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Biquinho pepper cultivated on the reflective bench in protected environments

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ABSTRACT

The choice of the cultivation environment interferes with the whole vegetable development because of the micro-meteorological conditions in which the plants are cultivated, and the use of technologies with reflective material aims to complement the production in both quantity and quality. In this sense, the objective was to analyze the growth and productivity of Biquinho pepper (*Capsicum chinese)* plants cultivated in two types of protected environments and benches with reflective material. The experiment was conducted in a completely randomized design, with five repetitions. A plastic greenhouse with 42% shading and agricultural screen with 30% shading, inside these environments, there were benches with and without reflective material of the type Aluminet® with 50% shading. The plastic greenhouse presented lower temperature and relative air moisture, besides lower global solar radiation and photosynthetically active radiation. The benches with reflective material, independently of the environment, have promoted higher photosynthetic reflected radiation. Plants produced in the greenhouse had larger sizes, diameters, and leaves in their initial growth stage. As of 56 DAT, the plants in the agricultural screen presented greater heights and promoted greater pepper production. The reflective benches have favored the growth in diameter and at 14 and 28 DAT, and greater fruit production. It is concluded that the agricultural screen with 30% shading and reflective benches favor the Biquinho pepper fruit production.

Keywords: *Capsicum chinense*, micro-meteorological conditions, Reflected photosynthetic radiation.

Pimenta biquinho cultivada em bancada refletora sob ambientes protegidos

RESUMO

A escolha do ambiente do cultivo interfere em todo o desenvolvimento vegetal em funções das condições micrometeorológicas nas quais as plantas são cultivadas e, o emprego de tecnologias com material refletor visa complementar a produção em quantidade e qualidade. Neste sentido, objetivou-se analisar o crescimento e a produtividade de plantas de pimenta biquinho (*Capsicum chinense*) cultivadas em dois tipos de ambiente protegido e bancadas com material refletor. O experimento foi conduzido em delineamento inteiramente casualizado, com 5 repetições. Foram utilizados a estufa plástica com 42% de sombreamento e telado agrícola com 30% de sombreamento, no interior desses ambientes foram dispostas bancadas com e sem material refletor do tipo Aluminet® de 50% de sombreamento. A estufa plástica apresentou menor temperatura e umidade relativa do ar, além de menor radiação solar global e radiação fotossinteticamente ativa. As bancadas com material refletor, independente do ambiente, promoveram maior radiação fotossintética refletida. Plantas produzidas sob a estufa plástica possuíam maiores médias de altura, diâmetro e número de folhas, em sua fase inicial de crescimento. A partir dos 56 DAT as plantas no telado agrícola apresentaram maiores alturas, e promoveu maior produção de pimentas. As bancadas refletoras favoreceram o crescimento em diâmetro aos 14 e 28 DAT, e maior produção de frutos. Conclui-se que o telado agrícola com 30% de sombreamento e as bancadas refletoras favorecem o crescimento de pimenta biquinho e a produção de frutos.

Palavras-chave: *Capsicum chinense*; condições micrometeorológicas, Radiação fotossintética refletida.

1. Introduction

The Biquinho pepper (*Capsicum chinense*) is in the ranking of the species most used in the diet of Brazilians (Jorge et al., 2018). Due to its lack of ardor, pleasant aroma, flavor, and crunchiness, the demand for its fruits is increasing, especially by people who do not value pungency (Oliveira et al., 2018). In the national and international market, pepper has stood out concerning other vegetables. It has a unique flavor in its fruits and the diversity of use, being consumed *in natura*, in the industry, and in a processed form (Alves et al., 2019).

The cultivation of vegetables in protected environments has attracted attention over the years due to the benefits promoted, especially concerning the quality of the fruits and better visual appearance compared to the traditional system (Melo et al., 2014). More and more, modern technologies are used in protected cultivation, bringing rapid information and product safety (Costa et al., 2020a), this type of cultivation is among the leading technologies of agricultural modernization, as it mitigates the damage caused by adverse climatic conditions, mainly high solar radiation and temperature, and the plant behavior within the environment is a factor that determines the type of environment to be chosen for the crop of interest (Rebouças et al., 2015).

The use of plastic films and screens in protected crops is of great importance for attenuating, especially, the density of the solar radiation flux, which enables cultivation in regions with high energy incidence. In a study that compared cultivation environments, the ornamental cultivar 'Pirâmide' in a protected environment with shading of 42–50% showed more significant initial growth of pepper plants and early fruiting compared to the same cultivar in shading of 18–22% (Costa et al. al., 2020b). For the chilli cultivars Tupã Bode Vermelha and Boyra Habanero Vermelha, as well as for the ornamental plants Etna and Pirâmide, the agricultural greenhouse was more suitable than the agricultural screens of Sombrite® and Aluminet® (Costa et al., 2017)

The use of benches with reflector material characterizes a recent technique used in plant production that makes it possible to return the radiation present in the environment to the leaves of plants, favoring the best use of energy, providing an increase in plant growth both qualitatively and quantitatively, observing a significant improvement (Salles et al., 2017). Studies with reflective material inside protected environments showed promising and beneficial results for seedlings of yellow passion fruit, *Passiflora edulis* Sims. f. flavicarpa Deg (Santos et al., 2017), jambolan, *Syzygium cumini* (Salles et al., 2017), *Schizolobium amazonicum* (Mortate et al., 2019), *Dipteryx alata* (Costa et al., 2020 c, d) and papaya, *Carica papaya* (Cabral et al., 2020).

Given the importance of determining the cultivation environment and the use of technologies that favor production in these environments, the objective of this work was to analyze two types of protected environments and the influence of benches with reflective material on the formation of Biquinho pepper production plants (*Chinese capsicum*).

2. Material and Methods

The experiments were carried out at the State University of Mato Grosso do Sul (UEMS), at the Cassilândia University Unit (UUC), in Cassilândia (latitude 19º07'21" S, longitude 51º43'15" W, and altitude of 516 m). According to the Köppen classification, it has a dry winter and a rainy summer, characterized as a rainy tropical climate (Aw).

To form seedlings of Biquinho pepper (*Capsicum chinense*), a completely randomized experimental design (RED) was adopted, with five replications containing four plants each, totaling 20 plants per plot. The treatments consisted of two protected cultivation environments, characterized by an agricultural greenhouse with 42% shading and an agricultural greenhouse with 30% shading. Inside these cultivation environments, benches constituted with the absence and presence of reflective material were used, composing a 2 x 2 double factorial scheme (two cultivation environments x two benches).

The environments in which the plants were conducted consisted of an agricultural greenhouse and a screen. The agricultural greenhouse had a dimension of 18.0m x 8.0m (144 m^2) with 4.0 m of ceiling height, covered with a 150-micron low-density polyethylene film (LDPE), light diffuser, pre-drilling, opening zenith sealed with 30% white screen, with 30% monofilament front and side shading screen and LuxiNet 42% aluminized thermo-reflective screen shading, under LDPE film.

The agricultural screen had a structure of 18.0 m long x 8.0 m wide (144 m^2) and 3.5 m in height, closed at 45 degrees of inclination, and black monofilament mesh (Sombrite®) in its entire length with 30% shading. The reflective benches had reflective material of the Aluminet® type (50% shading) arranged on the metallic structure of the bench to increase the incident solar radiation on the seedlings, and the control treatment consisted of the benches without reflective material. These benches were metal tables 1.40m wide x 3.50m long x 0.80m high.

Seeds were purchased commercially and sown in 128 cell trays with three seeds per cell, with sowing on August 19, 2019. The sowing period until seedling formation took place in the agricultural greenhouse (Costa et al., 2017). An emergence was verified seven days after sowing (DAS) on 8/26/19; as there was stabilization, thinning was performed. On October 2, 2019, at 44 DAS, the seedlings were transplanted into plastic pots with a capacity of 1.5 L, black on the inside and green on the outside. The seedlings were transplanted and distributed in different cultivation environments, where the seedlings were placed on the benches with reflective material. Also, those that did not contain reflective material were spaced out to increase the distribution of incident solar radiation. There was no application of nutrients in all phases of the experiment.

The formation of seedlings was carried out in a plastic greenhouse (Costa et al., 2017; Costa et al., 2020b), and both in the tray phase and in the pots, the Carolina® commercial substrate was used as described in its constitution. Sphagnum peat, expanded vermiculite, dolomitic limestone, agricultural gypsum, and NPK fertilizer. The seedlings were irrigated with a manual watering can. Each seedling received the necessary amount of water separately, keeping the substrate moist for the proper growth and development of the seedlings.

After transplanting the seedlings to the cultivation environments, five evaluations were carried out every 14 days. Thus, at 14, 28, 42, 56, and 70 days after transplanting (DAT), plant height (PH), stem diameter (SD), and the number of leaves (NL) were measured throughout the evaluations. In the last evaluation, the number of fruits per plant (NFR) was also counted; for the number of leaves (NL), the evaluation was not performed at 70 DAT, as there were aphid attacks.

The heights of the seedlings were measured with a graduated ruler, measuring the distance from the plant base to the stem apex (cm); the stem diameter was measured with a digital caliper (mm). The number of leaves and fruits, through counting, and for the number of leaves, only fully expanded ones were considered.

Data on air temperature (T, in °C), relative humidity (RH, in %), global solar radiation (GSR, Wm^{-2} were collected and obtained.), and photosynthetically active radiation (PAR, in μmol m^{-2} s^{-1}). The variables T, RH, and GSR in the cultivation environments were collected through meteorological stations model E4000 (Irriplus Scientific Equipment) and in the external environment through the station A742 - Cassilândia (INMET). Global solar radiation was considered in the period from 9 a.m. to 4 p.m., Brasília time (BR). The RFA was obtained through manual collection with a portable digital pyranometer (Apogee), on sunny days and with little or no cloudiness at 11:00 a.m. Brasília time. Reflected radiation data was collected with the device on top of the plants, while incident radiation data were collected with the device in the center of the environment.

Data were subjected to analysis of variance (F test), and means were compared by Student's t-test at 5% probability, using the Sisvar statistical program (Ferreira, 2010; Ferreira, 2019). As there is no repetition of the cultivation environments, the environments were evaluated by analyzing groups of experiments (Banzatto and Kronka, 2013). To compare the micrometeorological variables of air temperature, relative air humidity, global solar radiation, and photosynthetically active radiation, each 15-day period was a block, totaling four blocks.

3. Results and Discussion

By monitoring the micrometeorological data collected in the cultivation environments, it was observed that the climatic conditions inside the environments are different. For example, the highest temperatures were measured outdoors, in full sun, and a protected environment with a black screen, with 30% shading (Figure 1). As for the relative humidity (RH), the environments had higher humidity than the external environment, but the plastic greenhouse with 42% shading had higher humidity than the one covered with a black screen. (Figure 1).

The incident solar radiation was blocked by the constituent materials of the protected environments, and due to the blocking with these screens in these environments, the highest average of global solar radiation occurred in full sun, as expected, due to the absence of covering screens. Among the environments, the agricultural screen with black screen showed the lowest radiation (Figure 2).

Regarding protected environments, the plastic greenhouse with 42% shading promoted greater blocking of the sun's rays, in relation to the agricultural screen with a black screen, presenting a lower average of global solar radiation (Figure 2). Photosynthetically active radiation exhibited the same behavior in environments as verified for global solar radiation (Figure 3).

The analysis of photosynthetically active radiation reflected on the cultivation benches showed an interaction between production systems in the cultivation environments. In the plastic greenhouse and the black screen with 30% shading, the bench with reflective material promoted greater photosynthetic radiation reflected to the plants. The benches with and without reflective material showed higher radiation reflected in the black screen with 30% shading concerning the agricultural greenhouse (Figure 4).

Analysis of groups of experiments allowed to compare the cultivation environments, as the ratio between the largest and smallest mean square of residues (RMSR) was less than seven for all analyzed variables (Banzatto and Kronka, 2013), allowing to verify the best environment for the formation and production of Biquinho pepper (Table 1).

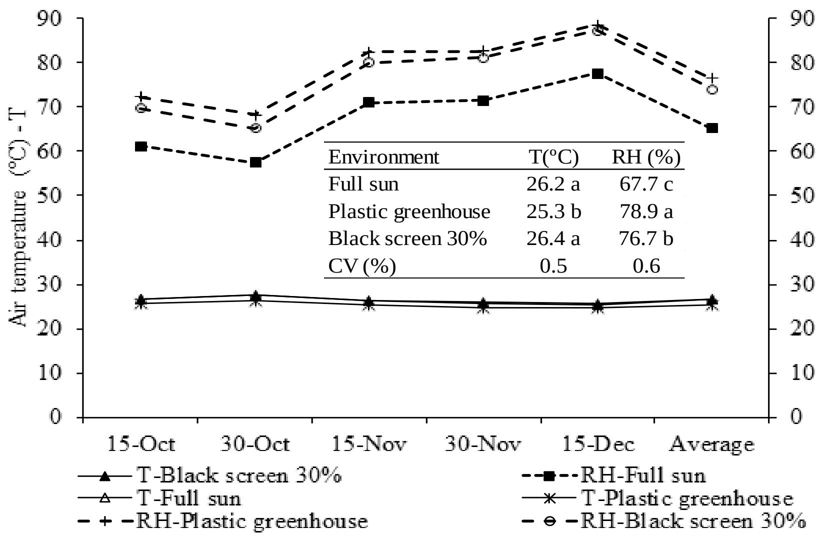

Figure 1. Air temperature (T, ºC) and relative air humidity (RH, %) in cultivation and outdoor environments. Means followed by the same lowercase letter in the column do not differ by the Tukey test at 5% probability. CV = coefficient of variation.

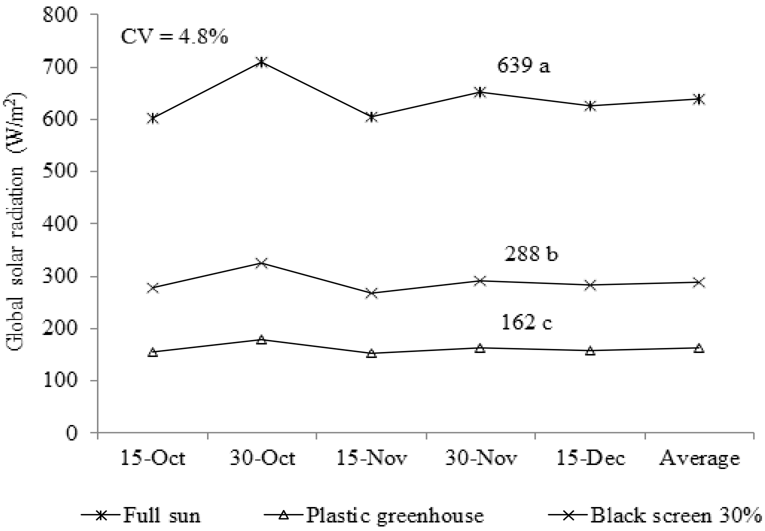

Figure 2. Global solar radiation (W m^{-2}) incident in protected environments and full sun. Means followed by the same lowercase letter do not differ by the Tukey test at 5% probability. CV = coefficient of variation.

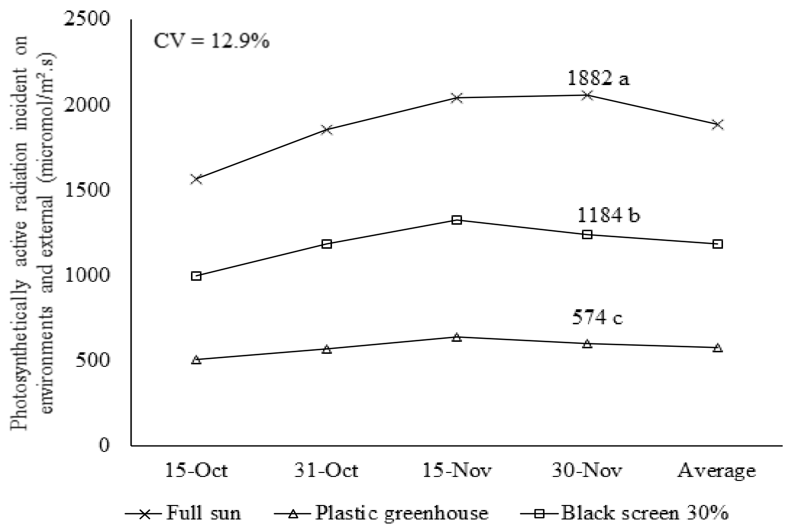

Figure 3. Photosynthetically active radiation (PAR, micromol.m^{-2}.s^{-1}) in cultured and outdoor environments. Means followed by the same lowercase letter do not differ by the Tukey-test at 5% probability. CV = coefficient of variation.

As for the analysis of variance, it was observed that only for the variable number of leaves at 56 DAT, there was an interaction between the factors (Table 2). However, for the other variables, plant height (PH), stem diameter (SD), and the number of fruits (FRUIT) at 14, 28, 42, 56, and 70 DAT, there was no interaction, and the significance of each independent factor was analyzed (Table 2).

The height of Biquinho pepper plants up to 28 DAT had greater growth in plants grown in a plastic greenhouse. At 42 DAT, there was no difference between the environments. Counting from 56 DAT on, there was an inversion of the means in the environments, in which the plant height was higher in pepper plants grown in the agricultural screen (Figure 5). Regarding the cultivation benches, these did not influence the height growth of the Biquinho pepper plants (Figure 5).

The initial growth of plants in the plastic greenhouse (Figure 5) may have been positively influenced by the higher level of shading. As a result of this factor, the plants grew in height as a response mechanism to seek energy for photochemical processes (Figure 2 and 3). Microclimatic conditions such as lower temperature and higher relative humidity may also have favored the development of plants in this environment (Figure 1).

Plant development is highly influenced by light, which is characterized as an essential signal for several biochemical processes of plant development, including photomorphogenesis. Among the photomorphogenic responses, there is the greatest elongation of the hypocotyl due to lower irradiance (Taiz et al., 2017), featuring greater height growth in an environment with a higher level of shading.

Biquinho pepper plants had a larger collar diameter diameter in all collections carried out in the plastic greenhouse with 42% shading, except at 70 DAT. There was no difference between the cultivation environments. (Figure 6). Regarding the cultivation benches at 14 and 28 DAT, the plants with larger diameters came from the benches with reflective material at 42, 56, and 70 DAT. (Figure 6).

The highest means of plant height were accompanied by a larger collar diameter, as verified in a study by Ávila and Barbosa (2019). They report that the shading level may have protective or inhibiting action on photosynthesis and, consequently, it can affect all plant growth. When working with low radiation (80% shading) and under full sun, these authors reported better results in seedlings produced under low radiation, both in height and in diameter. Due to the parallel growth of the diameter, the possibility of etiolation is eliminated, as occurred in this research. However, at 70 DAT, the plants in the black screen environment managed to surpass the size of the plants in the plastic greenhouse.

Similar to the diameter of the collar, plants at 14. 28, and 42 DAT had a greater number of leaves in the agricultural greenhouse. Both cultivation benches similarly influenced the number of leaves (Figure 7).

For the variable number of leaves at 56 DAT, there was an interaction between the study factors. It was observed that there were fewer leaves in the plastic greenhouse with reflective material. In contrast, in the agricultural screen, the reflective material promoted greater leaf formation (Table 3). Concerning the environments, the seedlings produced under an agricultural greenhouse had a more significant number of leaves in the benches without reflective material. In contrast, with reflective material, no differences were observed between the environments.

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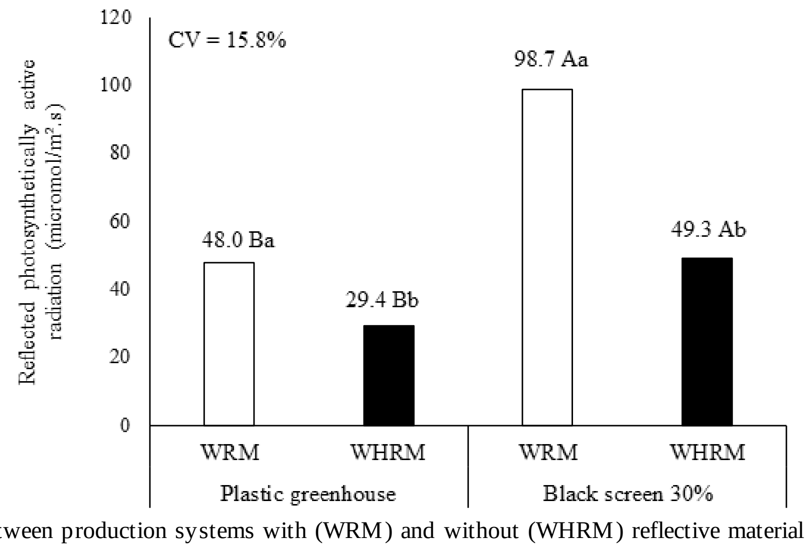

Figure 4. Interaction between production systems with (WRM) and without (WHRM) reflective material on the cultivation bench and protected environments for reflected photosynthetically active radiation (PAR). Means followed by the same lowercase letter for the production system and uppercase for the environments do not differ from each other by the F-test at 5% probability. CV = coefficient of variation.

Table 1. Relationship between the largest and smallest medium square of residues (RMSR) for plant height (PH1, PH2, PH3, PH4, and PH5), collar diameter (SD1, SD2, SD3, SD4, and SD5), number of leaves (NL1, NL2, NL3, and NL4) number of fruits (FRUIT). Cassilândia-MS, 2021.

	PH1	PH2	PH3	PH4	PH5
Plastic greenhouse	0.160	0.337	0.777	1.533	3.922
Black screen 30%	0.114	0.111	0.787	0.697	1.750
RMSR	1.40	3.04	1.01	2.20	2.24
Cultivation Environments/Variables	SD1	SD2	SD3	SD4	SD5
Plastic greenhouse	0.052	0.136	0.054	0.130	0.333
Black screen 30%	0.036	0.043	0.056	0.026	0.052
RMSR	1.43	3.15	1.04	5.01	6.43
Cultivation Environments/Variables	NL1	NL2	NL3	NL4	FRUIT
Plastic greenhouse	1.819	2.909	1.691	0.688	1.328
Black screen 30%	0.684	0.997	0.866	0.325	1.997
RMSR	2.66	2.92	1.95	2.12	1.50

RMSR = ratio between the largest and smallest medium square of the residue of the individual analyzes in the environments.

Table 2. Analysis of variance of the variables plant height (PH1, PH2, PH3, PH4, and PH5), collar diameter (SD1, SD2, SD3, SD4, and SD5), number of leaves (NL1, NL2, NL3, and NL4), and number of fruits (FRUIT). Cassilândia-MS, 2021.

Source of Variation/Variables	PH1	PH2	PH3	PH4	PH5
Cultivation Environments (A)	**	**	ns	*	**
Production System (S)	ns	ns	ns	ns	ns
H x S	ns	ns	ns	ns	ns
CV (%)	6.2	7.1	8.5	7.3	9.2
Source of Variation/Variables	SD1	SD2	SD3	SD4	SD5
Cultivation Environments (A)	**	**	**	**	ns
Production System (S)	*	*	ns	ns	ns
x S	ns	ns	ns	ns	ns
CV (%)	11.4	14.8	8.1	7.3	9.2
Source of Variation/Variables	NL1	NL2	HNL3	NL4	FRUIT
Cultivation Environments (A)	**	**	**	**	**
Production System (S)	ns	ns	ns	ns	*
x S	ns	ns	ns	**	ns
CV (%)	8.8	9.0	8.1	6.3	22.8

* significant at 5% probability; ** significant at 1% probability, ns = not significant

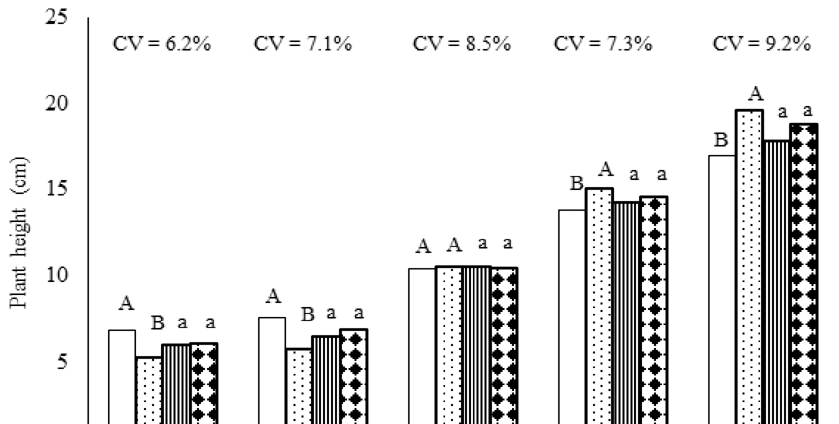

Figure 5. Plant height (PH) at 14, 28, 42, 56, and 70 days after transplanting (DAT) in protected environments and production systems with (WRM) and without (WHRM) reflective material on the cultivation bench. Uppercase letters, equal, for protected environments and lowercase, equal, for production systems with and without reflective material on the cultivation bench, do not differ from each other at 5% probability by the F test. CV= coefficient of variation.

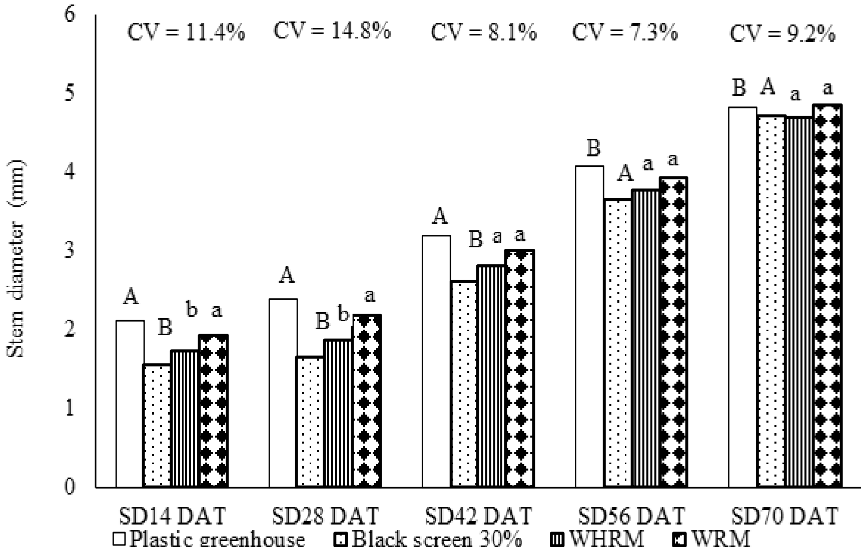

Figure 6. Stem diameter SD) at 14, 28, 42, 56, and 70 days after transplanting (DAT) in protected environments and production systems with (WRM) and without (WHRM) reflective material on the cultivation bench. Uppercase letters, equal, for protected environments and lowercase, equal, for production systems with and without reflective material on the cultivation bench, do not differ from each other at 5% probability by the F test. CV= coefficient of variation.

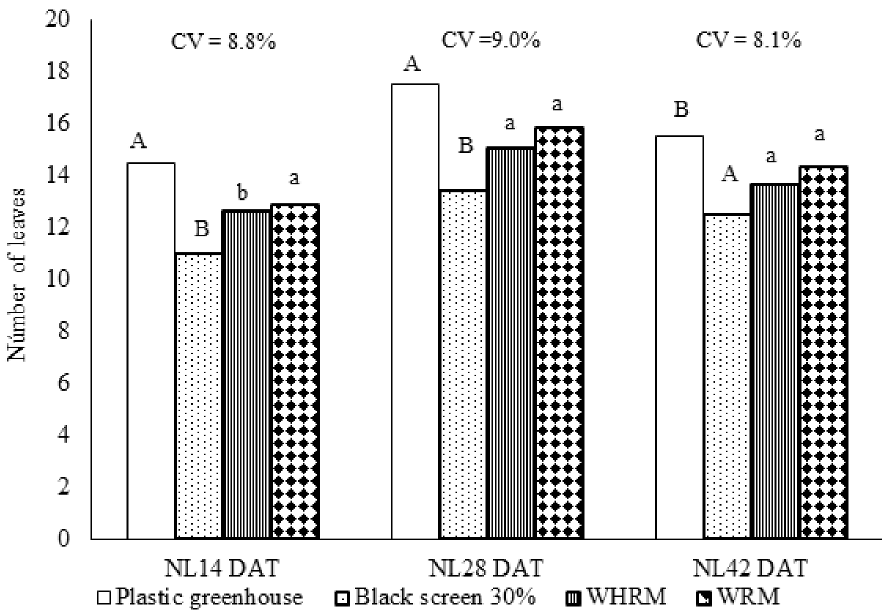

Figure 7. Number of leaves (NL) at 14, 28, and 42 days after transplanting (DAT) in protected environments and production systems with (WRM) and without (WHRM) reflective material on the cultivation bench. Equal uppercase letters for protected environments and equal lowercase letters for production systems with and without reflective material on the cultivation bench do not differ at 5% probability by the F test. CV= coefficient of variation.

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According to Moreira et al. (2009), the cultivation of pepper in a protected environment is beneficial for the growth and production of fruits, as observed by Costa et al. (2017) in pepper cultivars Tupã Bode Vermelha, Boyra Habanero Vermelha, and ornamental pepper cultivars Etna and Pirâmide, which show greater growth and production in a plastic greenhouse with 50% shading.

The highest fruit production occurred in plants cultivated in the agricultural screen with a black screen with 30% shading (Figure 8). The micrometeorological conditions of the environment provided a favorable microclimate for the development of Biquinho pepper.

The use of reflective material on the benches promoted more significant fruit formation. Possibly due to the greater light distribution inside the environments. Thus, the plants produced a more significant amount of photoassimilates that favored the reproductive stage.

Table 3. Interaction between protected environments and production system with and without reflective material for the number of leaves (NL) at 56 days after transplanting (DAT) in protected environments.

	Number of leaves at 56 DAT	
	WHRM	WRM
Plastic greenhouse	13.0 Aa	11.4 Ba
Black screen 30%	10.0 Bb	11.0 Aa

Means followed by the same lowercase letter in the column and uppercase letters in the row do not differ from each other by the F-test at 5% probability.

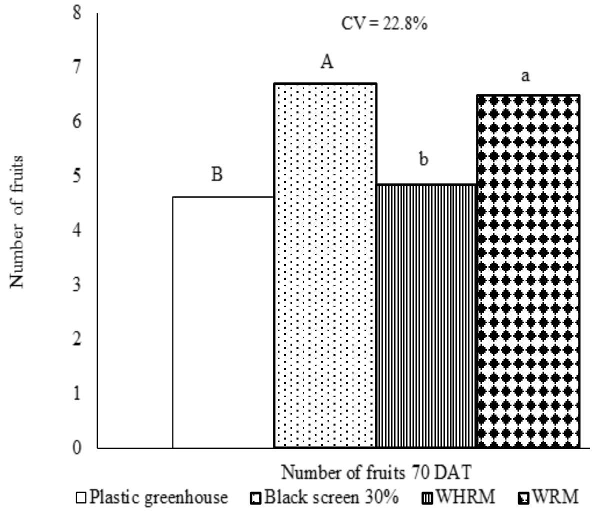

Figure 8. Number of fruits at 70 days after transplanting (DAT) in protected environments and production systems with (WRM) and without (WHRM) reflective material on the cultivation bench. Equal uppercase letters for protected environments and equal lowercase letters for production systems with and without reflective material on the cultivation bench do not differ at 5% probability by the F-test. CV= coefficient of variation.

The highest fruit production occurred on benches with reflective material, demonstrating the efficiency of these materials in increasing the distribution of radiation within the cultivation environment and promoting greater use by plants, being essential for photosynthesis. Since the fruits are the main drains of photoassimilates, according to Duarte and Peil (2010), the leaves are the primary sources of production of assimilates. The distribution of dry matter results from metabolic and transport processes (Taiz et al., 2017).

Positive effects of the greater distribution of photosynthetically active radiation focused on the leaf area of the plants, through the use of benches with reflective material, were also observed for seedlings of jambolão, *Syzygium cumini* (Salles et al., 2017), for seedlings of yellow passion fruit, *Passiflora edulis* Sims. f. flavicarpa Deg (Santos et al., 2017), seedlings *Schizolobium amazonicum* (Mortate et al., 2019), seedlings *Dipteryx alata* (Costa et al., 2020 c, d) and papaya seedlings, *Carica papaya* (Cabral et al.., 2020).

4. Conclusions

The plastic greenhouse had lower temperature and relative humidity, in addition to lower global solar radiation and photosynthetically active radiation. Benches with reflective material, regardless of the environment, promoted more significant reflected photosynthetic radiation.

The plastic greenhouse promoted higher means of height, diameter, and the number of leaves in the initial growth phase. From 56 days after transplanting (DAT), the plants in the agricultural greenhouse showed greater heights and promoted a more outstanding production of pepper.

Reflective benches favored more significant growth in diameter at 14 and 28 DAT and greater fruit production. For the production of Biquinho pepper, the agricultural screen with 30% shading and reflective benches favor growth and production.

Authors' Contribution

Loryelle de Jesus Moreira contributed to setting up the experiment, collecting data, and writing the manuscript. Bruna Finotti Fonseca Reis de Mello 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. Flávio Ferreira da Silva Binotti and Gustavo Haralampidou da Costa Vieira contributed to writing the article.

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