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Production of ornamental pyramid pepper with reflective material on benches in different environments

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ABSTRACT

Pepper trees have great ornamental value due to the varied colors of their fruits. Thus, the objective was to evaluate the Pyramid cultivar's production in different cultivation environments using benches with reflective material. The experiment was carried out in two protected environments: a) agricultural greenhouse with 42-50% shade screen under the plastic film and b) agricultural screen with black monofilament screen with 18% shade. Inside the environments, the production system was tested with and without reflective material on the cultivation bench. The experiments were conducted in a completely randomized design, with four replicates and six plants per plot. Joint analysis was used to compare environments. At 45, 60, and 75 days after transplantation, plant height, stem diameter, number of leaves, canopy area, and number of fruits were evaluated. The agricultural greenhouse with a 42/50% shade screen under the plastic film provided the formation of higher plants with greater stem diameter, greater number of leaves and fruits, and greater top diameter than the screen with 18% shading. The reflective mirror material showed positive results only for plant height.

Keywords: *Capsicum frutescens*, Pyramid cultivar, Mirror

Produção de pimenta pirâmide ornamental com uso de material refletor em bancadas em diferentes ambientes

RESUMO

As pimenteiras apresentam grande valor ornamental devido as cores variadas de seus frutos. Dessa forma, objetivou-se avaliar a produção da cultivar Pirâmide, em diferentes ambientes de cultivo com uso de bancadas com material refletivo. O experimento foi realizado em dois ambientes protegidos: a) estufa agrícola com tela de 42-50% de sombreamento sob o filme plástico e b) telado agrícola com tela de monofilamento preta com 18% de sombreamento. No interior dos ambientes foi testado o sistema de produção com e sem material refletor na bancada de cultivo. Os experimentos foram conduzidos em delineamento inteiramente casualizado, com quatro repetições e seis plantas por parcela. Utilizou-se a análise conjunta para comparar os ambientes. Aos 45, 60 e 75 dias após o transplante foi avaliado a altura de plantas, diâmetro do colo, número de folhas, área da copa e número de frutos. A estufa agrícola com tela de 42/50% de sombreamento sob o filme plástico propiciou a formação de plantas com maior altura, maior diâmetro do colo, maior número de folhas, maior número de frutos e maior diâmetro de copa que o telado de 18% de sombreamento. O material refletivo espelho apresentou resultados positivos apenas para altura de plantas.

Palavras-chave: *Capsicum frutescens*, cultivar Pirâmide, Espelho.

1. Introduction

The genus Capsicum has been used in cooking since ancient civilizations in South America and Mexico, where its aroma, flavor, pungency, and color properties provide food with greater attractiveness. They have the characteristic of assisting digestion and stimulating appetite, in addition to being sources of natural antioxidants such as vitamin C, E, and carotenoids (Pinto et al., 2013; Naves et al., 2019).

In addition to their culinary use, many pepper trees are used in decoration: they have fruits with considerable durability and a wide variety of colors. Its seedlings are small in size and are valued in the ornamental plant market (Stommel et al., 2018; Parladore et al., 2019).

The cultivation in a protected environment is gaining space among the producers mainly for facilitating the handling. In high-temperature regions, excessive radiation and long periods of rain can be harmful to plant physiology. Thus, using a protected environment composed of films or screens can mitigate direct radiation incidence from the sun's rays, protecting plant tissues from these stresses (Costa et al., 2015). Much research has shown the advantages of using greenhouses which allow greater emergencies, seedling quality, and productivity (Carrijo et al., 2004).

Global solar radiation (GR) is the main available energy source for carrying out physical, physiological, and biochemical processes. Photosynthetically active solar radiation (PAR), part of the GR, is responsible for influencing plant growth and phenology. Its intensity can modify leaf structure, chloroplasts, and plant pigments (Taiz et al., 2017). The efficiency of converting physical energy into chemical gradually decreases with the increase in the radiation flow above the optimum point and results in the upper leaves' saturation.

Thus, using cultivation benches with reflective material is a recent technique that aims to reflect the PAR and uses unsaturated leaves to capture this energy and contribute to the photosynthesis process. Recent studies have shown that using these materials resulted in a higher growth rate of *Passiflora edulis* (Santos et al., 2017) and were significant for the quality of *Syzygium cumini* (Salles et al., 2017) and parica (*Schizolobium amazonicum*) seedlings in an agricultural greenhouse (Mortate et al., 2019) and baruzeiro shoots, *Dipteryx alata* (Costa et al., 2020).

In this sense, pepper plant production in a protected environment, when appropriate, can promote favorable conditions for plant growth, and their association with reflective material can increase their productivity. Given these assumptions, the study aimed to evaluate ornamental pepper production, Pyramid cultivar, in different protected environments in cultivation systems with or without reflective material on the cultivation bench.

2. Material and Methods

The experiments with pepper, Pyramid cultivar, were carried out in an experimental area of the State University of Mato Grosso do Sul, Cassilândia University Unit - MS, from August to December 2017. The region is located at an altitude of 516 m, latitude of 19º07'21 " S, and longitude 51º43'15 " (Automatic station CASSILANDIA-A742) and classified as Tropical Rainy Climate (Aw), characterized as hot and humid, with two well-defined seasons being rainy in the summer and dry in the winter.

Two protected environments were used: a) Agricultural Greenhouse, consisting of galvanized steel (18.0 x 18.0 x 4.0 m) covered with low-density polyethylene (LDPE) film, light diffuser, and 150-micron anti-drip, with zenith opening and 42/50% mobile LuxiNet® aluminum thermoreflective screen (screen shading can vary from 42 to 50%) under the LDPE film; b) Agricultural screen, consisting of galvanized steel (18.0 m x 8.0 m x 3.5 m), closed at 45 degrees, with black monofilament screen with 18% shading.

Inside these environments, the cultivation benches' reflective material was placed, constituting two cultivation systems, one with and the other without (control) reflective material. The mirror was used as a reflective material with 0.8 x 1.2 m dimensions.

The pepper seedlings were produced in 72 cell expanded polystyrene trays, filled with the substrate composed of 50% soil, 30% vermiculite and 20% tanned manure. Sowing took place on August 23, 2017.

This substrate's characteristics were: 5.6 pH in CaCl2; 26.6 organic matter - MO (g dm^{-3}); 75.3 Pmehlich-1 (mg dm^{-3}); 0.54 K^+ (g cmolc dm-3); 2.20 Ca^{2+} (cmolc dm^{-3}); 2.00 Mg^{2+} (cmolc dm^{-3}); 0.05 of Al^{3+} (cmolc dm^{-3}); 2.00 H^+ Al (cmolc dm^{-3}); 6.7 cation exchange capacity - CEC (cmolc dm^{-3}); 70.3 of Sat. Bases (%); 0.66 B (mg dm^{-3}); 0.8 Cu (mg dm^{-3}); 104 Fe (mg dm^{-3}); 37.8 Mn (mg dm^{-3}) and 6.4 Zn (mg dm^{-3}).

The seedlings' transplanting to the 3.0 L cultivation pots, with the same substrate as the seedling phase, occurred 40 days after sowing (DAS) when the plants had four to five definitive leaves. The pots were fertilized with 1.0g of 4-18-08 (NPK) at 20 days after transplantation (DAT).

At 45, 60, and 75 days after transplantation (DAT), plant height, stem diameter, number of leaves, canopy area, and number of fruits were collected. The plant's height was measured with a ruler's aid considering the distance from the neck to the apex of the stem's meristem and the crown area with the diameters' average in two perpendicular directions. The neck diameter was measured with a digital caliper. The number of leaves and fruits was obtained by counting.

Photosynthetically active radiation (PAR), air temperature, and relative humidity were monitored. The PGR incident in the protected and external environments (µmol.m^{-2}.s^{-1}) and the PGR reflected in the cultivation benches, on clear days (without cloudiness), were obtained at 10:00 am with the aid of the Apogee device.

The air temperature (T, °C) and the relative air humidity (RH, %) were obtained from weather stations model E4000 (Irriplus Scientific Equipment) installed in the center of each protected environment. External data were obtained from the automatic data collection station A742 - Cassilândia (INMET).

The incident PAR data, air temperature, and relative air humidity were evaluated by comparing the protected and external environments with the reflected PAR data in a 2 x 2 factorial scheme (two protected environments x two production systems, with and without the reflective material on the cultivation bench). A randomized block design with three replications (three months: October, November, and December) was used.

As there are no replicates of the cultivation environments, each of them was considered an experiment, conducted in a completely randomized design, with four replicates and six plants per plot. The Sisvar statistical program was used to analyze variance (F test) and compare the averages (Ferreira, 2014; Ferreira, 2019).

The joint analysis was performed in a 2 x 2 factorial scheme (two environments x two production systems, with and without reflective material on the cultivation bench). The fruit data were transformed into the root of x plus a half.

3. Results and Discussion

The photosynthetically active radiation (PAR) incident in the cultivation environments decreased according to the type of environment and its constituent materials. Depending on the roofing material, it was found that the greenhouse covered with low-density polyethylene film and with a 42/50% shade screen under the film presented a lower PAR than the shade screen, and both smaller than the external. The incident PGR, available for plants, increased from October to November, decreasing in December (Figure 1).

The average PAR incident at the full sun was 1677 µmol m^{-2}s^{-1}. Of this total, an average of 33% reached the greenhouse interior and 69% the black screen in the studied period (Figure 1). These results show that the shading value does not correspond to the percentage of PGR inside the environment since the black 18% shading screen allows only 69% of the external PGR to pass.

There was an interaction between the protected environment factors and production systems with and without reflective material on the cultivation bench for the reflected PGR. Inside the two protected environments, the reflected PGR was higher in the system with reflective material, and when comparing the environments within the production systems, the PGR did not differ (Figure 2).

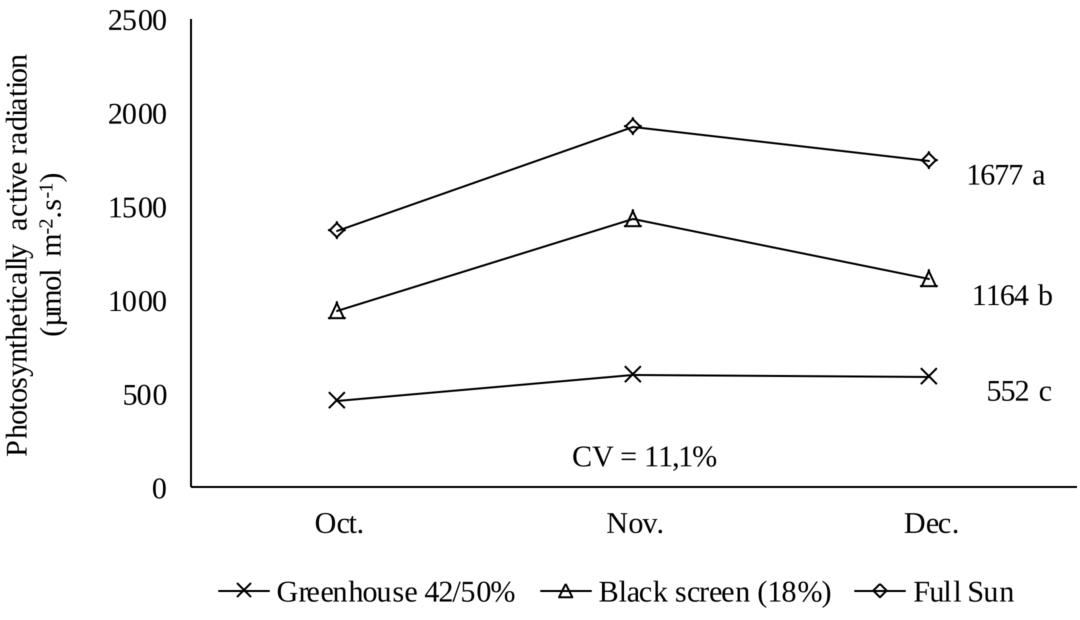

Figure 1. Photosynthetically active radiation (PAR, µmol m^{-2}.s^{-1}) incident in protected environments and full sun. Means followed by the same lowercase letters do not differ by the Tukey test at 5% probability. CV = coefficient of variation.

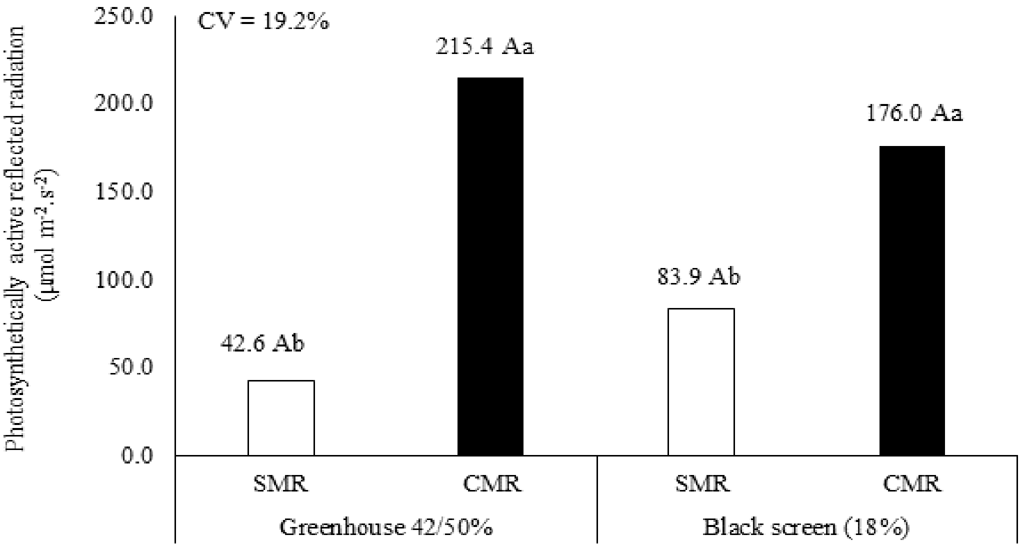

Figure 2. Photosynthetically active reflected radiation (PAR, µmol $m^{-2}.s^{-1}$) on benches with (CMR) and without (SMR) reflective material in protected environments. Same lowercase letters for the benches within each protected environment and equal uppercase letters for the protected environments within each production system do not differ at 5% probability by the F-test. CV = coefficient of variation

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In the plastic greenhouse with a 42/50% screen under the film, the system with reflective material reflected, on average, 4.05 (405%) times the system without reflective material, and in the 18% shade screen, it was 1.10 (110%) times. The full sun temperature was higher than that of the protected environments that did not differ in the studied period (Figure 3).

The relative humidity (%) in the black screen environment of 18% shading was higher than in the plastic greenhouse and the external environment, which did not differ in the studied period (Figure 3). The environment protected by an 18% shade screen presented a higher relative humidity since it allowed the rainwater to enter.

All variables showed a relationship between the largest and smallest residual mean square (RMSD) less than 7 (Table 1). These results made it possible to carry out the experiment group analysis and compare the cultivation environments effect (Banzatto and Kronka, 2013) through the factorial 2 x 2 (two protected environments x 2 production systems reflective material on the cultivation bench).

The analysis of variance allowed to verify that there was no significant interaction between the factors "cultivation environment" and "production system with reflective material" for the studied variables. The environments are significant for PH at 45, 60, and 75 DAT, SD at 60 and 75 DAT, NL at 45 and 60 DAT, NF at 60 DAT and canopy area (CA) at 45, 60 at 75 DAT. For the production system with and without reflective material, the significant variables were PH at 60 and 75 DAT, SD at 75 DAT, and NF at 60 DAT (Table 2).

The agricultural greenhouse seedlings covered with LDPE film and a 42/50% shade screen under the film were higher than 18% black screen shading, with larger stem diameters, greater number of leaves, and larger crown area (Table 3).

The seedlings of the agricultural greenhouse covered with LDPE film and a 42/50% shade screen under the film develop mechanisms to increase the number of leaves and, consequently, the canopy area (Table 3) to capture more light energy and perform photosynthesis since they are in a more shaded environment with less PGR (Figure 1) (Taiz et al., 2017). In this environment, the plants were larger, but there was no etiolation due to an increase in the neck's diameter.

The highest amount of PAR in the shade screen of 18% (Figure 1) may be in excess for the pepper plant during the studied period and associated with higher relative humidity (Figure 4) promoted by the rains causing physiological stress, negatively influencing the tree plant growth in this environment. However, some vegetables have inherited the ability to generate responses to these stresses through evolutionary physiological adaptations (Cotrozzi and Couture, 2020; Cotrozzi and Landi, 2018; Taiz et al., 2017).

The reflective material's use had a positive influence only on the seedlings' height (Table 3). The reflected PGR (Figure 2) promoted greater plant growth corroborating with Salles et al. (2017), who found larger jambolan (*Syzygium cumini*) seedlings on benches with reflective material that promoted an adequate distribution of solar energy between the seedling's lines and abaxial leaves, as observed by Santos et al. (2017) in passion fruit shoots.

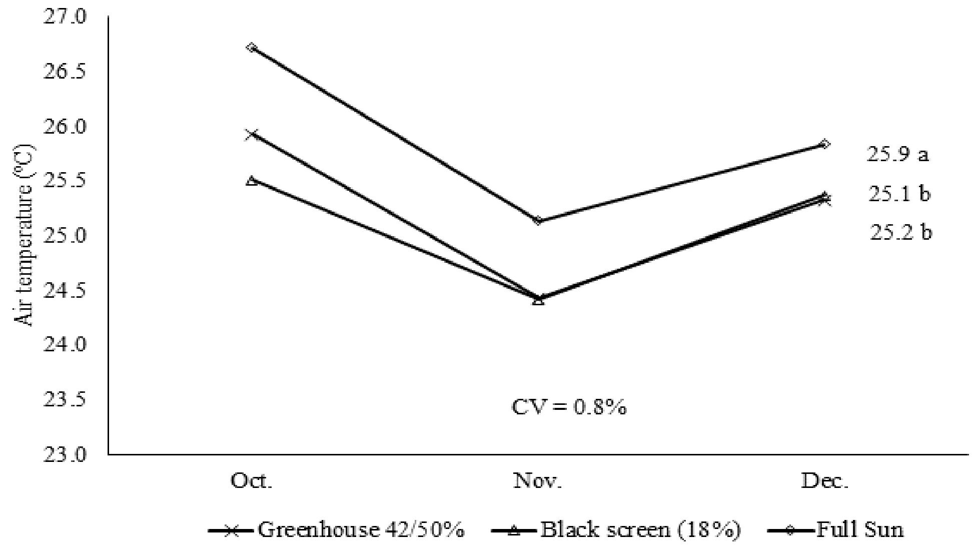

Figure 3. Air temperature (ºC) in protected environments and full sun. Means followed by the same lowercase letters do not differ by the Tukey test at 5% probability. CV = coefficient of variation.

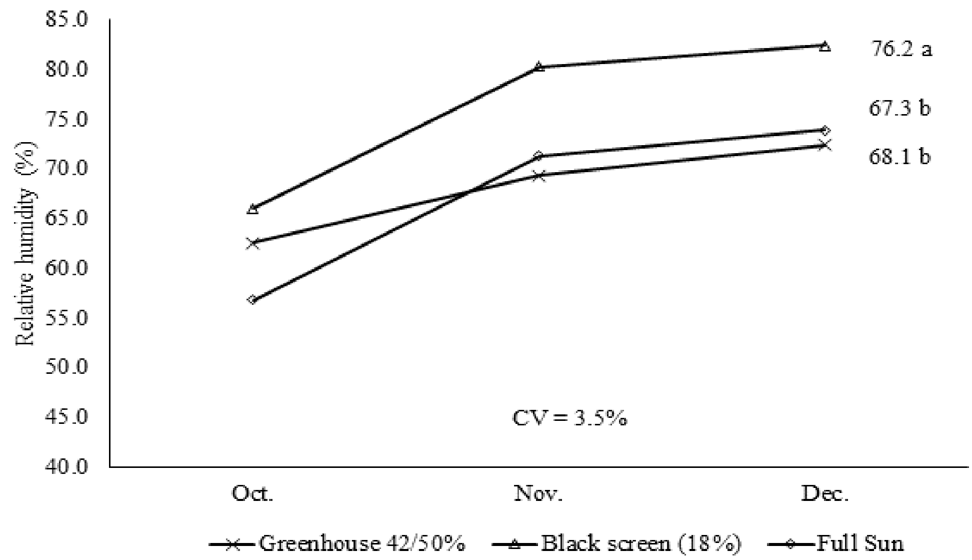

Figure 4. Relative humidity (%) in protected environments and full sun. Averages followed by the same lowercase letters do not differ by the Tukey test at 5% probability. CV = coefficient of variation.

Table 1. Ratio of the mean square of the residue (RMSD) for the variables, seedling height (PH), stem diameter (SD), number of leaves (NL), number of fruits (NF), crown area (CA) at 45, 60, and 75 days after transplantation within each environment.

Environment	PH 45	PH 60	PH 75	SD 45	SD 60
Greenhouse 42/50%	1.01	0.25	0.46	0.08	0.04
Black screen (18%)	0.32	0.29	1.02	0.12	0.14
RMSD	3.2	1.1	2.2	1.5	3.8
Environment	SD 75	NL 45	NL 60	NL 75	NF 45
Greenhouse 42/50%	0.04	110.2	153.8	113.8	0.09
Black screen (18%)	0.16	87.9	185.6	75.7	0.02
RMSD	4.4	1.3	1.2	1.5	5.2
Environment	NF 60	NF 75	CA 45	CA 60	CA 75
Greenhouse 42/50%	1.07	5.8	3030.7	3882.4	1406.4
Black screen (18%)	0.73	4.4	13495.2	1281.0	383.7
RMSD	1.47	1.3	4.45	3.03	3.7

Table 2. Analysis of variance for plant height (PH), stem diameter (SD), number of leaves (NL), number of fruits (NF), and crown area (CA) after transplanting ornamental pepper plants in different environments and reflective benches.

Treatments	PH 45	PH 60	PH 75	SD 45	SD 60
Environment (E)	**	**	**	ns	**
Material (M)	ns	**	**	ns	ns
E X M	ns	ns	ns	ns	ns
Treatments	SD 75	NL 45	NL 60	NL 75	NF 45
Environment (E)	**	**	**	ns	ns
Material (M)	*	ns	ns	ns	ns
E X M	ns	ns	ns	ns	ns
Treatments	NF 60	NF 75	CA 45	CA 60	CA 75
Environment (E)	**	ns	**	**	**
Material (M)	*	ns	ns	ns	ns
E X M	ns	ns	ns	ns	ns

* Significant at 5%; ** significant at 1%; ns = not significant. Pr > Fc.

Table 3. Plant height (PH), stem diameter (SD), number of leaves (NL), and crown area (CA) at 45, 60, and 75 DAT in protected environments and the system with (CRM) and without (SRM) reflective material on the bench. Cassilândia-MS, 2018.0

	Plant height (PH), cm			Stem diameter (DC), mm		
	45 DAT	60 DAT	75 DAT	45 DAT	60 DAT	75 DAT
Greenhouse	13.72 a	15.38 a	15.95 a	5.24 a	6.29 a	6.48 a
Black screen	9.16 b	9.57 b	11.26 b	4.99 a	5.50 b	5.86 b
SRM	11.15 a	12.07 b	13.11 b	5.15 a	5.85 a	6.03 a
CRM	11.73 a	12.88 a	14.10 a	5.09 a	5.95 a	6.32 a
CV (%)	7.12	4.15	6.32	6.17	4.97	5.11
	Number of leaves (NL)			Crown area (CA), cm^2		
Greenhouse	84.16 a	80.18 a	85.25 a	569.15 a	545.45 a	446.15 a
Black screen	54.79 b	55.77 b	78.25 a	221.58 b	192.71 b	149.61 b
SEM	65.41 a	64.10 a	78.72 a	367.73 a	366.50 a	299.28 a
CRM	73.54 a	71.85 a	84.77 a	423.01 a	371.66 a	295.48 a
CV (%)	14.32	19.16	11.91	22.99	13.77	10.06

In the columns, means followed by the same letter for each studied factor do not differ by the t-test (LSD) at 5% probability. DAT = days after transplant.

Most of the variables were not influenced by the reflective material, similar to that verified by Lima et al. (2018) in a study with ornamental pepper on countertops with materials of different colors to reflect PGR.

As for the number of fruits, at 60 DAT, the plants conducted under the agricultural greenhouse shading 42/50% showed more fruits than those of the black screen with 18% shading. Conversely, at 45 and 75 DAT, the environments did not differ, as well as the production system with and without reflective material on the cultivation bench at the three measurement dates (Figure 5).

The greenhouse (42/50%) showed better production conditions for the ornamental Pyramid pepper, with greater height, number of leaves, stem diameter, number of fruits, and crown area. This result is similar to that found by Lima et al. (2018), where this environment formed higher plants in average, flower buds, and fruit quantity, indicating that this environment is more suitable for the production of this ornamental pepper cultivar.

When using countertops with reflective material, there were positive results: the reflective material was effective in directing the PGR, and it was captured and used by the vegetable. On the other hand, for the pepper plants, in some growth stages, it is possible to verify that the reflected PGR benefited some variables; however, others were indifferent to the reflected radiation. As in the study by Santos et al. (2017) and de Salles et al. (2017), FRG's seize by using reflective materials resulted in the greatest plant growth.

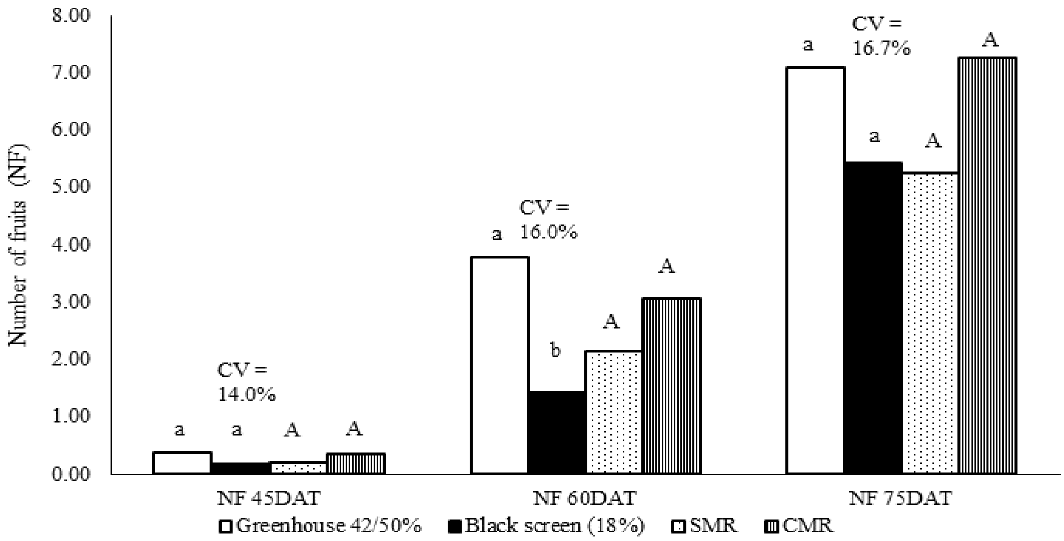

Figure 5. Number of fruits (NF) at 45, 60, and 75 days after transplantation (DAT) in protected environments and on benches with (CRM) and without (SRM) reflective material. Same lowercase letters for protected environments, and similar upper-case letters, for countertops do not differ at 5% probability by the F test. CV = coefficient of variation.

4. Conclusions

For the production of ornamental pepper, Pyramid cultivar, it is recommended to sow in an agricultural greenhouse environment with a 42/50% shade screen under the plastic film since it provides better growth and productivity.

Seizing the Photosynthetically Active Radiation (PAR) with reflective material influences the pepper plant growth.

Authors' Contribution

Laura Araújo Silva contributed to setting up the experiment, collecting data, and writing the manuscript. Josiane Souza Salles contributed to collecting data on the ambiance and writing the manuscript. Luiz Martins Cambui Neto contributed to setting up the experiment, collecting data, and writing the manuscript. Edilson Costa contributed to guide the experiment assembly, collecting data, assisting in statistics, creating the figures, and writing the manuscript. Abimael Gomes da Silva contributed to statistics, creating the figures and writing the article. Daniele Ferreira Cavalcante and Flávio Ferreira da Silva Binotti contributed to writing the article. Tiago Zoz contributed to statistical analysis, and writing the manuscript.

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