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GROWTH OF ORNAMENTAL PEPPER IN COLORED CONTAINERS UNDER PROTECTED ENVIRONMENTS

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KEYWORDS

Capsicum frutescens, plant ambiance, pot colors.

ABSTRACT

Ornamental pepper plants produced in containers under protected environments have high added value. We carried out research with an aim to evaluate the growth and development of ornamental pepper in containers of different colors under two protected environments, both with thermal-reflective screens under a polyethylene film: one with 18–22 % shading and the other with 42–50 % in colored containers (brown, blue, black, and red). The treatments formed by a 2 × 4 factorial (environments × container colors) were arranged in a completely random pattern with 4 replications and 5 plants per plot, and a joint analysis of experiments was used to compare environments. The protected environment covered with low-density polyethylene film having 42–50 % of shading promoted higher initial growth of pepper plants, including early maturity, compared to the protected environment with 18–22 % of shading. The colored containers, namely, the brown container in a protected environment with 42–50 % shading and red container with 18–22 % shading formed plants with better growth and yield characteristics compared to the black container. The seedlings in the blue container had delayed flowering.

INTRODUCTION

The pepper tree belongs to the Solanaceae family and the *Capsicum* genus; it has appreciable fruit qualities, such as aroma, pungency, and a wide variety of colors and shapes. This genus can be grown in almost all Brazilian territories; however, pepper agribusiness in Korea, is very expressive (Kwon et al., 2006; Nascimento, 2014).

The growth of pepper plants in Brazil has increased yearly, with market acceptability ensuring a sizeable contribution to agribusiness, as well as use in a wide variety of products and byproducts. Its trade is distinguished by two markets: processing and natural. The production of ornamental pepper is included in the natural trade system. Despite good acceptance and growth in the market, studies on ornamental peppers remain scarce (Silva Neto et al., 2014; Crispim et al., 2015; Costa et al., 2015).

Ornamental production of pepper has a large share in the ornamental plant market, as it contains numerous characteristics that give aesthetic value, especially the pyramid cultivar, which stands out for its noticeable size, showy fruits with different colors during the ripening process, easy handling, and high durability. When adopted for landscaping, pepper can reach a larger size, but in containers, their root and shoot growth is limited (Neitzke et al., 2010; Rêgo et al., 2009; Costa et al., 2015).

Protected environments have different configurations, sizes, and structures that provide varying conditions for plant development, such as a microclimate, as well as adequate irrigation protection against diseases, pests, and bad weather, promoting the growth of pepper with better characteristics compared to that grown in the field. Additionally, they also provide year round production (Costa et al., 2010; Rêgo et al., 2012). Black and aluminized silver shading screens (monofilament and thermoreflective, respectively), with 150-µm low-density polyethylene films (LPDE), (agricultural greenhouses) are widely used (Costa et al., 2010).

Another important aspect in crop production is the container used for growing the plant. The most commonly used container for ornamental peppers is a black plastic

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container. However, in the midwest region of Brazil, owing to a high level of solar radiation, the black container gets heated very quickly; this slows down plant growth because of thermal stress. In bean plants, a reduction of root density from 63 to 71 % in black containers has been observed, suggesting that heat-sensitive plants are benefited if they are grown in white containers (Markham et al., 2011).

In addition to the influence of container color on the substrate temperature, another hypothesis may be raised regarding the possibility of photosynthetically active radiation reflectance of container colors favoring photosynthesis, and consequently, plant growth and performance. The aim of this research was to evaluate the growth and development of ornamental pepper, Pirâmide cultivar (*Capsicum frutescens*) in containers of different colors under two protected environments.

MATERIAL AND METHODS

Two protected environments were used: (1) Agricultural screen house 18.0 m × 8.0 m × 4.0 m, covered with a 150-μm LDPE (light diffuser and antidrip), zenithal opening sealed with white shading screen of 30 %, black screen on the sides, shading screen (in monofilament) of 30 % in front, and LuxiNetr® aluminized thermal-reflective shading screen of 42–50 % under the LDPE film. (2) Same as 1, with LuxiNetr® aluminized thermal-reflective shading screen of 18–22 % under the LDPE film. Inside each protected environment, 0.8-L capacity plastic containers of brown, red, black, and blue colors, were tested.

As there was only one setup for the protected evnironments, the colored containers were tested in a completely random pattern with four replicates and five plants per plot. When the ratio of the largest to smallest residual mean square of the individual analysis was less than 7, the joint analyses of experiments was used (Banzatto & Kronka, 2013) to test the protected environments, allowing a 2 × 4 factorial scheme (protected environments × container colors).

Sowing in the trays was done on April 23, 2018, and then transplanted to containers on June 11, 2018, in substrates composed of 50 % soil, 30 % sand, and 20 % vermiculite for both environments. The substrate had the following chemical properties: $P_{(Mel)}$: 75.30 mg dm^{-3}; K, Ca, Mg, SB, and CEC of 0.49, 2.50, 2.50, 5.49, and 7.39 $cmol_c$ dm^{-3}, respectively; BS: 74.3 %; $pH_{(CaCl2)}$: 5.3; M.O.: 18.20 g dm^{-3}; and B, Cu, Fe, Mn and Zn of 0.48, 1.50, 155.0, 53.20, and 5.00 mg dm^{-3}, respectively. Irrigation was done daily by a suspended microsprinkler system with NETAFIM SPINNET® emitters maintaining adequate moisture conditions for the development of the plant.

At 15, 30, 45, 60, 90, and 120 d after transplanting (DAT) the plant height was measured (PH, cm) using a ruler, and stem diameter (SD, mm) with a digital caliper. At 15, 30, 45, and 60 DAT, the number of leaves (NLV) was evaluated. At 60 and 90 DAT, the number of flowers (NFL) and flower buds (NFB) were evaluated. At 60, 90, and 120 DAT, the number of fruits (NFR) was evaluated, and at 120 DAT, the crown area (CWA) was measured with a ruler using two perpendicular measurements of the plant crown diameter.

Data was subjected to analysis of variance (F-test). Means from containers were compared by Tukey's test, and means from protected environments by t-test, both at 5 % probability level (Banzatto & Kronka, 2013). SISVAR software version 5.6 was used for the analyses.

Temperature (T °C), relative air humidity (RH %), and global solar radiation (RG W/m^2) were monitored daily using the E4000 weather station (Irriplus Scientific Equipment) installed at the center of each protected environment. External data was acquired from the weather station A742 - Cassilândia (INMET). The substrate temperature (°C) was determined at 1:00 p.m. using a digital skewer-type thermometer.

RESULTS AND DISCUSSION

Except for the variable stem diameter at 90 DAT (SD-5), the other variables had the ratio of mean square of the error less than 7 (RMSE), which permitted the joint analysis and comparison of the protected environments (Table1) (Banzatto & Kronka, 2013) in a 2 × 4 factorial scheme (2 protected environments × 4 container colors).

TABLE 1. Mean square of the error (MSE) and the ratio of mean square of the error (RMSE) for the variables, plant height (PH), stem diameter (SD), number of leaves (NLV), number of flowers (NFL), number of flower buds (NFB), number of fruits (NFR), and crown area (CWA) of ornamental pepper plants within each protected environment.

Mean square of the errors (MSE)						
P. environment	**PH-1**	**PH-2**	**PH-3**	**PH-4**	**PH-5**	**PH-6**
42–50 % shading	0.061	0.176	1.009	0.367	0.885	0.476
18–22 % shading	0.051	0.327	0.932	0.306	4.437	0.517
RMSE	1.181	1.854	1.083	1.201	5.015	1.087
P. environment	**SD-1**	**SD-2**	**SD-3**	**SD-4**	**SD-5**	**SD-6**
42–50 % shading	0.031	0.041	0.159	0.061	0.124	0.043
18–22 % shading	0.034	0.111	0.291	0.131	0.881	0.080
RMSE	1.097	2.707	1.829	2.161	7.120	1.833
P. environment	**NLV-1**	**NLV-2**	**NLV-3**	**NLV-4**	**NFL-4**	**NFL-5**
42–50 % shading	0.356	4.309	18.216	9.864	0.256	0.603
18–22 % shading	0.250	7.223	37.702	6.179	0.106	2.290
RMSE	1.425	1.676	2.070	1.596	2.424	3.795
P. environment	**NFB-4**	**NFB-5**	**NFR-4**	**NFR-5**	**NFR-6**	**CWA**
42–50 % shading	0.515	3.886	0.303	0.251	1.138	66.853
18–22 % shading	0.500	7.146	0.107	0.204	0.701	103.788
RMSE	1.032	1.839	2.819	1.228	1.622	1.552

1= 15 DAT; 2= 30 DAT; 3= 45 DAT; 4 = 60 DAT; 5 = 90 DAT; 6 = 120 DAT.

Interaction between the protected environments and containers (E × C) for the variable number of flower buds at 90 DAT, number of fruits at 90 DAT, and crown area at 120 DAT were observed. Protected environments influenced the most variables; there was a difference among the containers only for plant height at 30 DAT, stem diameter at 15 and 30 DAT, and number of flowers at 90 DAT (Table 2). The shading levels of the protected environment affected pepper cultivation more than the color of pots, as greater shading favored growth, development, and production of the plants, in agreement with Zhu et al. (2012) and Oliveira et al. (2018), who had verified that this species adapted better in shaded environments.

TABLE 2. Significance of F-test of variance analysis for plant height (PH-1, PH-2, PH-3, PH-4, PH-5, PH-6), stem diameter (SD-1, SD-2, SD-3, SD-4, SD-5, SD-6), number of leaves (NLV-1, NLV-2, NLV-3, and NLV-4), number of flowers (NFL-4 and NFL-5), number of flower buds (NFB-4, NFB-5), number of fruits (NFR-4, NFR-5, NFR-6), and crown area (CWA) of ornamental pepper plants in different protected environments and colored containers.

Treatments	**PH-1**	**PH-2**	**PH-3**	**PH-4**	**PH-5**	**PH-6**
Environment (E)	**	**	*	ns	ns	ns
Container (C)	ns	*	ns	ns	ns	ns
E X C	ns	ns	ns	ns	ns	ns
Treatments	**SD-1**	**SD-2**	**SD-3**	**SD-4**	**SD-5**	**SD-6**
Environment (E)	ns	ns	ns	ns	ns	**
Container (C)	*	*	ns	ns	ns	ns
E X C	ns	ns	ns	ns	ns	ns
Treatments	**NLV-1**	**NLV-2**	**NLV-3**	**NLV-4**	**NFL-4**	**NFL-5**
Environment (E)	ns	**	**	ns	ns	*
Container (C)	ns	ns	ns	ns	ns	*
E X C	ns	ns	ns	ns	ns	ns
Treatments	**NFB-4**	**NFB-5**	**NFR-4**	**NFR-5**	**NFR-6**	**CWA**
Environment (E)	ns	**	*	**	*	*
Container (C)	ns	ns	ns	ns	ns	**
E × C	ns	*	ns	ns	**	**

1 = 15 DAT; 2 = 30 DAT; 3 = 45 DAT; 4 = 60 DAT; 5 = 90 DAT; 6 = 120 DAT. ns = not significant; * significant at 5 %; ** significant at 1 %.

At 15, 30, and 45 DAT, the plants that were grown in the environment with 42–50 % of shading had a higher plant height than the plants grown with 18–22 % shading. However, at 60 DAT, there was no difference in the plant height between the two protected environments. In the environment with 42–50 % shading, solar radiation was lower than that of 18–22 % of shading (Figure 1A). This result is due to the shading promoted by the mesh. In this environment, the plant height was higher for some days due to the plants searching for luminosity because the temperature and relative air humidity were similar (Figures 1A and 1B). Evaluating the different levels of shading, Monteiro Neto et al. (2016) reported that 50 % shading provides higher plant height for bell peppers when compared to environments with a lower percentage of shading. Shading allows the microclimate within the environment to be differentiated and influences plant development (Áscoli et al., 2015, Paula et al., 2017). Some species showed impaired growth in an environment without protection from direct solar radiation such as *Garcinia humilis* (Silva et al., 2018). For presenting morphophysiological characteristics adapted to this type of shaded environment, high exposures to light increases photo-oxidation and causes damage to the photosynthetic apparatus of plants, impairing its photosynthetic rate and, consequently, growth, as observed under the environment with 18–22 % of shading in the present study.

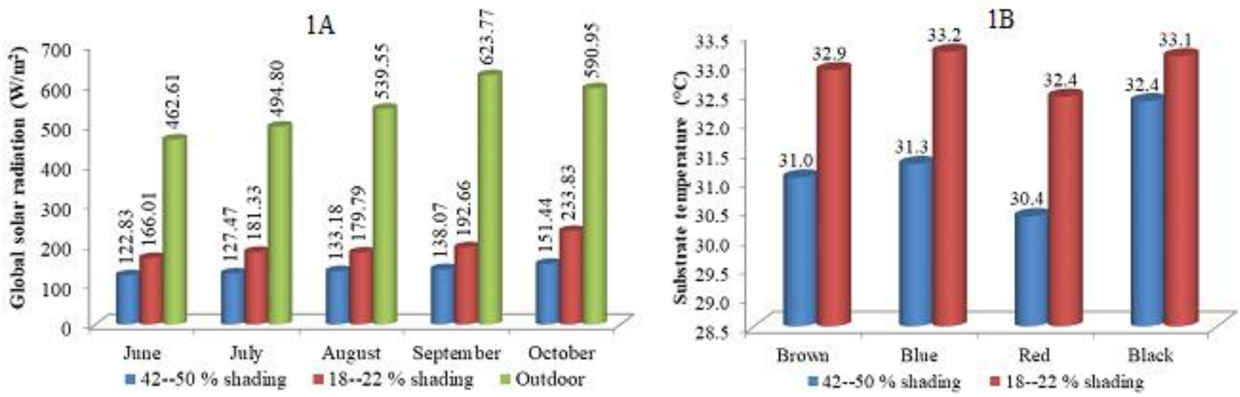

FIGURE 1. Monthly global solar radiation (1A) and substrate temperature (1B) recorded in protected environments and outdoors during the experimental period.

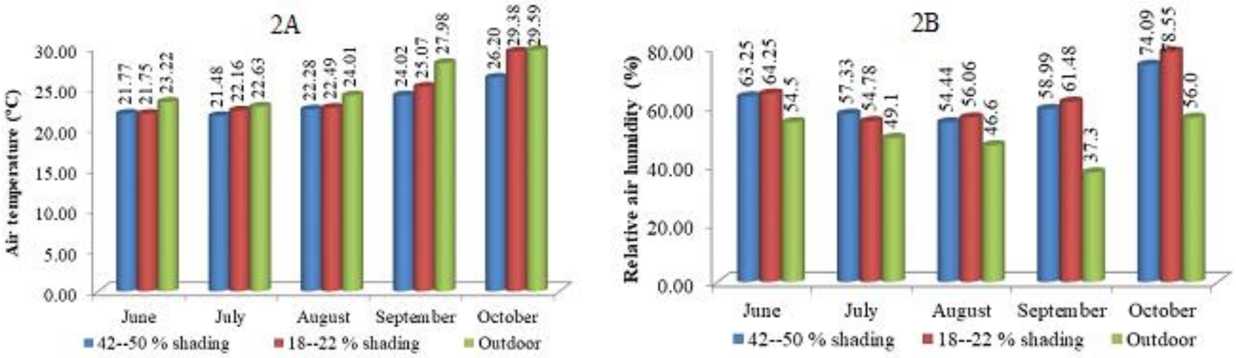

FIGURE 2. Air temperature (2A) and relative air humidity (2B) were recorded in protected environments and outdoors during the experimental period.

Considering containers, only the Brown container had plants with higher plant height than black containers at 30 DAT. There was no difference among other plant height evaluations (Table 3) for other containers. The substrate temperature was higher in the black container than the Brown in both protected environments (Figure 1B). Markham et al. (2011) stated that reduction of root biomass occurred in black containers due to increased substrate temperature, which explains the possible reason for lower plant height.

TABLE 3. Plant height at 15, 30, 45, 60, 90, and 120 days after transplanting of ornamental pepper in different environments and colored containers.

P. environment	PH-1 (15DAT)	PH-2 (30DAT)	PH-3 (45DAT)	PH-4 (60DAT)	PH-5 (90DAT)	PH-6 (120DAT)
42-50 % shading	1.92 a	5.25 a	6.88 a	7.26 a	9.37 a	10.59 a
18–22 % shading	1.60 b	4.44 b	6.25 b	7.05 a	9.23 a	10.92 a
Containers	**PH-1 (15DAT)**	**PH-2 (30DAT)**	**PH-3 (45DAT)**	**PH-4 (60DAT)**	**PH-5 (90DAT)**	**PH-6 (120DAT)**
Black	1.67 a	4.57 b	6.70 a	7.12 a	9.61 a	10.71 a
Blue	1.72 a	4.70 ab	6.15 a	7.22 a	8.78 a	10.75 a
Red	1.73 a	4.92 ab	6.71 a	7.05 a	9.44 a	10.59 a
Brown	1.94 a	5.20 a	6.71 a	7.24 a	8.78 a	10.97 a
CV (%)	13.37	10.33	14.99	8.1	17.53	6.55

Means followed by the same lowercase letters in the columns for each variable do not differ from each other by the t-test for environments and Tukey's test for containers, both at 5 % probability.

The protected environment having 18–22 % of shading developed plants with a larger stem diameter than plants under 42–50 % shading at 120 DAT. It was observed that global radiation was higher in the environment with 18–22 % shading (Figure 1A), which explained the larger stem diameter in conditions more favorable to its development. According to Costa et al. (2010) the lower luminosity offered by the environment with higher shading promotes stem elongation in plants, occurring due to the response of photoreceptors such as phytochrome present in the plant. Less irradiance leads to a change in the active/inactive phytochrome ratio, which possibly influenced the greater production of gibberellin, reflected in the increase of height of the plant. This is similar to the increase in stem knot observed in the 42–50 % shading environment of the present study.

At 15 DAT, the red containers had plants with a higher stem diameter than black containers, but there was no difference for other variables (Table 4). Studies on the influence of the type and color of the container on the development of pine (*Pinus Greggii* and *P. Oaxacana*) seedlings in nurserys showed that the white container for *Pinus Greggii* plant promoted larger stem diameter than the black container including a higher Dickson quality index for *Pinus Oaxacana* (Sánchez-Aguilar et al., 2016).

TABLE 4. Stem diameter at 15, 30, 45, 60, 90, and 120 d after transplanting ornamental pepper plants in different protected environments and colored containers.

P. environment	SD-1 (15DAT)	SD-2 (30DAT)	SD-3 (45DAT)	SD-4 (60DAT)	SD-5 (90DAT)	SD-6 (120DAT)
42-50% shading	1.67 a	2.80 a	3.82 a	4.19 a	4.47 a	4.65 b
18-22% shading	1.68 a	2.80 a	3.75 a	4.36 a	4.27 a	5.17 a
Containers	**SD-1 (15DAT)**	**SD-2 (30DAT)**	**SD-3 (45DAT)**	**SD-4 (60DAT)**	**SD-5 (90DAT)**	**SD-6 (120DAT)**
Black	1.54 b	2.69 a	3.81 a	4.17 a	4.52 a	4.97 a
Blue	1.67 ab	2.86 a	3.65 a	4.24 a	4.06 a	4.99 a
Red	1.80 a	2.97 a	3.86 a	4.24 a	4.41 a	4.82 a
Brown	1.68 ab	2.68 a	3.83 a	4.45 a	4.50 a	4.85 a
CV (%)	10.78	9.83	12.51	7.24	16.19	5.05

Means followed by the same lowercase letters in the columns for each variable do not differ from each other by the t-test for environments and Tukey’s test for containers, both at 5% probability.

At 30 DAT, the highest number of leaves was found in the environment with 42–50 % of shading, and at 45 DAT, the highest value for the same variable was observed in the environment with 18–22 % of shading (Table 5). According to Huang et al. (2011), leaves show plasticity in their morphological characteristics due to environmental conditions, and Dousseau et al. (2007) reported that with more light, they tend to have a higher number of leaves, which corroborates the present study at 45 DAT. In a study with eggplant, Costa et al. (2017) reported that depending on the type of container in which the plant is submitted, the environment may promote different developments. Dalastra et al. (2016), in a study on different shading levels, stated that the number of leaves is a genetic trait, which can vary according to cultivar, environment, and other attributes. From 60 DAT, there is a decrease in the number of leaves, which coincides with the formation of flower buds and flowers. That is, the fall of the leaves occurred due to the use of photoassimilates for flowering.

TABLE 5. Number of leaves (NLV) at 15, 30, 45, and 60 d after transplanting ornamental pepper plants in different protected environments and colored containers.

P. environment	NLV-1 (15DAT)	NLV-2 (30DAT)	NLV-3 (45DAT)	NLV-4 (60DAT)
42-50% shading	6.85 a	18.87 a	25.51 b	25.10 a
18-22% shading	6.67 a	16.11 b	32.65 a	26.13 a
Containers	**NLV-1 (15DAT)**	**NLV-2 (30DAT)**	**NLV-3 (45DAT)**	**NLV-4 (60DAT)**
Black	6.75 a	17.50 a	29.35 a	26.25 a
Blue	6.55 a	16.00 a	26.57 a	26.24 a
Red	6.87 a	18.22 a	31.85 a	24.75 a
Brown	6.87 a	18.25 a	28.55 a	25.24 a
CV (%)	8.14	13.73	18.18	11.05

Means followed by the same lowercase letters in the columns for each variable do not differ from each other by the t-test for environments and Tukey’s test for containers, both at 5 % probability.

The number of flowers at 90 DAT was lower in the 42–50 % shading environment than in 18-22 % of shading. However, the environment with 42–50 % of shading had more fruits at the same evaluation time, indicating that fewer flowers occurred because fruit formation had already occurred. That is, in this environment, the development of plants meeting market conditions and standards was faster, reducing the crop cycle. With regard to the containers, a higher number of flowers was observed at 90 DAT in the black container than in the blue containers, but other characteristics remained the same (Table 6).

It was observed that plants needed more time to flower in blue containers (NFL-5) than in black containers (Table 6), which may be related to the wavelength reflected by this container because, according to Nunes (2013), the increase in blue light inhibits flowering. This fact can be considered as a possible form of management to stagger the growth of plants and thus enable trade at different times.

Container color and its influence on plants have already been reported by Beltrão et al. (2002) when advising on the appropriate use of protected environments in experimentation. These authors state that containers should be uniform in color and size to prevent influence of treatment outcomes.

TABLE 6. Number of flowers (NFL) and number of fruits (NFR) at 60 and 90 d after transplanting, and number of flower buds (NFB) at 60 d after transplanting of ornamental pepper plants in different protected environments and colored containers.

P. environment	**NFL-4 (60DAT)**	**NFL-5 (90DAT)**	**NFB-4 (60DAT)**	**NFR-4 (60DAT)**	**NFR-5 (90DAT)**
42-50% shading	0.61 a	2.39 b	1.84 a	1.09 a	1.89 a
18-22% shading	0.57 a	3.17 a	2.18 a	0.83 a	0.83 b
Containers	**NFL-4 (60DAT)**	**NFL-5 (90DAT)**	**NFB-4 (60DAT)**	**NFR-4 (60DAT)**	**NFR-5 (90DAT)**
Black	0.52 a	3.60 a	2.25 a	0.90 a	1.12 a
Blue	0.65 a	2.05 b	1.65 a	1.22 a	1.53 a
Red	0.49 a	2.67 ab	2.03 a	1.00 a	1.25 a
Brown	0.73 a	2.80 ab	2.12 a	0.73 a	1.54 a
CV (%)	6.47	6.47	35.33	46.96	46.96

Means followed by the same lowercase letters in the columns for each variable do not differ from each other by the t-test for environments and Tukey’s test for containers, both at 5% probability.

The brown container at 90 DAT had a higher number of flower buds when compared to the blue container in a protected environment with 42–50 % of shading. In the protected environment with 18–22 % of shading, the red container had a higher number of flower buds than the brown one (Table 7).

There were a higher number of flower buds in the environment with 18–22 % of shading than with 42–50 % of shading in the black, blue, and red containers. According to Lima et al. (2010), the reflection of red light can influence the development of the plant, providing greater flowering, however, excess light can compromise the emission of flowers. For flowering to occur, the plant must have gone through a phase of vegetative growth and later have a floral induction, which is influenced by the environment, with light being one of the main inducing factors.

TABLE 7. Interaction between protected environments and colored containers for the number of flower buds at 90 DAT, number of fruits, and crown area at 120 DAT in ornamental pepper plants.

P. environment/Containers	**Black**	**Blue**	**Red**	**Brown**
Number of flower buds at 90 DAT				
42-50% shading	3.45 Bab	1.75 Bb	2.85 Bab	5.20 Aa
18-22% shading	7.06 Aab	7.51Aab	8.50 Aa	4.53 Ab
CV (%) = 45.98				
Number of fruits at 120 DAT				
42-50% shading	3.60 Ab	3.35 Ab	2.91 Bb	5.00 Aa
18-22% shading	4.73 Aab	4.11 Aab	5.30 Aa	3.76 Ab
CV (%) = 23.40				
Crown area 120 DAT (cm^2)				
42-50% shading	57.78 Bb	79.79 Aa	59.39 Ab	50.42 Bb
18-22% shading	74.14 Aa	67.69 Ba	63.21 Aa	68.74 Aa
CV (%) = 14.18				

Means followed by the same lowercase letter in the rows and uppercase in the columns for each variable do not differ from each other by the t-test for the environments and Tukey’s test for the containers, both at 5% probability.

In the protected environment with 42–50 % shading, at 120 DAT, there was a higher number of fruits in the brown containers, whereas with 18–22 % of shading, there was a higher number of fruits in the red containers than in the brown containers. When comparing between environments, at 120 DAT, there was a difference only in the red containers, in which the plants had a higher number of fruits in the protected environment with 18–22 % of shading (Table 7). Costa et al. (2017) stated that a protected environment with aluminized material having 50 % shading can increase the number of pepper fruits.

At 120 DAT, with 42–50% shading, the pepper plants had a larger canopy area in the blue container. In contrast, with 18–22 % shading, there was no difference between the containers with different colors. When the two protected environments were compared, the black and brown containers formed plants with a larger crown area under the 18–22 % shading. In comparison, the blue container developed plants with a larger crown area under the 42–50 % shading (Table 7). Differences in the color of containers may have influenced the intensity and quality of the light reflected by them, which in turn may have influenced the plant's photomorphogenesis.

The protected environment of 42–50 % shading promoted greater initial growth in the height of pepper plants. However, at 120 DAT, the same growth was observed to occur with larger diameter under the 18-22 % shading. At 90 DAT under the 18-22 % shading environment, the plants had a higher number of flowers, and the number of fruits at 120 DAT was only influenced by the environment used in red containers, where the 18–22 % shading environment provided higher values. At 120 DAT, the growth in height and diameter was not influenced by the color of the containers.

CONCLUSIONS

The protected environment covered with LPDE and a 42–50 % shading screen under the plastic film promoted higher initial growth of the pepper plants as well as earlier fruiting compared to the protected environment with 18–22 % of shading.

The colored containers formed plants with better growth and yield characteristics when compared to the black container, with emphasis on the brown container in a protected environment with 42–50 % of shading and red container in a protected environment with 18–22 % of shading.

The seedlings in the blue container had delayed flowering.

The growth in height and diameter at 120 DAT was not influenced by the color of containers, however, a larger diameter under the 12–22 % shading environment was observed.

The brown-colored container provided a greater number of fruits than the other containers inside the protected environment under 42-50 % shading. However, under 18–22 % shading it provided less fruit than the red container.

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