Article

Reflective material on cultivation benches and rice straw over the substrate in papaya seedling production

Rogério do Carmo Cabral[1]
Eduardo Pradi Vendruscolo[1]
Murilo Battistuzzi Martins[1]
Tiago Zoz[1]
Edilson Costa[1]
Abimael Gomes da Silva[2§]

[1]Universidade Estadual de Mato Grosso do Sul-UEMS. Unidade Universitária de Cassilândia. Cassilândia, MS, Brasil. CEP. 79540-000. (rogeriocarmocabral@gmail.com; eduardo.vendruscolo@uems.br; murilo.martins@uems.br; zoz@uems.br; edilson.costa@uems.br). [2]Universidade Estadual Paulista-UNESP-*Campus* de Ilha Solteira. Ilha Solteira, SP, Brasil. CEP. 15385-000. (ag.silva@unesp.br).

[§]Corresponding author: ag.silva@unesp.br.

Abstract

Improving environmental conditions in the production of seedlings by expanding the distribution of photosynthetically active radiation in abaxial leaves and protecting the substrate with straw can promote the production of higher quality seedlings. This study aimed to evaluate the reflective materials over the cultivation bench and the use of rice straw over the substrate in the formation of papaya seedlings of the group 'Formosa'. The joint analysis was performed considering a completely randomized experimental design in a 3 x 2 factorial scheme, with five replications and six seedlings per plot. The use of aluminized screen (Aluminet®) and aluminum foil with an area of 1 m x 1.2 m as reflective material on the cultivation bench and treatment without reflective material were evaluated. Also, the presence and absence of a rice straw layer with 5 cm height, as covering over the substrate were evaluated. In the benches with aluminum foil and without reflective material, the seedling production without rice straw over the substrate provided papaya seedlings of higher quality than the rice straw over the substrate. The aluminum foil produced high-quality papaya seedlings in the treatments with rice straw over the substrate. The aluminized screen on the cultivation bench was not favorable for the papaya seedlings production.

Keywords: *Carica papaya*, aluminum foil, photosynthetic radiation, rice straw.

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Introduction

The plant ambiance technology applied to the papaya (*Carica papaya*) seedling production system has shown improvement and an increase in the quality of the seedlings formed for use in the field. Healthy seedlings, of superior quality, with adequate development and dry matter partition between aerial part and root, provide greater survival rate in the field after transplantation and have a positive impact on production. The protected environment has promoted an increase in the quality of papaya seedlings. However, several conditions and techniques influence the efficiency of protected environments, such as geographic location, time of year, type of environment in terms of shape and dimensions, levels of shading, types of material of the screens, as well as the screen under the polyethylene film.

In a period of lesser rainfall, the agricultural screenhouse with black and aluminized screens, compared to the agricultural greenhouse with polyethylene film, provide the papaya seedlings of the 'Sunrise solo' group with greater height and number of leaves (Costa *et al*., 2010), and seedlings with higher quality for the group 'Formosa' (Santos *et al*., 2016) and, larger dry matter in an agricultural screenhouse with aluminum screen for the group 'Sunrise solo' (Costa *et al*., 2009). In periods with higher precipitation, the greenhouse, compared to the screens, allows larger plants with a greater number of leaves (Costa *et al*., 2011). In a period of mild temperature, both the agricultural greenhouse and the black screen promote quality seedlings for the group 'Sunrise Solo' (Faria *et al*., 2013). The shading screen under the polyethylene film promotes greater emergence speed of papaya seedlings of the 'Formosa' group (Silva *et al*., 2013) and the shading screen of 18 and 35% originate seedlings with greater plant height, stem diameter, dry matter, and the Dickson quality index than the shading screen of 0 and 50% (Salles *et al*., 2019).

Combined with protected environments, the use of reflective material in cultivation benches has shown promise in increasing seedling quality. The use of aluminum foil as a reflective material in cultivation benches, in association with an agricultural greenhouse cultivation environment with a 42/50% shading screen under the polyethylene film, had a positive effect on increasing the quality of *Schizolobium amazonicum* seedlings (Mortate *et al*., 2019). For jambolan (*Syzygium cumini*), the best seedlings were formed with the use of reflective material of aluminum foil on an agricultural screenhouse with 30% shading (Salles *et al*., 2017). Passion fruit seedlings (*Passiflora edulis* Sims. F. Flavicarpa Deg) produced over the mirror as a reflective material showed a higher growth rate and shoot dry matter when compared to those produced over the fabric with sequins (Santos *et al*., 2017).

Another technique for improving seedling cultivation conditions, inside a protected environment, is the covering of the substrate with a layer of rice straw or other material, and, according to Carneiro (1995), the adequate thickness of this layer conserves the moisture for root development. The carbonized rice husk as a substrate cover provided higher-quality seedling seedlings (*Myracrodruon urundeuva*); however, the washed sand was not suitable for this purpose (Tsukamoto Filho *et al*., 2013). The coverage of the substrate with coconut fiber promoted negative effects on the production of *Capparis yco* seedlings (Freire *et al*., 2019).

This study aimed to evaluate the reflective materials over the cultivation bench and the use of rice straw over the substrate in the formation of papaya seedlings of the group ‘Formosa’.

Material and methods

The experiments were carried out in the experimental area of the Mato Grosso do Sul State University (UEMS), in Cassilândia-MS, from April 17, 2019, to June 24, 2019. A protected environment (agricultural greenhouse) was used, with a galvanized steel structure, 8.00 m wide by 18.00 m long and 4.00 m high, covered with 150-micron low-density polyethylene film and Thermo reflective screen (LuxNet) with 42-50% shading under the film.

The study evaluated the use of reflective materials on the cultivation bench and the use of rice straw as coring over the substrate. As there is no repetition of reflective materials, each material was considered an experiment, in which the presence and absence of rice straw as coring over the substrate was evaluated. The joint analysis was performed according to Banzatto and Kronka (2013).

The joint analysis was performed considering a completely randomized experimental design in a 3 x 2 factorial scheme, with five replications and six seedlings per plot. The use of aluminized screen (Aluminet®) and aluminum foil with an area of 1 m x 1.2 m as reflective material on the cultivation bench and treatment without reflective material were evaluated. Also, the presence and absence of a rice straw layer with 5 cm height, as covering over the substrate were evaluated.

Polyethylene plastic bags (15 x 25 cm) filled with 1.8 dm^3 of a commercial substrate (Carolina Soil®) were used to produce the papaya seedlings. Four seeds were sown per plastic bag on April 17, 2019, and the emergence of seedlings was observed eight days after sowing (DAS). When the seedlings had three fully expanded leaves, thinning was carried out, leaving the seedling with the highest vigor.

The seedlings were watered using a suspended micro-sprinkler system. At 20 DAS, fertilization with NPK (4-14-8) was performed at a dose of 400 kg ha^{-1}, diluted in water, and 50 ml of the solution were applied per seedling. At 35 DAS, 130 ml of liquid fertilizer Quimifol Fert (Nitrogen: 14%; Phosphorus: 18%; Potassium: 20%; Magnesium: 1%; Sulfur: 1.5%; Boron: 0.03%; Manganese: 0.1%; Molybdenum: 0.02%; and Zinc: 0.1%) were applied per seedling.

Measurements of photosynthetically active radiation reflected (micromol m^{-2} s^{-1}) in each bench were performed at 10 am, with the sensor facing downwards in an average distance 20 cm from the reflective material. The incident photosynthetically active radiation (micromol m^{-2} s^{-1}) inside and outside the protected environment was evaluated with the sensor facing upwards, being measured with Apogee model MP-200 equipment. Each month of collection, from April to June, was considered one repetition, totaling three repetitions (three blocks), and they were used to compare the data of reflected photosynthetically active radiation statistically. Incident photosynthetically active radiation outside the protected environment was 1410, 1288.6, 1208.5, and 1302.4 micromol m^{-2} s^{-1}, and inside the protected environment was 321, 275.9, 272.3, and 289.7 micromol m^{-2} s^{-1} for April, May, June, and the general average.

Plant height (PH), number of leaves (NL), and stem diameter (SD) were evaluated at 33, 49, and 68 DAS. Shoot dry matter (SDM), and root dry matter (RDM) was evaluated at 68 DAS. After the evaluations, the total dry matter (TDM), the relationship between plant height and stem diameter (H:D), the relationship between shoot dry matter and root dry matter (S:R), the relationship between root dry matter and total dry matter (R:T) were estimated. Dickson quality index (DQI) was estimated by the equation DQI= [TDM/H:D + S:R)] (Dickson *et al*., 1960; Silva *et al*., 2018). Also, the absolute growth rate (AGR) in height between the collection intervals was estimated (Benincasa, 2003). The data were subjected to analysis of variance (F test). Means from the reflective materials were compared by the Tukey test at 5% probability (Banzatto and Kronka, 2013; Ferreira, 2014; Ferreira, 2019).

Results and discussion

Photosynthetically active radiation (PAR) inside the protected environment (289.7 micromol m^{-2} s^{-1}) was equivalent on average to 22.2% of the external PAR (1 302.4 micromol m^{-2} s^{-1}). That is, of the total PAR, around 77.8% was retained by the polyethylene film associated with the shade screen. However, even so, this reduction allowed the seedlings to develop properly.

The cultivation bench without reflective material reflected around 4.72%, the aluminized screen around 6.95%, and aluminum foil around 10.91% of the total PAR inside the environment (289.7 micromol m^{-2} s^{-1}). Inside the protected environment, aluminum foil has the highest reflectance (Figure 1), and this positively influenced the growth of papaya seedlings.

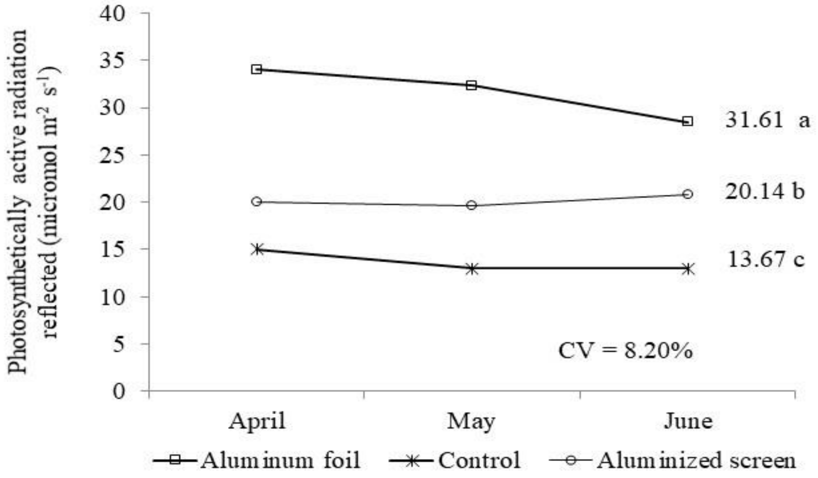

Figure 1. Photosynthetically active radiation reflected in the cultivation bench with and without reflective material. Cassilândia-MS, 2019.

The relationship between the largest and smallest mean square of the residue (RMSR) for the variables plant height at 33 (PH1), 49 (PH2), and 68 (PH3) DAS, stem diameter at 33 (SD1), 49 (SD2), and 68 (SD3) DAS, number of leaves at 33 (NL1), 49 (NL2), and 68 (NL3) DAS, shoot dry matter (SDM) root dry matter (RDM), total dry matter (TDM), S:R ratio, R:T ratio, H:D ratio, Dickson quality index (DQI), absolute growth rate between 33 and 49 DAS (AGR1), between 49 and 68 DAS (AGR2), and between 33 and 68 DAS (AGR3) were 2.1, 2.5, 3.6, 1.8, 2.2, 1.2, 1.3, 2.7, 2.5, 8.2, 2.2, 6, 7, 8.6, 2.5, 2.7, 3, 2.9, 2, 6.7 and 4.4 respectively.

The variables SDM, S:R ratio, and R:T ratio had the relationship between the largest and smallest mean square of the residue higher or equal to 7, and according to Banzatto and Kronka (2013), the joint analysis and the comparison between the reflective materials were not performed. The other variables made it possible to be performed the joint analysis and the comparison of reflective materials since the RMSR of individual analyzes was less than 7.

Influence of the interaction between the factors studied (reflective material and rice straw covering) on the variables stem diameter at 49 DAS (SD2), and 68 DAS (SD3), the number of leaves at 33 DAS (NL1), the root dry matter (MSSR), total dry matter (MST), and Dickson quality index (IQD) was observed. There was no influence of the interaction on the other variables, and their overall results were evaluated (Table 1).

Table 1. Summary of analysis of variance of plant height at 33 DAS (PH1), 49 at DAS (PH2), and 68 at DAS (PH3), stem diameter at 33 DAS (SD1), 49 DAS (SD2), and 68 DAS (SD3), number of leaves at 33 DAS (NL1), 49 DAS (NL2), and 68 DAS (NL3).

Treatments	PH1	PH2	PH3	SD1	SD2	SD3	NL1	NL2	NL3
Reflective material (RM)	**	**	**	**	**	**	*	*	ns
Substrate Covering (SC)	**	*	ns	ns	ns	ns	ns	ns	ns
RM x SC	ns	ns	ns	ns	*	*	**	ns	ns
Treatments	RDM	TDM	H:D1	H:D2	H:D3	DQI	AGR1	AGR2	AGR3
Reflective material (RM)	**	**	ns	**	ns	**	**	**	**
Substrate Covering (SC)	ns	ns	*	ns	ns	ns	ns	*	ns
RM Xx SC	*	**	ns	ns	ns	**	ns	ns	ns

Root dry matter (RDM); total dry matter (TDM); the ratio between the shoot dry matter and root dry matter (S:R); the relationship between plant height and stem diameter (H:D): Dickson quality index (DQI); the absolute growth rate between 33 and 49 DAS (AGR1), between 49 and 68 DAS (AGR2) and between 33 and 68 DAS (AGR3) of papaya seedlings; ns = not significant, *= significant at 1% probability; **= significant at 5% probability.

In the initial plant height assessments (33 and 49 DAS), the plants on the bench with aluminum foil and without reflective material, as well as on the substrate without cover, had the largest height. However, at 68 DAS, there was no difference between the presence and the absence of rice straw coverage over the substrate, and the plants on the bench with aluminum foil had greater height (Figure 2). The largest value of PAR promoted by aluminum foil (Figure 1) on the abaxial face of the leaves provided larger plants (Figure 2) because PAR is directly related to plant growth, phytomass production, and plant morphology.

There was no difference between the reflective materials for the number of leaves at 68 DAS (NL3) and H:D ratio at 33 DAS (H:D1) and 68 DAS (H:D3) Table 2). These results show that when the plants were able to be transplanted, they did not show a tendency to etiolation (H:D3) due to cultivation on benches with different reflective materials, and the number of leaves (NL3) was adequate to meet the photosynthetic demand.

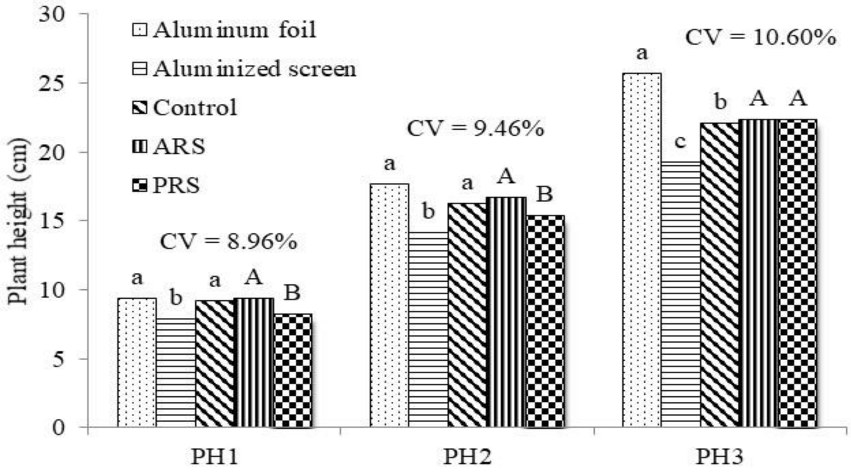

Figure 2. Plant height at 33 DAS (PH1), 49 DAS (PH2), and 68 DAS (PH3). Means followed by same letters in the columns, for each variable, do not differ from each other by the Tukey test for the reflective material on the cultivation benches, and by the F-test for the presence or absence of rice straw as coring over the substrate, both at 5% significance level. ARS= absence of rice straw as coring over the substrate; PRS= presence of rice straw as coring over the substrate. CV= coefficient of variation.

Table 2. Stem diameter at 33 DAS (SD1), number of leaves at 49 DAS (NL2) and 68 DAS (NL3), H:D ratio at 33 DAS (H:D1), 49 DAS (H:D2), and 68 DAS (H:D3), absolute growth rate from 33 to 49 DAS (AGR1), from 49 to 68 DAS (AGR2), and from 33 to 68 DAS (AGR3) of papaya seedlings grown on cultivation bench with reflective material and with presence and absence of rice straw as a covering over the substrate.

Cultivation bench	SD1	NL2	NL3	H:D1	H:D2	H:D3	AGR1	AGR2	AGR3
Aluminum foil	2.71 a	7.6 b	9.2 a	3.49 a	3.12 c	2.79 a	0.51 a	0.43 a	0.47 a
Aluminized screen	2.17 b	8.2 a	9.2 a	3.64 a	3.65 a	2.74 a	0.4 b	0.27 b	0.33 b
Control	2.61 a	8.3 a	9.6 a	3.54 a	3.36 b	2.73 a	0.44 ab	0.3 b	0.37 b
Substrate	SD1	NL2	NL3	H:D1	H:D2	H:D3	AGR1	AGR2	AGR3
Without covering	2.57 a	8.2 a	9.47 a	3.68 a	3.4 a	2.71 a	0.46 a	0.3 b	0.37 a
With covering	2.42 a	7.87 a	9.2 a	3.43 b	3.35 a	2.79 a	0.45 a	0.37 a	0.4 a
CV (%)	8.48	6.63	6.49	9.05	6.48	9.99	18.15	21.17	16.15

Means followed by same letters in the columns, for each variable, do not differ from each other by the Tukey test for the reflective material on the cultivation benches, and by the F-test for the presence or absence of rice straw as coring over the substrate, both at 5% significance level. CV= coefficient of variation.

The smallest stem diameter was observed at 33 DAS (SD1) in the plants grown on the aluminized screen. At 49 DAS, on aluminum foil, the smallest number of leaves (NL2) and the smallest H:D2 ratio were observed (Table 2). These results reveal that the smallest diameter (SD1) in the aluminized screen at the beginning of growth influenced the lengthening of the stem during development (H:D2). However, it did not influence at the end of cultivation (H:D3).

With the growth of seedlings, it is observed that the aluminum foil on the cultivation bench promoted higher rates of absolute growth from 33 to 49 and 33 to 68 DAS (Table 2) because of the greater reflection of this material (Figure 1) provided higher photosynthesis rate of seedlings.

At 33 DAS, the highest H:D ratio was found for the plants without the use of rice straw as coring over the substrate. There was no difference between the presence and absence of rice straw for the other variables (Table 2).

When rice straw was not used as covering over the substrate, the smallest diameter, the smallest dry matter, and the lowest quality index were verified in the seedlings grown on the aluminized screen. In the substrate with rice straw, the highest averages of these variables were found in the seedlings grown on aluminum foil. In the cultivation bench without reflective material, the highest values were observed in plants without straw. In the cultivation bench with aluminized screen, the coverage with rice straw did not influence the variables evaluated (Table 3).

Table 3. Stem diameter at 49 DAS (SD2) and 68 DAS (SD3), root dry matter (RDM), S:R ratio (S:R), number of leaves at 33 DAS (NL1), total dry matter (TDM), and Dickson quality index (DQI) of papaya seedlings grown on cultivation benches with reflective material and with presence and absence of rice straw as covering over the substrate.

Reflective material	Absence	Presence	Absence	Presence
	SD2		SD3	
Aluminum foil	5.56 Aa	5.78 Aa	8.9 Ab	9.6 Aa
Aluminized screen	4.02 Ca	3.78 Ca	7.13 Ba	6.96 Ba
Control	5.28 Aa	4.43 Bb	8.74 Aa	7.5 Bb
CV (%)	8.43		6.06	
Reflective material	NL1		RDM	
Aluminum foil	5.2 Ab	5.8 Aa	1.21 Ab	1.58 Aa
Aluminized screen	5.2 Aa	5.2 ABa	0.61 Ca	0.63 Ba
Control	5.6 Aa	5 Bb	0.92 Ba	0.79 Ba
CV (%)	6.49		19.29	
Reflective material	TDM		DQI	
Aluminum foil	3.98 Ab	5.01 Aa	0.79 Ab	1.02 Aa
Aluminized screen	1.8 Ba	1.73 Ba	0.39 Ba	0.38 Ba
Control	3.16 Aa	2.10 Bb	0.63 Aa	0.46 Ba
CV (%)	19.76		20.94	

Means followed by uppercase letters in the columns and lowercase letters in the rows, for each variable, do not differ from each other by the Tukey test for the reflective material on the cultivation benches, and by the F-test for the presence or absence of rice straw as coring over the substrate, both at 5% significance level. CV= coefficient of variation.

In the cultivation bench without reflective material, the influence of the substrate cover with rice straw differs from the results obtained by Tsukamoto Filho *et al*. (2013) that using carbonized rice husk as a substrate cover, obtained better *Schinus terebinthifolius* R. seedlings. However, Freire *et al*. (2019) do not recommend the use of coconut fiber as a substrate cover because it reduced the quality of *Capparys yco* seedlings, due to the production of secondary metabolites (allelochemicals) by the fiber.

The association of the use of rice straw as coring over the substrate and aluminum foil on the cultivation bench improved the quality of the papaya seedlings, in which the rice straw improved the conditions of the root system (Carneiro, 1995; Tsukamoto Filho *et al*., 2013), and the reflective material helped in the greater availability of light energy to the leaves, thus improving the photosynthesis process. These results were similar to those observed by Salles *et al*. (2017) for jambolan seedlings (*Syzygium cumini*), Santos *et al*. (2017) for passion fruit seedlings (*Passiflora edulis* Sims. f. flavicarpa Deg), Mortate *et al*. (2019) for paricá seedlings (*Schizolobium amazonicum*) and Costa *et al*. (2020) in the formation of Baru seedlings (*Dipteryx alata* Vogel).

For the variables that did not allow the comparison of the reflective materials on the cultivation bench, it was verified only in the bench without reflective material, greater dry mass of the aerial part in the substrate without rice straw as covering. In the benches with reflective materials, the use of rice straw as covering on substrate did not influence the variables of the papaya seedlings (Figure 3).

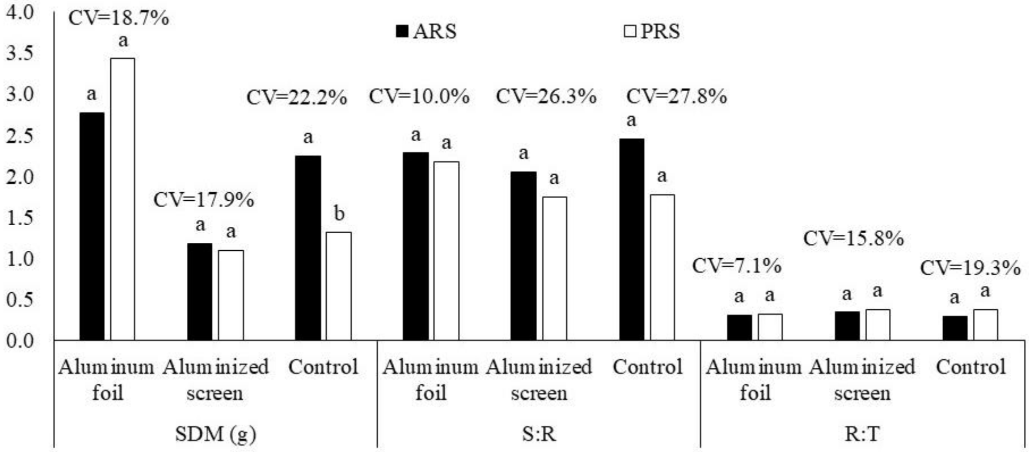

Figure 3. Shoot dry matter (SDM), relationship between shoot dry matter and root dry matter (S:R), and relationship between root dry matter and total dry matter (R:T) of papaya seedlings grown on cultivation bench with reflective material and with presence and absence of rice straw as a covering over the substrate. The same letters do not differ from each other by the Tukey test for the reflective material on the cultivation benches and by the F-test for the presence or absence of rice straw as coring over the substrate, both at 5% significance level. ARS= absence of rice straw as coring over the substrate; PRS= presence of rice straw as coring over the substrate; CV= coefficient of variation.

It is observed that the distribution of shoot and root dry matter follows a proportion, on average, 67% of the total dry matter is accumulated in the shoot, and 33% in the root system. The reflective materials on the cultivation bench and the presence and absence of rice straw as coring over the substrate did not influence this proportion. This shows that the reflective material and cover for substrate protection applied to the formation of papaya seedlings, practically maintain a ratio of 2:1 in the distribution of photoassimilates between shoot and root of the seedlings, that is, the shoot dry matter is twice higher than root dry matter (Figure 4).

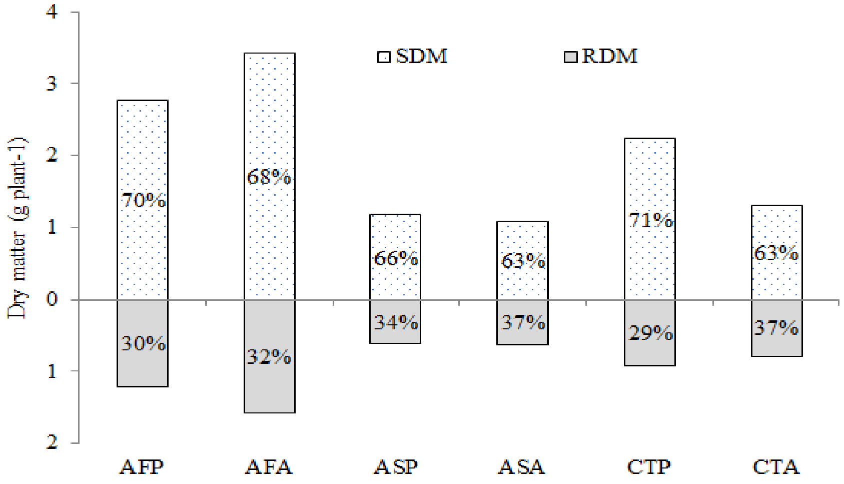

Figure 4. Dry matter distribution between aerial part and root system in papaya seedlings grown on cultivation bench with reflective material and with presence and absence of rice straw as a covering over the substrate. Cultivation bench with aluminum foil and presence of rice straw over the substrate (AFP); cultivation bench with aluminum foil and absence of rice straw over the substrate (AFA); cultivation bench with aluminized screen and presence of rice straw over the substrate (ASP); cultivation bench with aluminized screen and absence of rice straw over the substrate (ASA); cultivation bench without reflective material “control” and presence of rice straw over the substrate (CTP); cultivation bench without reflective material “control” and absence of rice straw over the substrate (CTA).

The aluminum foil provided better conditions for the accumulation of shoot and root dry matter with and without rice straw as coring over the substrate (AFP and AFA) (Figure 4), evidencing a positive effect of this technique in the formation of high-quality papaya seedlings. From the correlation between the quality of the seedling and the distribution of shoot and root dry matter, it can be inferred that a high-quality papaya seedling has, on average, 2/3 of total dry matter accumulated on the shoot and 1/3 on the root.

Conclusions

The use of substrate without rice straw as coring over the substrate provides the best seedlings in benches with aluminum foil and without reflective material. When rice straw is used as covering over the substrate, the aluminum foil produced papaya seedlings with the highest quality. The use of aluminized screen on the cultivation bench was not favorable for the formation of papaya seedlings.

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