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The production of *Physalis* spp. seedlings grown under different-colored shade nets

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ABSTRACT. The objective of this study was to evaluate the production of seedlings of *Physalis* L. species under different-colored shade nets. Four shade nets individually stained white, blue, red and black, all with 50% shading, were used in this study, and an additional treatment (control) was used in which seedlings were grown in full sun. The study examined four species of *Physalis*, namely, *P. peruviana*, *P. pubescens*, *P. minima* and *P. ixocarpa*. The experiment followed a randomized block design with three blocks and 25 seeds per plot. The species were sown in styrofoam trays. Germination was monitored daily to calculate the Emergency Velocity Index (EVI) and stabilize the overall percentage of emergence. Height, stem diameter, number of leaves, leaf area index and dry mass of seedlings were assessed at 50 days after sowing. The study found that these species react differently to changes in the light spectrum. Seedlings of *P. peruviana* should be grown under a white or red shade net; of *P. pubescens* under a white or black shade net; of *P. minima* under a white, red or black shade net; and of *P. ixocarpa* under a white shade net. For all species, 50% shade should be used.

Keywords: *Physalis* L., sexual propagation, seedling morphology, light spectrum.

Produção de mudas de espécies de *Physalis* cultivadas sob diferentes colorações de telas fotoconversoras

RESUMO. Objetivou-se com o presente trabalho, avaliar a produção de mudas de espécies pertencentes ao gênero *Physalis* L. sob telas fotoconversoras de diferentes colorações. Foram utilizadas quatro telas fotoconversoras, nas colorações branca, azul, vermelha e preta, todas com 50% de sombreamento, além de um tratamento a pleno sol (controle), e quatro espécies de *Physalis*: *P. peruviana*, *P. pubescens*, *P. minima* e *P. ixocarpa*. O delineamento experimental foi de blocos ao acaso contendo três blocos com 25 sementes em cada tratamento por parcela experimental. As espécies foram semeadas em bandejas de isopor. Acompanhou-se a germinação diariamente, para cálculo do Índice de velocidade de germinação (IVE) e ao estabilizar, calculou-se a porcentagem total de emergência. Aos 50 dias avaliou-se, altura, diâmetro do colo, número de folhas, índice de área foliar e massa seca das mudas. Concluiu-se que as espécies estudadas reagem de forma diferente à modificação do espectro luminoso. Mudas de *P. peruviana* devem ser formadas sob telado branco ou vermelho, de *P. pubescens* sob telado branco ou preto, de *P. minima* em telado branco, vermelho ou preto e de *P. ixocarpa* sob telado branco, com 50% de sombreamento.

Palavras-chave: *Physalis* L., propagação sexuada, morfologia de mudas, espectro luminoso.

Introduction

Physalis, commonly known as fisális in Brazil and as Physalis in English, is a genus comprising more than over one hundred species. Belonging to the family Solanaceae these species are characterized by a permanent and inflated calyx that surrounds and protects the fruit against herbivores and weather. Among the many species of the genus, some have potential for agronomic exploitation due to their nutritional and medicinal compounds, known for some time in popular culture and, more recently, through studies by researchers from several institutions (Silva et al., Villa, Barp, Rotili, & Stumm, 2013; Muniz et al., 2014).

Among the *Physalis* species whose fruits, which are rich in compounds beneficial to human health, have potential as food are *Physalis peruviana* L., *Physalis pubescens* L., *Physalis minima* L. and *Physalis ixocarpa* Brot.

Seedling growth is one of the most important stages in orchard production. The seedling stage directly influences performance and production, the return on invested capital and the quality of the fruit produced (Campanharo, Rodrigues, Lira Junior, Espindula, & Costa, 2006).

The attenuation of solar radiation is one of the most important factors in the production of seedlings, as this factor acts directly to affect the energy balance and, consequently, the environmental conditions (Hernandes, Pedro-Junior, & Bardin, 2004).

One method of reducing the radiation intensity and also modulating the quality of the incident radiation is to use colored shade nets.

These nets may differ in their transmission efficiency or diffusion of scattered light and also in their ability to distribute the light passing directly through them. These characteristics and differences depend on the physical properties of the nets (Oren-Shamir et al., 2001). The use of colored shade nets increases the growth capacity of the plants and, therefore, influences the quality of the product.

The quality of seedlings can be specified in terms of appropriate morphological and physiological parameters. The use of morphological evaluation by researchers is increasing because it is relatively easy to understand and intuitive for nursery professionals, whereas physiological assessment requires a knowledge of parameters that are not always simple and easy to measure (Gomes, Couto, Leite, Xavier, & Garcia, 2002).

In view of the importance of quality seedlings and the ability to enhance seedling quality by manipulating the light spectrum with shade nets, this study evaluated the seedling production of four species of Physalis grown under shade nets of different colors.

Material and methods

The shade materials used for the plants consisted of Cromatinet® shade nets, Polysack brand, with 50% shading, in four different colors: white, blue, red and black. The nets were deployed on a wooden frame from which they could be removed. The frame measured 3.0 x 3.0 x 1.5 m in width, length and height, respectively. In a control treatment, plants were grown in full sunlight.

Seeds of four species of Physalis were used, namely, *P. peruviana*, *P. pubescens*, *P. minima* and *P. ixocarpa*. The seeds were collected from mature fruits, which were dried in the shade, and then placed into polypropylene trays with 128 cells, using one seed per cell. The substrate used was a mix of soil (dystrophic red clay latosol characteristic of the region) plus commercial substrate, 1:1 v v^{-1}. After sowing, the trays were watered and placed under shade nets, and the seeds were allowed to germinate.

We used a DBC statistical design, a 4 x 5 factorial scheme with four species of Physalis and four color shade nets, in addition to the full-sun control treatment. Each treatment consisted of three replications of 25 seeds each. From the time of sowing, plants were monitored daily.

We evaluated daily the number of seedlings to calculate the Emergence Speed Index according to the equation proposed by Maguire (1962). At the end of this evaluation, 30 days after sowing, we calculated the total percentage of emergence.

Seedlings grown under shade conditions were taken into the field after 50 days. New evaluations were then performed, namely, height (cm), measured with a ruler; stem diameter (mm), measured with calipers; number of leaves; leaf area, measured with the LICOR® LAI-2200 apparatus; and dry mass, measured by drying of the seedlings in the greenhouse for three days and then weighing.

Five seedlings were evaluated as replicates, and an overall average was calculated for each parameter evaluated. We analyzed the data obtained in the experiment with Sisvar software (Ferreira, 2011). An analysis of variance was used. A Scott-Knott cluster test was used. The statistical significance level applied was 5%.

Results and discussion

The results showed significant interaction for the variables emergence speed index (ESI), height, stem diameter, number of leaves and total dry mass. The treatments were also significant for the species, for the color of the shade net, for the leaf area index, and, only among species, for the percentage of emergence.

There was no significant interaction between the color of the shade net and the species studied in relationship to the percentage of emergence. The results were significant only among species, where *P. ixocarpa* had a lower percentage of emergence than the other species (Table 1).

These results demonstrate that the four species of Physalis studied did not have their germination inhibited by the presence of light, demonstrating that positive or neutral photoblastic behavior was operative.

Environmental variations have the ability to facilitate the expression of certain genetic characteristics that may or may not be suitable for adaptive responses for a given plant at a given site

(Botezelli, Davide, & Malavasi, 2000). Thus, seeds of different origins show genetic variability and show relationships between this variability and the environment. This observation sheds light on the lower percentage of emergence in *P. ixocarpa*.

Table 1. Emergency percentage and leaf area index (LAI) of seedlings of four *Physalis* species grown under different-colored shade nets.

Species	Emergency percentage (%)*
P. peruviana	80.53a
P. pubescens	77.86a
P. minima	78.66a
P. ixocarpa	68.53b
CV (%)	1.54
Species	Leaf Area Index*
P. peruviana	1.89a
P. pubescens	1.72a
P. minima	2.16a
P. ixocarpa	1.30b
CV (%)	5.97
Shade net color	Leaf Area Index*
Pleno sol	2.58a
Branca	1.51b
Azul	1.71b
Vermelha	1.53b
Preta	1.43b
CV (%)	5.97

*Means followed by the same lower case letter in the column do not differ by Skott-Knott test at 5% probability.

The Emergence Speed Index (ESI) of *Physalis* seeds showed a significant interaction between species and the color of the shade net. However, *P. peruviana* was the only species to show a significant difference in ESI when grown under different-colored shade nets (Table 2). For this species, the red and white nets accelerated the germination of the seeds.

These results corroborate those obtained by Lessa, Ferreira, Araújo Neto, and Souza (2013) and Ferraresi, Yamashita, and Carvalho (2009), who also found superiority of red and white light for the germination of *Emilia coccinea* (Sims) G. Don. and *Murdannia nudiflora* (L.) Brenans seeds, respectively. The high ESI for the seeds germinated under the red and white nets is associated with phytochrome activity. To absorb light in the red range, phytochrome switches to its active form, promoting germination.

The white light treatment includes similar amounts of red and far-red light. However, under these light conditions, the predominant active form of phytochrome facilitates the outcome that the germination percentage and the speed thereof are magnified, accelerating the emergence of seedlings.

The lower value of ESI for *P. peruviana* seed occurred in full sun. This can be explained by the greater loss of substrate water when compared with the treatments under shade nets, regardless of color, due to the direct incident solar radiation on the plants. The presence of shade nets helps in maintaining the relative humidity by hindering ventilation (Oliveira, Leitão, & Rocha, 2012). Thus, the presence of the substrate screens can reduce water loss to the environment, allowing higher rates of imbibition of the seed by accelerating seed germination.

Table 2. Emergency Speed Index (ESI), length (cm), diameter (mm), number of leaves and dry mass (g) of seedlings of four Physalis species grown under different-colored shade nets.

Shade net color	*P. peruviana*	*P. pubescens*	*P. minima*	*P. ixocarpa*
	Emergency Speed Index (ESI)*			
Full sun	6.17Cc*	6.06Ac	18.27Aa	12.96Ab
White	11.83Ab	8.30Ac	18.24Aa	11.26Ab
Blue	9.37Bc	7.23Ac	16.94Aa	12.92Ab
Red	11.03Ac	6.59Ad	17.48Aa	13.85Ab
Black	8.60Bc	8.14Ac	15.04Aa	11.04Ab
CV (%)	13.37			
	Stem length (cm)*			
Full sun	1.95Ac*	1.67Ac	3.51Bb	10.15Ca
White	2.57Ac	2.09Ac	6.41Ab	17.00Aa
Blue	2.22Ac	2.27Ac	4.58Bb	8.40Da
Red	2.63Ac	2.20Ac	5.71Ab	12.85Ba
Black	2.21Ac	1.89Ac	5.38Ab	12.68Ba
CV (%)	13.18			
	Stem diameter (mm)*			
Full sun	1.54Ab*	1.33Ab	2.62Aa	2.74Ba
White	1.63Ac	1.08Ad	2.69Ab	3.93Aa
Blue	1.41Ac	1.20Ac	2.46Aa	1.99Cb
Red	1.54Ab	1.36Ab	2.98Aa	3.02Ba
Black	1.53Ab	1.03Ac	2.81Aa	2.97Ba
CV (%)	11.97			
	Number of leaves*			
Full sun	4.87Ac*	4.80Ac	7.20Bb	10.47Ba
White	5.67Ac	5.07Ac	10.13Ab	12.13Aa
Blue	5.40Ab	5.20Ab	8.20Ba	6.53Cb
Red	5.80Ab	5.20Ab	10.27Aa	10.53Ba
Black	4.33Ab	4.67Ab	9.73Aa	10.73Ba
CV (%)	12.12			
	Dry mass (g)*			
Full sun	0.51Aa	0.51Aa	0.48Aa	0.36Ab
White	0.05Cc	0.08Cc	0.20Bb	0.42Aa
Blue	0.06Cb	0.12Cb	0.26Ba	0.19Ba
Red	0.07Cb	0.06Cb	0.33Ba	0.36Aa
Black	0.19Bb	0.36Ba	0.51Aa	0.44Aa
CV (%)	24.35			

*Means followed by the same lowercase letter in uppercase line and column do not differ by Skott-Knott test at 5% probability.

The effects of the white net on the light spectrum are neutral, not interfering with the transmitted light spectrum. However, differences between the ESI seeds germinated under greenhouse white and full sun were observed (Table 2). This result is consistent with the environmental conditions provided by the white net.

Although this shade net does not cause changes in light quality, it can promote increases of ambient temperature relative to the external environment by hindering the air circulation due to the resistance to airflow, as mentioned above (Oliveira et al., 2012), and this factor is decisive for the germination of *P. peruviana* seed. However, it was quite close to the results found by the same authors when testing a second batch of seeds. For the species in all treatments, the result for *P. minima* was higher, which may be related to genetic factors linked to the colonizing ability of the environments by the various species.

There was a significant interaction between species and color of shade net for the length of the Physalis seedlings. The results showed that *P. minima* and *P. ixocarpa* were sensitive to the color of the shade net, displaying significantly different results. For *P. minima*, greater lengths were observed in seedlings grown under greenhouse white, red and black, and *P. ixocarpa* presented greater length seedlings when grown only under greenhouse white (Table 2, Figure 1).

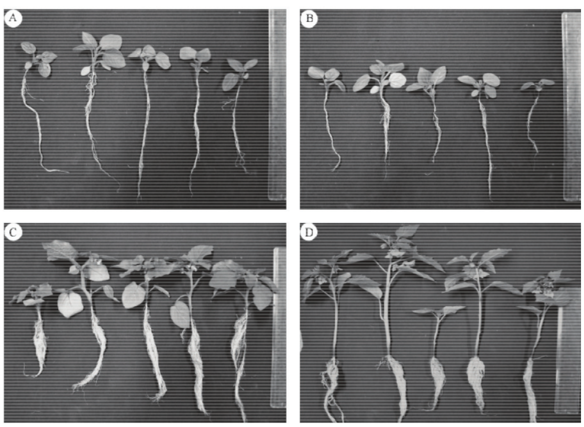

Figure 1. Seedlings of *P. peruviana* (A), *P. pubescens* (B), *P. minimum* (C) and *P. ixocarpa* (D) with 50 days of age, growing under full sun, white, blue, red and black shading net (left to right).

The longer length of the seedlings when grown under red and white shade nets is related to the greater balance in the relationship R:FR that they offer. Variations in the ratios R:FR stimulate responses to stem elongation. This stretching is connected to the phytochrome, which regulates the transport of plant growth regulators, among them, auxin. These regulators are observed in plants grown in bright cultures with red light and are degraded in crops cultivated under blue light. Thus, the shoot elongation and apical dominance are common under red light. However, the blue light acts to inhibit the growth of the plant. Thus, it is common to observe of side shoots in plants grown under blue light, depending on the breaking of the apical dominance due to the degradation of auxins (Oren-Shamir et al., 2001).

Thus, the effect of the increased intensity of the spectrum in the red range caused by manipulating with shade nets in stem elongation, together with the adverse effect of the blue shade net, was previously reported, e.g., by Oren-Shamir et al. (2001) and Ovadia, Dori, Nissim-Levi, Shahak, and Oren-Shamir (2009) in five ornamental species.

The plants may exhibit greater length when exposed to favorable environmental conditions, which allow them a high photosynthetic performance, resulting in greater amount of photosynthate, or when exposed to light deficiency, elongating their strategy to achieve organs such as those induced by light in higher strata. The reduction of light intensity without improvement in the quality of the light offered for black shade net can justify the growth of *P. minima* seedlings under the greenhouse conditions in this same growth intensity of seedlings grown under the red and white shade nets, which contain a more favorable light spectrum; however, in seedlings grown under black shade nets, rapid growth can lead to the formation of poor etiolated seedlings (Santos, Morais, Borsoi, Secco, & Moreira, 2010).

The occurrence of low rates in the growth of plants grown in full sun, relative to plants under shade nets, is a widespread result in the literature (Oliveira, Castro, Costa, & Oliveira, 2009; Holcman & Sentelhas, 2013; Souza, Oliveira, Silva, & Lima, 2013). This effect is a result of excessive light intensity, capable of generating damage to photosynthetic tissues (Araújo & Deminicis, 2009). However, the most different results are observed across species, although some have greater height in unshaded conditions. Examples include rosemary (*Rosmarinus officinalis* L.) and guanandi (*Calophyllum brasiliensis* Cambess.); under blue screens, raffia palm (*Rhapis excelsa* (Thunberg) Henry ex Rehder.) and basil (*Ocimum gratissimum* L.); under black shade nets, the *Anthurium andraeanum* Lindl, or exhibit similar growth in different color screens as the case of coffee seedlings (*Coffea arabica* L.) (Meirelles, Paiva, Oliveira, & Tavares, 2007; Martins, Alvarenga, Castro, Pinto, & Silva, 2008; Nomura et al., 2009; Henrique, Alves, Deuner, Goulart, & Livramento, 2011; Souza, Silva, Oliveira, Santos Neto, & Santos, 2014).

In increasing the thickness of the stems of Physalis seedlings in different colors, there was also a significant interaction between the factors. *P. ixocarpa* was the only species to show a significant difference between the treatments, showing diameter of the thicker stem when grown under a white shade net, similar to the pattern observed for seedling height (Table 2).

Corroborating Souza, Silva, Oliveira, Santos Neto, and Santos (2014), increased seedling stem diameter is a characteristic of the great phenotypic plasticity of some species. This occurs with the function of supporting the plant canopy. Thus, similarly to the results that the above authors found in rosemary plants, the treatment in which plants had higher length was also presented the greatest thickness of the stem of the seedlings of *P. ixocarpa*.

Although *P. minima* also showed differences in the length of the plants, the smaller amplitude between the results in relation to the seedlings of *P. ixocarpa*, made this species did not present significant difference for stem diameter. The lengthening of the changes, not accompanied by an increase in the thickness of the stem, can be unbalanced evidence provided in the light and may lead the seedling to shading and loss of quality.

The increased thickness of the stem is a desirable feature, as well as giving support to the mechanical room (Souza et al., 2013), a higher stem thickening can meet the increased need for transport of sap that feeds this room (Freitas, Oliveira, Carvalho, Santos, & Santos, 2007).

For the number of leaves in Physalis seedlings, *P. minima* showed a greater number of leaves under greenhouse white, red and black, *P. ixocarpa* only under the white greenhouse (Table 2). Both species showed higher number of leaves on the same treatment that was also observed higher stem length. These changes observed in the seedlings are results of photomorphogenesis, where low intensity and/ or light quality makes for greater growth and increase in the number of leaves as a strategy to meet the verified deficiency.

The increase in the number of leaves directly reflects the plant leaf area because this factor is dependent on the number, size and residence time leaf in plant (Monteiro et al., 2005). Among the species, decreasing values of the LAI were presented by *P. minima*, *P. peruviana*, *P. pubescens* and *P. ixocarpa*, in that order, that being only the last was significantly different from the others (Table 1).

Increased leaf area in plants, in turn, allows more light interception, with total potential favoring photosynthesis and, consequently, increased production of photosynthate that can be made available for plant growth and fruit production (Reis, Azevedo, Albuquerque, & Silva Junior, 2013).

The leaf area index (LAI) is of paramount importance for us to model the growth and development of plants, and therefore the productivity of the crop (Reis et al., 2013). In IAF analyses of four species of Physalis grown under shade nets of different colorations, each factor alone was significant (Table 1).

The order found for LAI in four species of *Physalis* studied is attributed to the morphology of each species where *P. peruviana* and *P. pubescens* have wider and long leaves for *P. minima* and *P. ixocarpa*. *P. minima*, although with relatively small leaves, also exhibits greater proximity between these, by having short internodes due to the small size of the species, which causes the projection to the ground to be greater than those in the other species, although this presents the only significant difference from *P. ixocarpa*.

The full sun environment elicited an increase in LAI fisális seedlings compared with the other treatments (Table 1). Unlike most results obtained in the literature, where the leaf expansion for light disability compensation is observed, fisális species had higher LAI in full sun.

Most of the projection area in the shadow of the leaves on the ground (LAI) in full sun were driven by the growth of these species in this treatment, so that the presentation of changes in leaf disposition in angularity, size, shape and curvature of the leaves can be expressed better as horizontal distribution.

Similar results were reported by Fagundes et al. (1999) employed in forage grasses, that the largest observed LAI was attributed to better architecture and arrangement of leaves. In addition, Lima, Silva, Moraes, Dantas, and Almeida (2008) found higher leaf area in *Caesalpinia ferrea* Mart ex Tul. seedlings when grown in full sun.

Another hypothesis supported by Bezerra Neto et al. (2005) based on studies with lettuce is that when subjected to excessive radiation, leaves of certain species can acquire particular morphology as an adaptation strategy and may thus alter its leaf area.

The dry mass of the analysis of the seedlings showed a significant interaction between species and shade net color (Table 2). In the dry mass of seedlings, full sun was more significant, providing greater accumulation in all species, but in *P. minima* and *P. ixocarpa*, other shade net colors also provided the same dry mass accumulation, which was not different from the full-sun treatment; they are the black shade net for *P. minima* and the white, red and black shade nets for *P. ixocarpa*.

The results showed that seedlings of *P. peruviana* and *P. pubescens* grown in the climatic conditions of Lavras, are insensitive to the intensity and quality of light, with no significant difference in height growth, stem diameter, number of leaves, which resulted in seedlings with equal dry weight, in all treatments for these species.

In addition to the full-sun treatment, under a black shade net, *P. minima* seedlings also had better outcomes in relation to dry biomass accumulation. This mass accumulation is one plant response to the reduction in the intensity of quality without implementation of light quality because the black shade net only reduces the light, without converting light to the red and blue spectrum, which is theoretically more favorable for photosynthesis.

High dry mass accumulation with a black shade net was also reported by Henrique, Alves, Deuner, Goulart, and Livramento (2011) in coffee seedlings, which had lower dry mass compared to the seedlings grown under a red shade net, from five luminous qualities evaluated.

The quality of light offered after passing through the blue shade net inhibited the growth of *P. ixocarpa* seedlings. Due to the low performance achieved in the evaluation of the length, diameter and number of leaves, the seedlings also had a lower dry mass accumulation when grown under this condition. The low solar radiation in the red band and the high incidence of blue light can affect auxin synthesis, also affecting the growth of plants, and consequently its biomass accumulation.

Lower dry mass results in plants under blue shade nets compared with other colors were also reported by Corrêa, Pinto, Reis, and Moreira (2012) and Henrique, Alves, Deuner, Goulart, and Livramento (2011), in *Origanum vulgare* L. and coffee, respectively. However, the accumulation of dry biomass is related to the response of each species to the light spectrum (Brant et al., 2009) and is not standardized to the lowest and highest accumulation in a single color.

After evaluating all of the parameters, you can see that the modulation of light quality during the training period of *Physalis* seedlings is able to influence its quality. Therefore, the analysis of aspects performed in this study, combined with the physiological and anatomical reviews context, become necessary for a final definition of the best light spectrum for the formation of seedlings of each species to reduce the time, cost and increase the quality of the seedlings to the producer.

Conclusion

Physalis peruviana, *Physalis pubescens*, *Physalis minima* and *Physalis ixocarpa* react differently to the light spectrum used for training quality seedlings. Seedlings of *P. peruviana* should be formed under white or red shade nets; *P. pubescens* under white or black shade nets; *P. minima* under white, red or black shade nets; and *Physalis ixocarpa* under white shade nets.

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