + ¾ C and ½ M + ½ C in all the protected environments yielded seedlings with lower quality than those produced using other substrates, as can be observed in their biomass values and Dikson quality indices (Tables 9 and 11). These substrates also presented higher shoot/root dry mass ratio and higher plant height/shoot dry mass ratio (Table 10), characterizing irregular growth when compared to the other substrates tested.

The Table 10 shows the interaction between environments and substrates regarding shoot/root dry mass ratio, plant height/shoot dry mass ratio of the genipap seedlings.

Table 10 - Interaction between environments and substrates (E x S) regarding shoot/root dry mass ratio (SRR), plant height/shoot dry mass ratio (HSR) of the genipap seedlings. Aquidauana, MS, Brazil, 2012.

**	Shoot/Root Dry Mass Ratio (SRR)				
	Greenhouses		Screened		Nursery
	Without cover under film	With cover under film	Black cover	Aluminized cover	Bacuri straw
¼ H + ¾ V	1.63 aC	1.34 bC	1.45 aB	1.03 bC	1.72 aB
½ H + ½ V	2.08 aB	1.50 bC	1.38 bB	1.45 bC	1.63 bB
¾ H + ¼ V	1.72 aC	1.71 aB	1.53 bB	1.34 bC	1.85 aA
¼ H + ¾ C	2.28 aA	1.28 cC	1.77 bA	2.38 aA	2.26 aA
½ H + ½ C	2.11 aB	1.31 bC	1.39 bB	1.40 bC	2.03 aA
¾ H + ¼ C	1.92 aB	1.14 bC	1.51 bB	1.35 bC	2.02 aA
¼ M + ¾ V	1.98 aB	1.46 bC	1.36 bB	1.50 bC	1.95 aA
½ M + ½ V	2.53 aA	1.67 cB	1.53 cB	1.42 cC	2.01 bA
¾ M + ¼ V	2.09 aB	1.79 bB	1.41 bB	1.59 bC	2.10 aA
¼ M + ¾ C	2.37 aA	1.86 bB	1.53 cB	1.46 cC	1.91 bA
½ M + ½ C	2.03 aB	2.11 aA	1.93 aA	1.90 aB	1.46 bB
¾ M + ¼ C	2.58 a A	2.03 bA	1.84 bA	2.08 bB	1.86 bA
⅓ H + ⅓ M + ⅓ V	1.61 aC	1.35 aC	1.26 aB	1.41 aC	1.52 aB
⅓ H + ⅓ M + ⅓ C	2.15 aB	1.31 cC	1.68 bA	1.88 bB	1.79 bB
	Plant Height/Shoot Dry Mass Ratio (HSR)				
¼ H + ¾ V	3.62 aC	5.26 aC	6.53 aD	7.92 aC	5.54 aD
½ H + ½ V	5.95 aC	4.62 aC	4.77 aD	4.57 aC	5.71 aD
¾ H + ¼ V	3.39 aC	4.15 aC	4.41 aD	4.27 aC	4.95 aD

¼ H + ¾ C	10.43 aB	6.08 bC	8.29 aC	6.02 bC	9.58 aC
½ H + ½ C	7.52 aC	4.73 aC	4.87 aD	5.62 aC	6.78 aD
¾ H + ¼ C	5.58 aC	4.76 aC	4.28 aD	3.92 aC	6.29 aD
¼ M + ¾ V	10.16 aB	10.28 aB	9.14 aC	6.80 aC	8.42 aC
½ M + ½ V	14.84 aA	7.06 bC	5.60 bD	7.77 bC	7.71 bD
¾ M + ¼ V	6.19 aC	5.97 aC	6.21 aD	5.96 aC	5.57 aD
¼ M + ¾ C	16.26 cA	23.16 bA	28.18 aA	23.93 bA	12.24 dB
½ M + ½ C	10.82 cB	9.56 cB	9.24 cC	13.74 bB	20.33 aA
¾ M + ¼ C	6.79 bC	7.30 bC	18.94 aB	6.66 bC	5.95 bD
⅓ H + ⅓ M + ⅓ V	6.10 aC	5.26 aC	5.09 aD	4.79 aC	5.58 aD
⅓ H + ⅓ M + ⅓ C	5.92 aC	6.16 aC	5.11 aD	5.49 aC	6.04 aD

* The same uppercase letters within a column and same lowercase letters within a row do not differ from one another by the Scott-Knott test at 5% probability; ** H = earthworm humus; V = vermiculite; M = bovine manure; C = shredded cassava stems. Source: Authors.

Shoot/root dry mass ratio (SRR) achieved adequate biomass distribution in all substrates, with minimum of 1.03 and maximum of 2.53 (Table 10). According to Brissette (1984), biomass partitioning should be around 2, that is, the shoot biomass should be twice the root biomass, as verified in the present study for many of the substrates and environments. This evaluation parameter allowed observing that the genipap seedlings achieved higher quality than the seedlings studied by Costa et al. (2007) with SRR values of minimum of 5.0 and maximum of 7.7; also higher than those obtained by Sassaqui et al. (2013) with minimum of 2.38 and maximum of 4.07 (SRR).

The plant height/shoot dry mass ratios calculated for the substrates containing ¾ H + ¼ V and ¾ H + ¼ C (Table 9) were similar to those obtained by Sassaqui et al. (2013). Gomes et al. (2002) reported that HSR showed satisfactory results for quality evaluation of Eucalyptus grandis.

The Table 11 presents the interaction between environments and substrates regarding total dry mass and Dickson quality index of the genipap seedlings.

Table 11 - Interaction between environments and substrates (E x S) regarding total dry mass (TDM) and Dickson quality index (DQI) of the genipap seedlings. Aquidauana, MS, Brazil, 2012.

	Total Dry Mass (TDM)				
	Greenhouses		Screened		Nursery
**	Without cover under film	With cover under film	Black cover	Aluminized cover	Bacuri straw
¼ H + ¾ V	2.566 aA	2.094 aB	1.573 bD	1.123 bD	1.230 bA
½ H + ½ V	1.265 cC	2.348 bB	2.635 bC	3.180 aB	1.499 cA
¾ H + ¼ V	2.746 bA	2.409 bB	3.395 aB	3.763 aA	1.911 cA
¼ H + ¾ C	0.680 bD	1.530 aC	1.163 aD	1.619 aD	0.683 bB
½ H + ½ C	1.024 cC	2.578 bB	3.218 aB	2.259 bC	1.481 cA
¾ H + ¼ C	1.815 cB	3.272 bA	4.255 aA	4.201 aA	1.454 cA
¼ M + ¾ V	0.511 aD	0.673 aD	0.713 aE	1.202 aD	0.843 aB
½ M + ½ V	0.334 bD	1.108 aC	1.550 aD	1.039 aD	0.970 aB
¾ M + ¼ V	1.023 aC	1.444 aC	1.481 aD	1.545 aD	1.442 aA
¼ M + ¾ C	0.247 aD	0.228 aD	0.147 aE	0.171 aE	0.429 aB
½ M + ½ C	0.473 aD	0.656 aD	0.624 aE	0.347 aE	0.298 aB
¾ M + ¼ C	0.779 bD	0.901 bD	0.280 bE	1.104 aD	1.585 aA
⅓ H + ⅓ M + ⅓ V	1.194 cC	2.232 bB	2.519 bC	3.205 aB	1.771 cA
⅓ H + ⅓ M + ⅓ C	1.062 bC	1.511 b C	2.309 aC	2.426 aC	1.586 bA
	Dickson Quality Index (DQI)				
¼ H + ¾ V	0.8267 aA	0.7046 aC	0.5023 bD	0.4570 bD	0.3901 bA
½ H + ½ V	0.3494 bC	0.7815 aC	0.8567 aC	1.0112 aB	0.4889 bA
¾ H + ¼ V	0.8434 cA	0.7572 cC	0.9905 bB	1.2800 aA	0.5686 dA
¼ H + ¾ C	0.1694 bD	0.5491 aD	0.3161 bE	0.4235 aD	0.1730 bB
½ H + ½ C	0.2764 cC	0.8989 aB	0.9791 aB	0.7412 bC	0.3982 cA
¾ H + ¼ C	0.5248 bB	1.1665 aA	1.2151 aA	1.3758 aA	0.3948bA
¼ M + ¾ V	0.1445 aD	0.2234 aF	0.2607 aE	0.4174 aD	0.2318 aB
½ M + ½ V	0.0808 bD	0.3386 aE	0.5196 aD	0.3849 aD	0.2681 aB
¾ M + ¼ V	0.2859 aC	0.4351 aE	0.5137 aD	0.5058 aD	0.3982 aA
¼ M + ¾ C	0.0649 aD	0.0647 aF	0.0506 aF	0.0675 aF	0.1249 aB
½ M + ½ C	0.1378 aD	0.1866 aF	0.1823 aE	0.1018 aF	0.0964 aB

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¾ M + ¼ C	0.1928 bD	0.2574 aF	0.0810 bF	0.3058 aE	0.4501 aA
⅓ H + ⅓ M + ⅓ V	0.3936 cC	0.7831 bC	0.8624 bC	1.0313 aB	0.5663 cA
⅓ H + ⅓ M + ⅓ C	0.3076 bC	0.5681 aD	0.6906 aC	0.6587 aC	0.4585 bA

* The same uppercase letters within a column and same lowercase letters within a row do not differ from one another by the Scott-Knott test at 5% probability; ** H = earthworm humus; V = vermiculite; M = bovine manure; C = shredded cassava stems. Source: Authors.

In the greenhouse without cover under film (E1), the largest TDM was observed for substrates containing ¼ H + ¾ V and ¾ H + ¼ V, with 2.566g and 2.746g, respectively. In the environments covered with black shade cover (E3) and aluminized shade cover (E4) and the greenhouse with shade cover under film (E2), the largest TDM was observed for the substrate containing ¾ H + ¼ C, with 4.255g, 4.201g and 3.272g, respectively. These total biomass results were inferior to those observed by Sassaqui et al. (2013), who verified plants weighing 6.95 g with the substrate containing 50% bovine manure + 50% cassava stems. Similarly, the DQI of 1.3758 found in the present study (Table 11) was superior to that verified by the latter authors, who obtained maximum DQI of 1.50 for the substrate containing 50% bovine manure + 50% Vida Verde®. However, the results of the present study were higher than those obtained by Costa et al. (2007) for genipap seedlings with total biomass of 3.82 g using a substrate containing black soil + carbonized rice husk + bovine manure in the ratio 1:1:1. Silva et al. (2018) reported that substrates fertilized soil, fertilized soil + coconut fiber, fertilized soil + sand and bovine manure + sand were more efficient for genipap seedlings.

The nursery covered with bacuri coconut straw (E5) and the greenhouse without cover under film (E1) yielded plants with lower biomasses and lower Dickson quality indices, in addition to higher shoot/root dry mass ratio and high plant height/shoot dry mass ratio (Tables 9, 10 And 11), which are negative factors for genipap seedling growth. The results observed for the bacuri straw nursery (E5) are in agreement with those verified by Sassaqui et al. (2013).

Therefore, this study can present which options are plausible for the cultivation of genipap seedlings in relation to the environment and substrate. These results will used for producers who want to cultivate for fruit production. As well as the planting of genipap seedlings for mitigation deforested areas.

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4. Conclusions

Genipap seedlings have better emergence results in the cultivation environments without shade cover under film.

Mixtures containing ¾ H + ¼ V and ¾ H + ¼ C promote best seedling growth, thus yielding high quality seedlings.

The environment covered with black shade cover and the one with aluminized shade cover promoted best seedling growth, producing seedlings of superior quality. The production system with better efficiency for the cultivation of genipap seedlings also appears to be a sustainable option. Considering that the greenhouse has long durability due to its construction materials, and these materials in addition to having longevity are considered recyclable.

The agricultural greenhouse without thermo-reflecting cover and the nursery covered with bacuri straw did not provide suitable seedling growth and, therefore, are not recommended for genipap seedling formation with the substrates tested.

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