Shading levels and substrates on quality of rose apple seedlings

Geany Giovana Silva da Costa, Josiane Souza Salles*, Eliamara Marques da Silva, Edilson Costa, Alexandre Henrique Freitas de Lima, Flávio Ferreira Binotti, Tiago Zoz, Andréia Froés Galuci Oliveira de Souza

(Department of vegetable ambiance, State University of Mato Grosso do Sul, Cassilândia, MS, Brazil, Zipcode 79.540-000, highway MS 306, km 6.4. Phone: +55(67)35967600)

Abstract: Studies on the formation of fruit tree seedlings provide information that helps in the production system of the species. The objective was to evaluate the effects of shading levels and substrates in the formation of rose apple seedlings. Environments with shading levels of 0% (full sunlight), 18%, 35% and 50% were evaluated. Four alternative substrates from the combinations of soil, bovine manure, Bioplant®, fine sand, and superfine vermiculite were used. A completely randomized design was used to evaluate the substrates, with five replicates of five seedlings and because there were no replicates of the cultivation environments, a joint analysis was carried out, allowing the comparison of the seedling production environments. Rose apple seedlings produced in protected environments had higher height, diameter, and dry mass. Substrates with a higher percentage of bovine manure resulted in the higher growth rate of the seedlings. The production of rose apple seedlings under full sunlight is not feasible. Thus, the production environment with 35% shading associated with the substrate consisting of 0% soil + 45% bovine manure + 20% Bioplant® + 20% fine sand + 15% superfine vermiculite should be recommended for the production of rose apple seedlings.

Keywords: *Syzygium jambos*, fruit tree, plant environment, bovine manure

Citation: Costa, G. G. S. Da, J. S. Salles, E. M. da Silva, E. Costa, A. H. F. de Lima, F. F. Binotti, T. Zoz, and A. F. G. O. de Souza. 2020. Shading levels and substrates on quality of rose apple seedlings. Agricultural Engineering International: CIGR Journal, 22 (4):75-82.

1 Introduction

The rose apple [*Syzygium jambos* (L.) Alston] is a fruit tree, belonging to the Myrtaceae family, and Asian origin specifically from India and Malaysia. The plant can reach up to 20 meters of height with dense branches, the fruit is characterized by pyriform drupe, and when ripe the coloration may vary from red to purplish purple, containing only one seed, with white flesh, thick, juicy and acidified taste. The inflorescence contains up to twelve flowers, being these hermaphrodites, and the species may bloom several times in the year (Benza, 1993; Cavalcante, 1991), but the plant's biological cycle depends on the edaphoclimatic condition of each region. Also, the vitamin C present in fruit peel is considered an excellent source of fiber and has high antioxidant potential, as well as high levels of lipids, carbohydrates, and proteins, demonstrating the great relevance of the species for diet (Augusta et al., 2010).

Many fruit species, both native and exotic, are widely distributed in the Brazilian Cerrado region and have potential for extractive exploitation due to the high potential for use in feeding and recovery of vegetation in degraded areas. Therefore, studies on the method of propagation and formation of seedlings are significant for commercial production. Thus, the plant environment is

Received date: 2019-04-17 **Accepted date:** 2019-09-13

* **Corresponding author: Josiane Souza Salles,** MSc., State University of Mato Grosso do Sul, Cassilândia, MS, Zipcode 79540-000, Brazil. Email: josi_souzasalles@hotmail.com. Tel: +55(67)35967600.

one of the most important factors for the formation of high-quality seedlings. There are several models of greenhouses or agricultural nurseries, and each plant species is best adapted to a particular condition of the growing environment. Therefore, there is a need for scientific research.

Growing environments minimize losses of seedling production, provide better thermal conditions for plants, reduce seedling emergence time and permanence time in nurseries, increase efficiency in technical management processes and increase seedling quality, which when planted to the field have greater resistance to climatic weather and attack of pests and diseases. According to Oliveira et al. (2012), the protected environment provides a set of elements that simulate the climatic conditions of the field, allowing better microclimate for seedling growth, quality, and yield.

Another important factor in producing quality seedlings is the use of substrates that provide adequate conditions for root development and support to plants. These substrates can be composed of vermiculite, sand, soil, pine bark, rice husk, commercial material, bovine manure, and goat manure, among others. Among the organic materials, bovine manure is the more used in the formulation of substrates form the production of several tree species, fruit plants, and vegetables. According to Costa et al. (2015), during the seedling production phase, the association of suitable substrates with protected environments in addition to the correct management of the production activities, provide ideal conditions to obtain uniformity and quality in the production system.

Several studies were carried out to define the best method for the conduction and formation of native or exotic seedlings for commercial production, aiming to reduce with exploratory activities and contribute to the vegetation preservation, such as the reports of Costa et al. (2015) and Pinho et al. (2018) for baru seedlings (*Dipteryx alata* Vog.), Salles et al. (2017) for jambolan (*Syzygium cumini* (L.) Skeels), Silva et al. (2018a) and Silva et al. (2018b) for achachairu (*Garcinia humilis* Vahl.), Arrua et al. (2016) for the mangaba (*Hancornia speciosa* Gomez), and Sanches et al. (2017) for jatoba seedlings (*Hymenaea courbaril* L.).

Information about the mode of conduction and formation of seedlings is variable with each species studied. Therefore, studies on the growth and formation of fruit tree seedlings in protected environments associated with the appropriate substrates, allow results that aid in the production systems of rose apple trees. Thus, the objective of the work was to evaluate the effects of different shading levels and substrates on the formation of rose apple seedlings (*Syzygium jambos* (L.) Alston).

2 Material and methods

Experiments with the formation of rose apple seedlings at different shading levels and substrates were conducted at Mato Grosso do Sul State University (UEMS), in Cassilândia, MS, Brazil (19º07'21" S, 51º43'15" W and altitude of 516 m), from November 2015 to February 2016. According to Köppen's climatic classification, the region has rainy tropical climate (Aw), characterized by being warm and humid, with two defined seasons, rainy in summer and dry in winter.

Four environments with different levels of shading were tested: seedling exposed to full sunlight with 0% shading (A1); agricultural shading screenhouse with a wooden structure, measuring 6.00 m width by 6.00 m length and 2.50 m high, closing at 90° inclination, with black shading screen (Sombrite®) on the sides and roof providing 18% of shade (A2); agricultural shading screenhouse with 6.00 m width by 6.00 m length and 2.50 m high, closing at 90º inclination, with black shading screen (Sombrite®) on the sides and roof providing 35% of shade (A3); and, agricultural shading screenhouse with galvanized steel structure, measuring 8.00 m width by 18.00 m length and 3.50 m high, closing at 45° inclination, with black shading screen (Sombrite®) on the sides and roof providing 50% of shade (A4). In these protected environments, the rose apple seedlings produced from seeds were grown in black polyethylene bags (15.0 × 25.0 cm), with a capacity of 1.8 liters. These containers were filled with substrates (S) from the combinations of sandy soil (SS), bovine manure (BM), Bioplant® (B), fine sand (FS) and superfine vermiculite (SFV), as shown in Table 1.

Table 1 Substrates formulated from different proportions (v:v) of sandy soil (SS), bovine manure (BM), Bioplant® (B), fine sand (FS) and superfine vermiculite (SFV)

Substrates (S)	Sandy soil (%)	Bovine manure (%)	Bioplant (%)	Fine sand (%)	Superfine Vermiculite (%)
S1	0	45	20	20	15
S2	15	30	20	20	15
S3	30	15	20	20	15
S4	45	0	20	20	15

The fresh bovine manure was acquired from the cattle slaughterhouse of the region, and subjected to aerobic composting for 45 days, in a closed shed, being stirred and moistened every two days. The composted material was then dried, homogenized, and sifted through a 3.70 mm mesh, and the main chemical and physical characteristics of the bovine manure are shown in Table 2. The soil was collected at from the 0 to 40 cm depth layer in a Cerrado native area located in the municipality of Cassilândia-MS, and the main chemical and physical characteristics of the sandy soil are shown in Table 3. The sand, Bioplant®, and vermiculite were purchased from commercial companies.

Table 2 Physicochemical characteristics of bovine manure used in the composition of the substrates for the formation of rose apple seedlings

N	P_2O_5	K_2O	Ca	Mg	S	H at 65ºC	C
-- % in natura ---							
0.9	0.3	0.1	0.3	0.1	0.2	2.0	11.0
Na	Cu	Fe	Mn	Zn	C/N	pH	O.M.
------------------ mg kg^{-1} in natura ----------------						$CaCl_2$	% in natura
624	18	12,103	204	53	12/1	5.3	20.0

Note: H = humidity; O.M. = organic matter; C/N = carbon and nitrogen ratio.

Table 3 Physicochemical characteristics of the sandy soil (SS) used in the composition of the substrates for the formation of rose apple seedlings

pH	------- cmol$_c$ dm^{-3} -------			mg dm^{-3}		cmol$_c$ dm^{-3}	Particle size (g kg^{-1})		
$CaCl_2$	Ca	Mg	Al	K	$P_{Mehlich-1}$	CEC	Clay	Silt	Sand
5.8	6.10	2.20	0.01	165	1.8	11.1	110	50	840
mg dm^{-3}		--------- mg dm^{-3} Mehlich-1---------					g dm^{-3}		%
S	B	Cu	Fe	Mn	Zn	Na	O.M.	O.C.	V
4.8	0.24	0.4	14	90.5	1.7	n.d.	35.6	20.6	78.4

Note: O.M.: organic matter. O.C. = organic carbon. V: soil base saturation. n.d.: not detected.

The water reposition was carried out daily with manual watering, in order to maintain the water content of the substrates close to the field capacity for the adequate development of the roots. Two rose apple seeds were sown per container at 3.0 cm depth, and after the establishment, they were thinned to one plant per container. The seedling emergence was recorded at 28 days after sowing (DAS). At 60, 74, 91 and 106 days after sowing (DAS), the plant height (PH) and stem diameter (SD) were measured using a millimeter ruler and digital caliper, respectively. At 106 DAS, the shoot dry mass (SDM) and root dry mass (RDM) were determined after drying in an oven at 65ºC, until constant mass. From the SDM and RDM, the total dry mass (TDM) was calculated.

The Dickson quality index (DQI) was determined from the morphological characteristics using the following equation proposed by Dickson et al. (1960):

$$DQI = \frac{TDM}{\frac{PH}{SD} + \frac{SDM}{RDM}} \quad (1)$$

where TDM is total dry mass (g); PH is plant height (cm); SD is stem diameter (mm); SDM is shoot dry mass (g); and RDM is root dry mass (g).

The absolute growth rate (AGR) was determined from the morphological characteristics using the following equation proposed by Benincasa (2003):

$$AGR = \frac{PH4 - PH1}{T2 - T1} \quad (\text{cm plant}^{-1}\ \text{day}^{-1}) \quad (2)$$

where, *PH4* and *PH1* were the plant height of last and first samplings (cm); and, T_2 and T_1 represented the sampling time (days).

In the protected environments, the data of photosynthetically active radiation (μmol m^{-2} s^{-1}), air temperature (ºC) and relative humidity (%) were gathered daily using a GP2 Datalogger installed within the seedling production environments. The system was programmed to perform readings at 10-second intervals, with averages every minute. For the radiations, the daily average was calculated from 7:00 to 18:00 hours. In the full sunlight environment, the data concerning air temperature and relative air humidity were obtained from an automatic weather station of the Brazilian National Institute of Meteorology (A742, INMET-SONABRA), while photosynthetically active radiation was collected at midday (± 12:00 h) using a photosynthetically active radiation meter (APOGEE MQ-200). Data collected during the experiment are shown in Figures 1, 2 and 3.

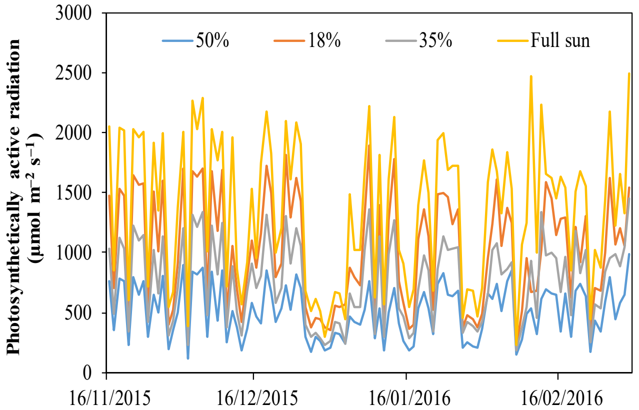

Figure 1 Photosynthetically active radiation (μmol m^{-2} s^{-1}) in full sunlight conditions, and inside the seedling production environments constructed with 18%, 35%, and 50% shading screens

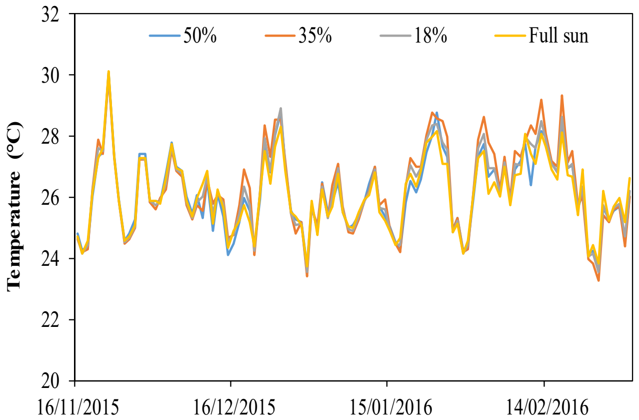

Figure 2 Temperature (°C) in full sunlight conditions, and inside the seedling production environments constructed with 18%, 35%, and 50% shading screens

Since there were no replicates of the seedling production environments, each one was considered an experiment. In each environment, completely randomized design was used to evaluate the four substrate compositions, with five replicates of five plants each. Subsequently, the residual mean squares of the analyzes of individual variances of the substrates were evaluated to verify the homogeneity of variances. The results were submitted to analysis of variance and the means compared by Tukey test at 5% probability level.

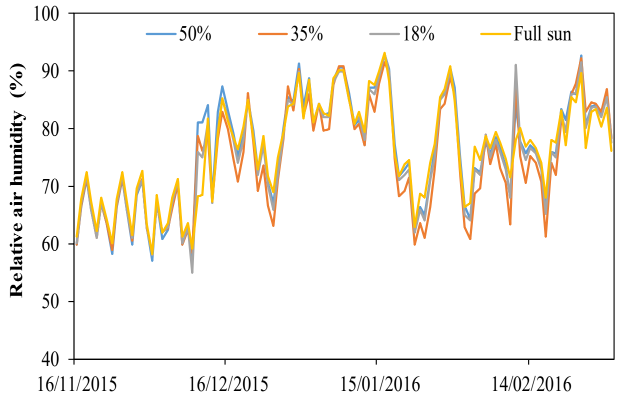

Figure 3 Relative air humidity (%) in full sunlight conditions, and inside the seedling production environments constructed with 18%, 35%, and 50% shading screens

3 Results and discussion

It was possible to perform joint analysis, and the comparison of seedling production environments for all variables measured since the ratio between the largest and smallest residual mean square (RMSR) was lower than 7 (Table 4) (Banzato and Kronka, 2013).

Table 4 Residual mean square and residue mean square ratio (RMS_R) for the joint analysis of rose apple seedlings

Production environment	PH_1	PH_2	PH_3	PH_4	SD_1	SD_2	SD_3
Full sunlight	0.8545	0.8012	1.6244	2.2745	0.0250	0.0415	0.0689
18% shading	1.4526	1.8217	1.9640	3.3782	0.0314	0.0519	0.0959
35% shading	0.5860	1.7525	1.2903	3.9170	0.0449	0.0443	0.0997
50% shading	1.3457	4.3543	4.7502	6.2678	0.0774	0.0647	0.0894
RMSR	2.48	5.44	3.68	2.76	3.10	1.56	1.45
Production environment	SD_4	SDM	RDM	TDM	HSDMR	DQI	AGR
Full sunlight	0.0546	0.0237	0.0042	0.0390	52.5913	0.00099	0.00090
18% Shading	0.0699	0.0564	0.0058	0.0574	17.9422	0.00063	0.00085
35% Shading	0.1148	0.0380	0.0069	0.0681	2.7908	0.00116	0.00107
50% Shading	0.0466	0.1066	0.0059	0.1580	11.9651	0.00104	0.00125
RMSR	2.46	4.63	1.65	4.05	18.84	1.85	1.47

Note: RMSR: ratio between the residual mean square of individual analyses of the four production environments. PH: plant height. SD: stem diameter; SDM: shoot dry mass (SDM). RDM: root dry mass. TDM: total dry mass. HSDMR: height-shoot dry mass ratio. DQI: Dickson quality index. AGR: absolute growth rate.

The analysis of variance did not show a significant effect for the interaction between environments and substrates for the shoot dry mass (SDM), total dry mass (TDM), Dickson quality index (DQI) and absolute growth rate (AGR). However, there was significance for environments or substrates for most of the variables measured (Table 5).

Table 5 Significance of variance analysis of rose apple seedlings grown in different shading levels and substrates

Cause of variation	PH_1	PH_2	PH_3	PH_4	SD_1	SD_2	SD_3
Environment (E)	**	**	**	**	**	**	**
Substrates (S)	ns	ns	**	**	ns	ns	ns
E × S	ns	ns	ns	ns	ns	ns	ns
RMSR	2.48	5.44	3.68	2.76	3.10	1.56	1.45
Cause of variation	SD_4	SDM	RDM	TDM	HSDMR	DQI	AGR
Environment (E)	**	**	**	**	**	**	**
Substrates (S)	*	**	**	**	*	**	**
E × S	ns	**	ns	**	ns	*	*
RMSR	2.46	4.63	1.65	4.05	18.84	1.85	1.47

Note: *: significant at 5%; **: significant at 1%, ns: non-significant; RMSR: ratio between the residual mean square of individual analyses of the four production environments. Plant height (PH1, PH2, PH3, and PH4) and stem diameter (SD1, SD2, SD3, and SD4) at 60, 74, 91 and 106 days after sowing. SDM; shoot dry mass. RDM: root dry mass. TDM: total dry mass. HSDMR: height-shoot dry mass ratio. DQI: Dickson quality index (DQI). AGR: absolute growth rate.

For the variable plant height (pH) at 60, 74, 91 and 106 days after sowing (DAS) the largest seedlings were produced in the protected environments, with an average of 14.44 cm in height compared to the full sunlight environment with 10.89 cm (Table 6). Emphasizing the relevance of the seedling production environment, as the effect of light on plant development and cell metabolism, according to Taiz and Zeiger (2013) consists of photomorphogenesis, and one of the responses induced by high irradiance consists of the inhibition of hypocotyl elongation, inhibiting stem growth, corroborating with the results obtained (Table 6).

Table 6 Plant height of rose apple seedlings at 60 (PH_1), 74 (PH_2), 91 (PH_3) and 106 (PH_4) days after sowing

Environments or Substrates	HS1	HS2	HS3	HS4
Full sunlight (0%)	5.49 B	6.61 C	9.15 B	10.89 B
Shading level (18%)	6.99 A	8.60 B	12.63 A	14.08 A
Shading level (35%)	7.71 A	10.18 A	12.34 A	15.27 A
Shading level (50%)	7.22 A	9.32 AB	12.21 A	13.97 A
S1: 0%SS+45%BM+20%B+20%FS+15%SFV	7.37 A	9.43 A	12.64 A	15.44 A
S2: 15%SS+30%BM+20%B+20%FS+15%SFV	6.62 A	8.51 AB	11.66 AB	13.84 AB
S3: 30%SS+15%BM+20%B+20%FS+15%SFV	6.73 A	8.62 AB	11.60 AB	13.46 B
S4: 45%SS+0%BM+20%B+20%FS+15%SFV	6.70 A	8.14 B	10.43 B	11.47 C
CV (%)	15.01	17.02	13.39	14.68

Note: SS: sandy soil; BM: bovine manure; B: Bioplant® (B); FS: fine sand; SFV: superfine vermiculite (SFV). Mean followed by distinct letters in the column show significant differences by the Tukey test at 5% probability level.

At 60 DAS there was no difference between the substrates used, however from the 74 DAS, significant differences were recorded with the use of substrates between 30% and 45% of bovine manure (S1 and S2) that favored the higher growth (Table 6). This fact demonstrates that at the beginning of the growth period due to the short period of time (60 DAS) there was no difference, since this species presents a high amount of reserve substances, so the seed reserve was nourishing the seedlings, but after total reserve degradation, the seedlings needed the nutrients contained in the substrate.

Rose apple seedlings produced in the protected environment showed a higher stem diameter since the higher intensity of direct radiation in the seedlings influenced the growth in thickness, that is, smaller stem diameter (Figure 1). Since the environment with 35% of shading stood out about the others, as it presented the highest stem diameter in all the evaluation periods (Table 7).

The substrates did not influence the increase of the stem diameter until the 91 DAS, only in the last evaluation to the 106 days after the sowing, differences between the stem diameter of the rose apple seedlings were observed, which presented greater stem diameter in the substrates S1, S2, and S3, with formulation varying from 0% to 30% of sandy soil and from 15% to 45% of bovine manure (Table 7).

In a study with the jambolan fruit, the same family of the rose apple, Salles et al. (2017) report that the production of seedlings in full sunlight is not feasible, and that seedlings formed by 18% and 30% shading, favored growth in diameter, dry mass, and quality.

Table 7 Stem diameter of rose apple seedlings at 60 (SD_1), 74 (SD_2), 91 (SD_3) and 106 (SD_4) days after sowing

Environments or Substrates	ND1	ND2	ND3	ND4
Full sunlight (0%)	1.33 B	1.26 C	1.78 B	2.16 C
Shading level (18%)	1.48 AB	1.52 B	2.10 A	2.66 AB
Shading level (35%)	1.56 A	1.83 A	2.23 A	2.74 A
Shading level (50%)	1.53 A	1.84 A	2.11 A	2.44 B
S1: 0%SS+45%BM+20%B+20%FS+15%SFV	1.53 A	1.73 A	2,16 A	2.66 A
S2: 15%SS+30%BM+20%B+20%FS+15%SFV	1.51 A	1.60 A	2.01 A	2.47 AB
S3: 30%SS+15%BM+20%B+20%FS+15% SFV	1.47 A	1.56 A	2.09 A	2.45 AB
S4: 45%SS+0%BM+20%B+20%FS+15% SFV	1.40 A	1.55 A	1.96 A	2.43 B
CV (%)	14.27	13.91	14.44	10.67

Note: SS: sandy soil; BM: bovine manure; B: Bioplant® (B); FS: fine sand; SFV: superfine vermiculite (SFV). Mean followed by distinct letters in the column show significant differences by the Tukey test at 5% probability level.

The highest means for root dry mass (RDM) was observed in the seedlings produced in protected environments, evidencing that the direct radiation incident on the seedlings affected the photosynthetic process, which may have caused an increase in the respiratory rate, accelerating the metabolic process and decreasing, thus the accumulation of dry matter in all parts of the plants (Table 8).

Regarding the substrates, it is verified according to the results obtained that the seedlings respond well to the higher contents of nutrients, coming from organic matter, provided by the substrate (Table 8). In that, the substrate S1 formed seedlings with higher RDM, but not differ from the substrate S4, so it is noted that the greatest accumulation of RDM occurred on substrates containing 45% bovine manure or 45% sandy soil.

The height-shoot dry mass ratio (HSDMR) is a relation that shows the distribution of plant growth, and the lower values for this relation indicate a higher survival capacity of the seedlings when submitted to the field (Gomes et al., 2002), pointing out that the relationship is in equilibrium, so the seedlings are of quality.

In the present study, the protected environments had an adequate balance between the ratios, with lower mean values of HSDMR (Table 8). As for the substrates, the seedlings produced in the substrate S3 presented the lowest mean but did not differ from the substrates S1 and S2, or with substrates with 0% to 30% of sandy soil and 15% to 45% of bovine manure provided the best relations (Table 8).

Table 8 Root dry mass (RDM) and height/shoot dry mass ratio (HSDMR) of rose apple seedlings at 106 days after sowing

Environments or Substrates	RDM	HSDMR
Full sunlight (0%)	0.17 B	20.76 A
Shading level (18%)	0.32 A	14.34 B
Shading level (35%)	0.37 A	13.00 B
Shading level (50%)	0.37 A	13.18 B
S1: 0%SS + 45%BM + 20%B + 20%FS + 15%SFV	0.36 A	15.27 AB
S2: 15%SS + 30%BM + 20%B + 20%FS + 15%SFV	0.29 B	15.15 AB
S3: 30%SS + 15%BM + 20%B + 20%FS + 15% SFV	0.27 B	13.19 B
S4: 45%SS + 0%BM + 20%B + 20%FS + 15% SFV	0.30 AB	17.66 A
CV (%)	24.23	30.13

Note: SS: sandy soil; BM: bovine manure; B: Bioplant® (B); FS: fine sand; SFV: superfine vermiculite (SFV). Mean followed by distinct letters in the column show significant differences by the Tukey test at 5% probability level.

For the variables SDM, TDM, AGR, and DQI there was an interaction between environments and substrates. For the dry mass for shoots and roots, the results were similar, and in the full sunlight, the seedlings presented smaller dry mass production (Table 9) emphasizing that the higher incidence of photosynthetically active radiation can be detrimental to the initial growth of rose apple seedlings. Similar results were verified by Salles et al. (2017) for the jambolan, and Silva et al. (2018b) for achachairu seedlings that do not recommend the production of seedlings in full sunlight (0% shading), since direct solar radiation for some species can be harmful in the initial growth phase.

Regarding the substrates, in the environment in full sunlight, for the SDM and TDM, the substrates did not differ statistically, however in the other environments, these presented differences, and in all environments the substrate S1 presented conditions that favored the growth of the seedlings and consequently their greater accumulation of dry mass (Table 9). Thus, the influence of the shading level is observed, because according to the presented results there is the need of shading for the seedlings to be able to extract the maximum of nutrients without accelerating the metabolic process, improving the distribution of photo assimilates to the regions of demand, thus favoring the greater accumulation of total dry mass.

Table 9 Effects of shading levels and substrates on shoot dry mass (SDM) and total dry mass (TDM) of rose apple seedlings at 106 days after sowing

Substrates	Environments			
	0%	18%	35%	50%
Shoot dry mass (SDM)				
S1: 0%SS+45%BM+20%B+20%FS+15%SFV	0.51 Ac	1.04 ABb	1.57 Aa	1.60 Aa
S2: 15%SS+30%BM+20%B+20%FS+15%SFV	0.50 Ab	1.30 Aa	1.14 Ba	1.32 ABa
S3: 30%SS+15%BM+20%B+20%FS+15% SFV	0.71 Ab	1.16 Aa	1.21 ABa	1.18 Ba
S4: 45%SS+0%BM+20%B+20%FS+15% SFV	0.59 Aa	0.74 Ba	0.89 Ba	0.60 Ca
CV (%)	23.66			
Total dry mass (TDM)				
S1: 0%SS+45%BM+20%B+20%FS+15%SFV	0.72 Ac	1.41 ABb	2.02 Aa	2.05 Aa
S2: 15%SS+30%BM+20%B+20%FS+15%SFV	0.67 Ab	1.62 Aa	1.42 Ba	1.73 ABa
S3: 30%SS+15%BM+20%B+20%FS+15% SFV	0.87 Ab	1.42 ABa	1.56 ABa	1.51 Ba
S4: 45%SS+0%BM+20%B+20%FS+15% SFV	0.75 Ab	1.10 Bab	1.31 Ba	0.90 Cab
CV (%)	21.50			

Note: SS: sandy soil; BM: bovine manure; B: Bioplant® (B); FS: fine sand; SFV: superfine vermiculite (SFV). Mean followed by distinct uppercase letters, in the columns for the substrates or distinct lowercase letters, in the rows between seedling production environments show significant differences by Tukey test at the 5% probability level.

According to Benincasa (2003), the absolute growth rate is the variation or increment of the growth in grams per day between two samples throughout the plant cycle. In relation to the presented results, for the substrate S1, the highest growth rates occurred in the environments with 18%, 35% and 50% of shading, for the substrate S2, there was no difference in function of the environment, for the substrate S3 occurred in the environments 35% and 50% shading, whereas in the seedlings formed in the substrate S4 the best performances demonstrated through the absolute growth rate occurred in the environments of 18% and 35% (Table 10).

It was evident that the 35% shading environment for all substrates provided conditions that promoted adequate plant performance. In general, the substrate S2 had the highest absolute growth rate in all environments, as well as S1, except for the environment in full sunlight (Table 10).

Table 10 Effects of shading levels and substrates on the absolute growth rate (AGR) of rose apple seedlings at 106 days after sowing

Substrates	Environments			
	0%	18%	35%	50%
S1: 0%SS+45%BM+20%B+20%FS+15%SFV	0,14 Ab	0,16 Aab	0,20 Aa	0,20 Aa
S2: 15%SS+30%BM+20%B+20%FS+15% SFV	0,13 ABa	0,18 Aa	0,16 ABa	0,16 Aa
S3: 30%SS+15%BM+20%B+20%FS+15% SFV	0,12 ABb	0,13 Ab	0,18 Aa	0,15 Aab
S4: 45%SS+0%BM+20%B+20%FS+15% SFV	0,08 Bb	0,14 Aa	0,11 Bab	0,08 Bb
CV (%)	21.42			

Note: SS: sandy soil; BM: bovine manure; B: Bioplant® (B); FS: fine sand; SFV: superfine vermiculite (SFV). Mean followed by distinct uppercase letters, in the columns for the substrates or distinct lowercase letters, in the rows between seedling production environments show significant differences by Tukey test at the 5% probability level.

The DQI allows evaluating the quality of the seedlings and the balance between them, as well as the quality index of the seedlings when submitted to field conditions (Gomes and Paiva, 2012). For the full sunlight and environment of 18% shading, there is no difference between the substrates. In the environment with 35% shading the substrates S1 and S4, they form the quality seedlings. While in the environment with 50% shading, substrate S1, S2, and S3 are more indexes of quality than substrate S4, Table 11.

For each substrate within the four levels of shading, the substrate S1 formed quality seedlings in the environment with 35% shading, not differing from the environment with 50% shading while the substrates S2 and S3 in the three protected environments presented superior quality to the full sunlight environment, and the seedlings conducted in the substrate S4 presented a higher quality index in the environments 18% and 35% of shading (Table 11).

The nutritional requirement varies according to species. The formation of rose apple seedlings, in a stage of seedling formation, are independent of the substrates used. After this phase, the substrate contained 45% bovine manure, added greater growth and dry mass accumulation as seedlings, forming quality seedlings. In this way, the observation of reaction responds favorably to the higher content of organic matter.

Table 11 Effects of shading levels and substrates on Dickson quality index (DQI) of rose apple seedlings at 106 days after sowing

Substrates	Environments			
	0%	18%	35%	50%
S1: 0%SS+45%BM+20%B+20%FS+15%SFV	0.090 Ac	0.169 Ab	0.221 Aa	0.206 Aab
S2: 15%SS+30%BM+20%B+20%FS+15%SFV	0.084 Ab	0.166 Aa	0.145 Ba	0.188 Aa
S3: 30%SS+15%BM+20%B+20%FS+15% SFV	0.094 Ab	0.147 Aa	0.156 Ba	0.159 ABa
S4: 45%SS+0%BM+20%B+20%FS+15% SFV	0.087 Ac	0.155 Aab	0.196 ABa	0.135 Bbc
CV (%)	20.55			

Note: SS: sandy soil; BM: bovine manure; B: Bioplant® (B); FS: fine sand; SFV: superfine vermiculite (SFV). Mean followed by distinct uppercase letters, in the columns for the substrates or distinct lowercase letters, in the rows between seedling production environments show significant differences by Tukey test at the 5% probability level.

4 Conclusion

The production of rose apple seedlings under full sunlight is not feasible. Thus, the production environment with 35% shading associated with the substrate consisting of 0% sandy soil + 45% bovine manure + 20% Bioplant® + 20% fine sand + 15% superfine vermiculite should be recommended for the production of rose apple seedlings.

References

Arrua, L. C., E. Costa, E. M. Bardiviesso, D. M. Nascimento, and F. F. S. Binotti. 2016. Protected environments and substrates for mangabeira seedlings (*Hancornia speciosa* gomez) production. *Engenharia Agrícola*, 36(6): 984-995.

Augusta, I. M., J. M. Resende, S. V. Borges, M. C. A. Maia, and M. A. P. G. Couto. 2010. Caracterização física e química da casca e polpa de jambo vermelho (*Syzygium malaccensis*, (L.) Merryl and Perry). *Ciência e Tecnologia de Alimentos*, 30(4): 928-932.

Banzatto, D. A., S. N. Kronka. 2013. *Experimentação Agrícola*. 4. ed. Jaboticabal-SP: FUNEP.

Benincasa, M. M. P. 2003. *Análise De Crescimento De Plantas.* Jaboticabal–SP: FUNEP.

Benza, J. C. 1993. *Frutales Nativos*. pp.143. La molina: Universidad Nacional Agrária La Molina.

Cavalcante, P. B. 1991. *Frutas Comestíveis Da Amazônia*. 5th ed. Belém: Edições CEJUP, CNPq/Museu Paraense Emílio Goeldi.

Costa, E., J. G. Dias, K. G. Lopes, F. F. S. Binotti, and E. D. Cardoso. 2015. Telas de sombreamento e substratos na produção de mudas de *Dipteryx alata* Vog. *Floresta e Ambiente*, 22(3): 416-425.

Dickson, A., A. L. Leaf, J. F Hosner. 1960. Quality appraisal of white spruce and white pine seedling stock in nurseries. *Forestry Chronicle*, 36(1): 10-13.

Gomes, J. M., L. Couto, H. G. Leite, A. Xavier, and S. L. R. Garcia. 2002. Parâmetros morfológicos na avaliação da qualidade de mudas de *Eucalyptus grandis*. *Revista Árvore*, 26(6): 655-664.

Gomes, J. M., and H. N. Paiva. 2012. *Viveiros Florestais: Propagação Sexuada*. Viçosa-MG: Editora UFV.

Oliveira, L. C., E. Costa, J. A. S. Cortelassi, E. T. Rodrigues. 2012. Formation of beetroot seedlings in different protected environments, substrates and containers in Aquidauana region, State of Mato Grosso do Sul, Brazil. *Engenharia Agrícola*, 32(3): 415-422.

Pinho, E. K. C., A. N. K. Lopes, A. C. Costa, A. B. V. Silva, F. C. M. Vilar, R. G. E. Reis. 2018. Substratos e tamanhos de recipiente na produção de mudas de baruzeiro (*Dipteryx alata* Vog.). *Ciência Agrícola*, 16(1): 11-19.

Salles, J. S., A. H. F. Lima, and E. Costa. 2017. Mudas de jambolão sob níveis de sombreamento, bancadas refletoras e profundidade de semeadura. *Revista de Agricultura Neotropical*, 4(Supl.1): 110-118.

Sanches, C. F., E. Costa, G. G. S. Costa, F. F. S. Binotti, and E. D. Cardoso. 2017. Mudas de *Hymenaea coubaril* em ambientes protegidos e substratos. *Engenharia Agrícola*, 37(1): 24-34.

Silva, B. L. B., E. Costa, J. S. Salles, F. F. S Binotti, and C. G. S. Benett. 2018a. Protected environments and substrates for achachairu seedlings. *Engenharia Agrícola*, 38(3): 309-318.

Silva, B. L. B., E. Costa, F. F. S. Binotti, C. G. S. Benett, and A. G. Silva. 2018b. Growth and quality of *Garcinia humilis* seedlings as a function of substrate and shading level. *Pesquisa Agropecuária Tropical*, 48(4): 407-413.

Taiz, L., and E. Zeiger. 2013. *Fisiologia Vegetal*. 5th ed**.** Porto Alegre-RS: Artmed.