



## Growth and physiology of jelly palm (*Butia capitata*) grown under colored shade nets

Irton de Jesus Silva Costa\*, Bárbara Nogueira Souza Costa, Franscinely Aparecida de Assis, Adalvan Daniel Martins, Leila Aparecida Salles Pio and Moacir Pasqual

Departamento de Agricultura, Universidade Federal de Lavras, Av. Doutor Sylvio Menicucci, 1001, Kennedy, 37200-000, Lavras, Minas Gerais, Brazil. \*Author for correspondence. E-mail: jc.agro12@yahoo.com.br

**ABSTRACT.** *Butia capitata* (Mart.) Becc., commonly known as jelly palm, is a palm tree native to the Cerrado biome. It is considered an endangered species owing to intensive extractive exploitation of its fruits, with slow and uneven seminiferous propagation as an aggravating factor. Thereby, there are some bottlenecks related to jelly palm seedling production that needs to be optimized. Light quality and intensity is very important to seedling production, as it controls the metabolism of plants and consequently their growth and development. Thus, the aim of this work is to evaluate the effect of shade nets on the growth and physiological aspects of jelly palm seedlings. The experimental design was completely randomized, with five treatments, ten replicates and eight plants per replicate, totaling 400 plants. Experimental treatments consisted of the use of shade nets with 50% shading and different radiation intensity: white ( $985 \mu\text{mol m}^{-2} \text{s}^{-1}$ ), red ( $327 \mu\text{mol m}^{-2} \text{s}^{-1}$ ), black ( $433 \mu\text{mol m}^{-2} \text{s}^{-1}$ ), and silver ( $405 \mu\text{mol m}^{-2} \text{s}^{-1}$ ). Full sun ( $1000 \mu\text{mol m}^{-2} \text{s}^{-1}$ ) was used as the control treatment. Growth and physiological analyses of the plants were performed after six months of treatment. We concluded that the red shade net increases growth and biomass of *Butia capitata* plants. However, the use of shade nets had no effect on the tested physiological characteristics of this species. The red shade net is the most suitable for the production of *Butia capitata* seedlings in the southern region conditions of Minas Gerais State.

**Keywords:** shading; palm tree; colored nets; light.

## Crescimento e aspectos fisiológicos de coquinho azedo (*Butia capitata*) cultivados sob malhas fotoconversoras

**RESUMO.** *Butia capitata* (Mart.) Becc. é uma palmeira nativa do bioma Cerrado, popularmente denominada coquinho azedo. Espécie considerada em extinção, devido a exploração extrativista intensiva de seus frutos, apresentando como agravante a propagação seminífera lenta e desuniforme. Por isso, existem alguns gargalos relacionados a produção dessa palmeira que precisa ser otimizado. A qualidade e intensidade de luz são muito importantes para a produção de mudas, pois controla o metabolismo das plantas e conseqüentemente seu crescimento e desenvolvimento. Assim, objetivou-se avaliar o efeito de malhas fotoconversoras no crescimento e aspectos fisiológicos de mudas de coquinho azedo. O delineamento experimental foi inteiramente casualizado, com cinco tratamentos, dez repetições e oito plantas por repetição, totalizando 400 plantas. Os tratamentos consistiram da utilização de malhas fotoconversoras com 50% de sombreamento, sob diferentes radiações proporcionadas: branca ( $985 \mu\text{mol m}^{-2} \text{s}^{-1}$ ), vermelha ( $327 \mu\text{mol m}^{-2} \text{s}^{-1}$ ), preta ( $433 \mu\text{mol m}^{-2} \text{s}^{-1}$ ), e prata ( $405 \mu\text{mol m}^{-2} \text{s}^{-1}$ ). As plantas mantidas a pleno sol ( $1000 \mu\text{mol m}^{-2} \text{s}^{-1}$ ) foram consideradas como o tratamento controle. Após seis meses foram realizadas análises de crescimento e fisiológicas. Conclui-se que a malha vermelha proporciona maior crescimento e aumento de biomassa das plantas de *Butia capitata*. No entanto, o uso de malhas fotoconversoras não influenciam nas características fisiológicas dessa espécie. A malha vermelha é a mais adequada para a produção de mudas de *Butia capitata* nas condições do Sul de Minas Gerais.

**Palavras-chave:** sombreamento; palmeira; malhas coloridas; luz.

### Introduction

The genus *Butia* Becc. (Arecaceae) originated in South America, and the plants belonging to this genus are widely distributed in the south and southeast regions of Brazil (Lorenzi, Noblick, Kahn, & Ferreira, 2010). This species has significant ecological importance, especially in

terms of providing food resources for native fauna (Sarmiento & Villela, 2010).

Jelly palm (*Butia capitata* Mart. Becc.) is a palm tree native to the Cerrado and has great economic potential because its fruits are widely used by regional populations in juice, ice cream, and popsicle production (Martins, 2003; Moura, 2008).

Because of its wide use and the extractive production of this species, the commercial plantation of Jelly palm becomes important to extend the territorial limits. Commercial production is challenging, not only because the propagation of this palm tree is exclusively seminiferous (Lorenzi, 2004) but also because seed germination is low, slow, and uneven, requiring up to one year to complete the germination process (Aquino et al., 2007).

Another factor that must be taken into account during the production of plants is light, because it controls the metabolism of plants and consequently their growth and development. However, light intensity and spectral quality may cause morphophysiological changes in the plant (Meira, Martins, & Manganotti, 2012).

One of the tools used to manipulate the light spectrum transmitted to plants is the use of shade nets. Shade nets combine physical protection of the cultivation environment with differential solar radiation filtering to promote desirable physiological responses regulated by light (Henrique, Alves, Deuner, Goulart, & Livramento, 2011). Many desirable physiological responses have been documented for crop species, including *Physalis* (*Physalis* spp.; Silva et al., 2016), ipe (*Handroanthus* spp.; Sabino, Korpan, Ferneda, & Silva, 2016), rosemary (*Rosmarinus officinalis* L.; Souza, Silva, Oliveira, Santos Neto, & Santos, 2014), and yarrow (*Achillea millefolium*; Pinto et al., 2014).

Shade nets of different light spectra are commercially available. Black shade nets (sombrite nets) are considered neutral and help reduce the incidence of radiation on plants without affecting the spectral quality of light. Red shade nets reduce blue, green, and yellow waves and add waves in the red and far-red spectral range, with transmittance for wavelengths greater than 590 nm (Nomura et al., 2009; Costa, Chagas, Pinto, & Bertolucci, 2012). Silver shade nets increase light reflection and allow temperature control (Polysack Indústrias Ltda, 2011). Conversely, white shade nets do not affect the transmitted light spectrum (Henrique et al., 2011).

Costa, Silva, Sampaio, and Martins (2011) and Amarante, Steffens, Mota, and Santos (2007) report the importance of the transmitted light spectrum when using colored shade nets in fruit growing. They found that using different shade net colors affected a range of variables.

Given both the need to minimize Jelly palm propagation bottlenecks and the potential for optimizing the use of solar radiation for plant metabolism, the present study aimed to assess the effect of shade nets on Jelly palm growth and physiology.

## Material and methods

The experiment was conducted in the Universidade Federal de Lavras (UFLA) Pomology Division's experimental area (21° 14' S, 45° 00' W, 918 m asl). According to the Köppen climate classification, the climate is Cwa (Dantas, Carvalho, & Ferreira, 2007).

Jelly palm (*Butia capitata*) fruits from the 2014/2015 harvest were picked, pulped by hand, and kept in the shade to dry for 4 d in the town of Mirabela, located in the northern region of the Minas Gerais State. The fruits were subsequently taken to the Tissue Culture Laboratory of the Department of Agriculture. The seeds were removed from the endocarp using a vise and were treated with carboxin-thiram (Vitavax-thiran® 200 SC). The seeds were immersed in full-strength fungicide and subsequently dried in the shade for 4h.

The seeds were then taken to the laminar flow hood, wherein the operculum of the embryonic cavity was removed from the seeds. The seeds were then sown in 50-seed-capacity plastic trays containing medium-texture vermiculite as substrate (60 mg + 300 mL distilled water). The trays were placed in a Biological Oxygen Demand incubator at 30°C, 80% humidity, and a 12-h photoperiod for a period of 30 days until full germination. Plants were transferred to pots of 1.1 kg containing soil substrate consisting of clayey dystroferic Red Latosol typical of the region, sand, and organic matter (2:1:1 v/v/v ratio) and were watered.

The treatments utilized the colored shade net ChromatiNET®, provided by the company Polysack Plastic Industry with 50% shade and different proportions of radiation: white (985  $\mu\text{mol m}^{-2} \text{s}^{-1}$ ), red (327  $\mu\text{mol m}^{-2} \text{s}^{-1}$ ), black (433  $\mu\text{mol m}^{-2} \text{s}^{-1}$ ) and silver (405  $\mu\text{mol m}^{-2} \text{s}^{-1}$ ). The net was stretched in a wooden structure of 2 x 2 x 1.5 m length, width and height, respectively. Control group plants were kept in full sun (1000  $\mu\text{mol m}^{-2} \text{s}^{-1}$ ). After six months, the plants were subjected to analysis, using 10 replicates per treatment.

Growth analysis – Plants were assessed for leaf number (units), root number (units), height (cm), stipe diameter (mm), root diameter (mm), leaf length (cm), taproot length (cm), fresh and dry shoot biomass (g) and fresh and dry root biomass (g). Dry mass of plant material was assessed after oven drying at 60°C for 72h.

Relative chlorophyll index (RCI) - RCI was determined using a portable chlorophyll meter (model SPAD-502; Soil and Plant Analysis Development, Minolta Co., Osaka, Japan). The reading was performed between 900 and 1000h. Before performing the readings, the device was calibrated using the

reading checker, according to the recommendations of the manual (Minolta Camera, 1989). Readings were taken for two points in each plant, totaling 20 readings per treatment.

**Chlorophyll content** – Chlorophyll content was assessed using a simplified version of the Scopel, Barbosa, and Vieira (2011) protocol. Leaf tissue samples were collected and transported in a Styrofoam box with ice. Leaf discs with 1-cm diameter were transferred intact into test tubes with lids containing 10 ml of 80% acetone (v/v) and were stored for 24h in a cold room, protected from light. Extracts were then filtered and the resulting solution was placed in cuvettes. The reference sample (blank) consisted of 80% acetone (v/v) solution. The absorbance readings were performed in a spectrophotometer at 645, 652 and 663 nm and chlorophyll *a*, *b* and total contents were calculated using the obtained readings (Witham, Blaydes, & Devlin, 1971). The results were expressed as mg per gram fresh weight of leaf tissue ( $\text{mg g}^{-1}$ ).

**Gas exchange** – Photosynthetic and transpiration rates of fully expanded leaves were evaluated using an infrared gas analyzer (IRGA) model LI-6400 equipped with a quantum sensor. Solar radiation was expressed as  $\mu\text{mol m}^{-2} \text{s}^{-1}$ . The photosynthetically active photon flux density was fixed in the device camera to  $1,000 \mu\text{mol m}^{-2} \text{s}^{-1}$ . Solar radiation was measured at  $405 \mu\text{mol m}^{-2} \text{s}^{-1}$  (40.5%) under the silver net,  $327 \mu\text{mol m}^{-2} \text{s}^{-1}$  (32.7%) under the red net,  $433 \mu\text{mol m}^{-2} \text{s}^{-1}$  (43.3%) under the black net, and  $985 \mu\text{mol m}^{-2} \text{s}^{-1}$  (98.5%) under the white net. The control treatment was measured at  $1,000 \mu\text{mol m}^{-2} \text{s}^{-1}$ , corresponding to 100% incident radiation.

**Electrolyte leakage (protoplasmic tolerance)** – Leaf protoplasmic tolerance was assessed by electrolyte release from leaf discs (Leopold, Musgrave, & Williams, 1981) immersed in 30 ml distilled water in test tubes. Ten leaf discs were collected in 10 replicates per treatment. First, electrical conductivity was measured with a conductivity meter (DIGIMED brand, CD 21A model), after the leaf discs had been immersed for 24h. The first reading was considered free conductivity (FC).

After this measurement, the test tubes were placed in a water bath at  $100^\circ\text{C}$  for 1h and then electrical conductivity was measured again, which was termed total conductivity (TC). The percentage of absolute integrity ( $\text{PAI} = 1 - \text{FC}/\text{TC}$ ) was calculated from these data, according to the method described by Vasquez-Tello et al. (1990).

**Relative water content (RWC)** – Leaf discs from the youngest fully expanded leaf were removed from

the center of the leaf blade of each plant and were massed to determine fresh mass (FM). Leaf discs were then placed in Petri dishes, where they were submerged in distilled water for a 24-h period to assess their turgid mass (TM). Leaf discs were then dried in a forced-air circulation oven at  $70^\circ\text{C}$  for 48h in order to assess their dry mass (DM). RWC was calculated using the following equation:  $\text{RWC} = \{[(\text{FM}-\text{DM}) / (\text{TM}-\text{DM})]\} \times 100$ , according to the method by Barrs and Weatherley (1962).

The experimental design used was completely randomized, with five treatments and 8 plants  $\text{plot}^{-1}$ , totaling 400 plants. All data obtained were subjected to analysis of variance, using the statistical software SISVAR (Ferreira, 2011). In the qualitative tests, the averages were compared using the Scott-Knott test at 5% probability.

## Results and discussion

Shade nets positively influenced most of the assessed growth characteristics (Figure 1); shaded plants exhibited increased root growth and plant height compared to control plants (control).

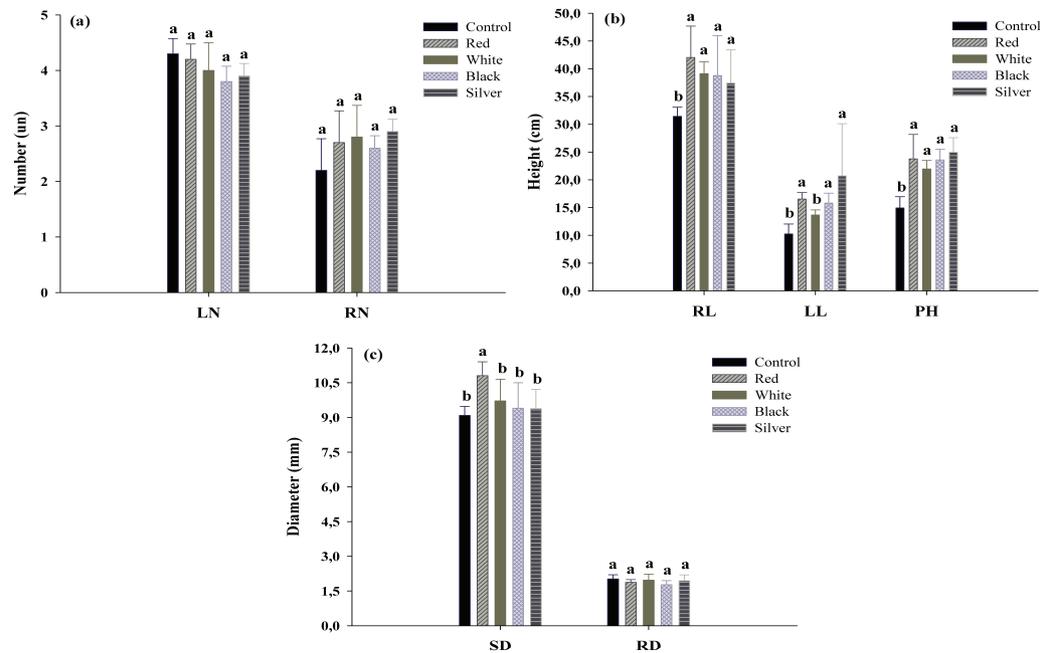
The red, black, and silver net groups exhibited greater leaf length than the white net and control groups (Figure 1b). The red net group exhibited a larger stipe diameter than the other groups (Figure 1c).

The control and white net groups exhibited the lowest leaf length and plant height values. This suggests that Jelly palm plants are sensitive to light quality and that the 50% shading from the nets was beneficial.

This is consistent with the findings of Souza et al. (2011a), where the authors found that guaco (*Mikania glomerata*) plants grown under colored shade nets invested a greater quantity of photoassimilates in shoots than those grown in full sun, probably associated with the increased cell elongation of plants growing under shade.

Conversely, the low plant growth for the white net group most likely occurred because emitted light quality is the main factor controlling plant metabolism, and the white net failed to improve the transmitted light spectrum (Henrique et al., 2011).

The use of shade nets may cause changes in the radiation spectrum available to the plant, leading to metabolic adjustments in the photosynthetic system (Sabino et al., 2016), which may contribute to increasing growth characteristics such as those assessed in this study (i.e., taproot length, leaf length and plant height).



**Figure 1.** a) – Leaf number (LN), root number (RN), b) – taproot length (RL), leaf length (LL), plant height (PH), c) – stipe diameter (SD) and root diameter (RD) of Jelly palm (*Butia capitata*), under shade nets (Lavras, 2016).

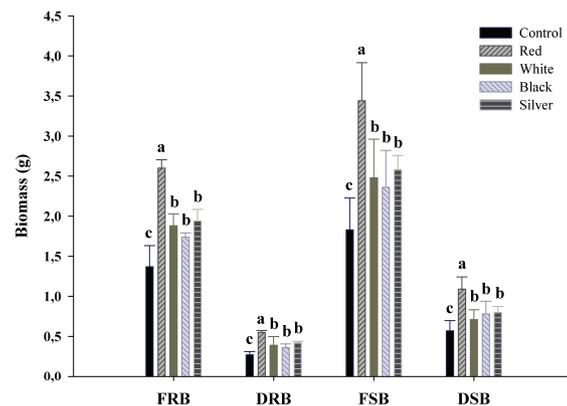
Plants grown under red nets obtained improved incident and absorbed light quality. Therefore, they acquired increased stipe diameters. This phenotypic plasticity is favorable because it improves adaptation to the planting process in the field, thus avoiding possible damping off (Souza et al., 2014). Red nets increased stem diameter in yellow trumpet tree (*Handroanthus serratifolius*) and yellow trumpet tree of the Cerrado (*Handroanthus ochraceus*) plants (Sabino et al., 2016), which corroborates our results.

The use of colored shade nets aims to cause changes in the spectrum of solar radiation available to plants, producing metabolic adjustments in the photosynthetic system (Sabino et al., 2016). Henrique et al. (2011) report that using red light leads to positive responses in plant development.

No differences in leaf number, root number (Figure 1a) or root diameter (Figure 1c) occurred among treatments. Similarly, Henrique et al. (2011) found no effect of shade net color on leaf number in coffee (*Coffea arabica*) seedlings. This may have occurred because, although no differences were found in the number of leaves with respect to the treatments, the meshes provided the study species with the expansion of the organs that is confirmed by the biomass of the plant.

Fresh and dry biomass of roots and shoots (Figure 2) varied among treatments. Plants grown under red nets exhibited higher values of these growth parameters than the other treatments.

Nonetheless, the plants grown under white, black, and silver nets exhibited higher values of fresh root biomass (FRB), dry root biomass (DRB), fresh shoot biomass (FSB) and dry shoot biomass (DSB) compared to the control group.



**Figure 2.** Fresh root biomass (FRB), dry root biomass (DRB), fresh shoot biomass (FSB) and dry shoot biomass (DSB) of Jelly palm (*Butia capitata*) under shade nets (Lavras, 2016).

In this context, the increased biomass accumulation of plants grown under red shade nets may be attributed to a stimulation of growth rate and plant vigor (Tinyane, Sivakumar, & Soundy, 2013).

The red shade nets allow plants to absorb more photons from the red wavelength, which benefit the

activity of the photosynthetic pigments, leading to a higher production of photoassimilates (Taiz & Zeiger, 2013). Thus, plants cultivated under red shade nets usually show greater leaf and root mass (Nascimento, Pinto, Silva Jr, Castro, Santos, 2014; Oren-Shamir et al., 2001).

Henrique et al. (2011) reported that coffee plants grown under red nets exhibited higher dry and total leaf biomass than coffee plants grown under other types of shade nets. The same authors state that the red shade net was the most effective in promoting growth and development of coffee seedlings.

Similar to our study, lemon balm (*Melissa officinalis*) (Brant et al., 2009) and guaco (Souza et al., 2011a) plants grown under colored shade nets accumulated drier biomass than plants grown in full sun.

The colored shade nets represent an agricultural technology that combines the physical protection of the growing environment with the differential filtering of solar radiation (Henrique et al., 2011). The intensity and light quality are of considerable significance for the conversion of the chemical energy in the photosynthetic process, as well as for some morphogenic effects, which can be observed by the variations in the size of the leaves. In addition, the adaptive plasticity of the species associated with the accumulation of biomass depends on the adjustment of its photosynthetic apparatus and are subject to the different solar radiation conditions (Song, 1991).

For RCI, chlorophyll *a*, *b* and total chlorophyll, no difference was noted among the treatments, demonstrating that these characteristics were not affected by shade net color (Table 1).

**Table 1.** Relative chlorophyll index (RCI) and chlorophyll *a*, *b* and total content ( $\text{mg}\cdot\text{g}^{-1}$  fresh matter) in Jelly palm (*Butia capitata*) plant leaves subjected to different shade nets (Lavras, 2016).

Treatments	RCI (%)	Chlorophyll <i>a</i>	Chlorophyll <i>b</i>	Chlorophyll total
Control	53.71 a	0.012 a	0.006 a	0.018 a
Red	53.39 a	0.010 a	0.007 a	0.014 a
White	53.31 a	0.011 a	0.005 a	0.016 a
Black	51.00 a	0.012 a	0.004 a	0.016 a
Silver	55.23 a	0.012 a	0.004 a	0.015 a
CV	12.16	39.81	49.33	35.60

\*Averages followed by the same letters in columns belong to the same group according to the Scott-Knott test ( $p \leq 0.05$ ).

Gonçalves et al., (2012) and Rego and Possamai (2006) report a strong correlation between the increase in chlorophyll content and lower intensity of radiation in mahogany and jequitibá-rosa, respectively. However, Sabino et al. (2016) and Henrique et al. (2011) analyzed ipe and coffee seedlings grown under colored shade nets,

respectively, and found results that corroborate those found in this study.

For photosynthetic rate, internal carbon, transpiration rate, stomatal conductance and internal and external carbon ratio, no difference among treatments was found (Table 2). This implies that the varied spectra transmitted by the colored shade nets had no effect on the photosynthetic activity of the study species.

**Table 2.** Photosynthetic rate – *A* ( $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ ), internal carbon – *Ci* ( $\mu\text{mol CO}_2 \text{ mol}^{-1}$ ), transpiration rate – *E* ( $\text{mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$ ), stomatal conductance – *Gs* ( $\text{mol H}_2\text{O m}^{-2} \text{ s}^{-1}$ ) and internal and external carbon ratio – *Ci/Ca* of Jelly palm (*Butia capitata*) leaves, under shade nets (Lavras, 2016).

Treatments	A	Ci	E	Gs	Ci/Ca
Control	1.7658 a	284.6894 a	0.0005 a	0.0337 a	0.7551 a
Red	1.7149 a	290.3312 a	0.0006 a	0.0369 a	0.7779 a
White	1.7308 a	281.6456 a	0.0006 a	0.0311 a	0.7482 a
Black	1.7982 a	290.1410 a	0.0006 a	0.0375 a	0.7729 a
Silver	1.7235 a	281.2603 a	0.0005 a	0.0334 a	0.7495 a
CV	18.25	5.31	18.50	21.53	5.46

\*Averages followed by the same letters in columns belong to the same group, according to the Scott-Knott test ( $p \leq 0.05$ ).

Souza, Castro, Soares, Santos, and Alves (2011b) also found no differences in photosynthetic rate in guaco plants under colored shade nets. Additionally, stomatal conductance and photosynthesis were not changed in pitomba (*Talisia subalbans*) grown under different shade conditions, according to Nery et al. (2011).

Plants subjected to water stress conditions exhibit a reduction in stomatal opening and in the time during which the stomata remain open (Santos, Silva, & Silva Junior, 2014). Stomatal conductance values reflect the resistance associated with  $\text{CO}_2$  diffusion through the stomatal opening (Silveira et al., 2013). We expected that plants in full sun would have a different photosynthesis rate when compared to other treatments because shading provided by the nets would minimize the loss of water. However, no difference was observed to this characteristic, which might be due to the mild temperature in the region when the experiment was conducted.

The different values of solar radiation in the treatments caused no change in stomatal conductance. Lobos (2012), also observed no changes in stomatal conductance, when studying blueberry (*Vaccinium corymbosum*) under different shade levels (40, 50, and 75% shade). In eucalyptus (*Eucalyptus citriodora*), the highest stomatal conductance values occur when solar radiation is maximal and the leaf water potential has not yet reached the minimum values capable of inducing stomatal closure, according to Ferreira, Davide, and Carvalho (1999). It appears that in our study, the irrigation of the pots was sufficient to maintain leaf

water potential, even with the different solar radiation intensities and air temperatures experienced by the treated plants.

No difference in electrolyte leakage occurred among treatments. Electrolyte leakage is expressed as free and total conductivity and as a percentage of absolute integrity (Table 3).

**Table 3.** Electrolyte leakage of Jelly palm (*Butia capitata*) leaves under shade nets. Free (FC) and total (TC) conductivity and percentage of absolute integrity (PAI) (Lavras, 2016).

Treatments	FC ( $\mu\text{s cm}^{-1}$ )	TC ( $\mu\text{s cm}^{-1}$ )	PAI (%)
Control	33.91 a	135.77 a	0.74 a
Red	34.06 a	139.11 a	0.75 a
White	34.22 a	146.74 a	0.76 a
Black	34.55 a	145.73 a	0.76 a
Silver	35.07 a	130.87 a	0.73 a
CV	13.19	11.69	2.78

\*Averages followed by the same letters in columns belong to the same group according to the Scott-Knott test ( $p \leq 0.05$ ).

The release of electrolytes occurs at severe drought levels because of the increased quantity of reactive oxygen species (superoxides), free radicals, and “lysis” enzymes (Roy-Macauley, Zuily-Fodil, Kidric, Phan Thi, & Vieira da Silva, 1992), which can cause increased membrane permeability and irreversible damage to organelles and molecules present within the cells (Alonso, Queiroz, & Magalhães, 1997).

Thus, the present study aimed to observe through the analysis of electrolyte extravasation whether the plants in full sun would suffer some type of stress due to exposure to higher temperatures when compared to the plants that were under photoconverting mesh, since they had 50% shading.

Although plants went through a period of low temperatures, their water requirements were met adequately. This precluded stress, which was confirmed by electrolyte leakage analysis.

The increased concentration of electrolytes in leaf cells, measured by the total conductivity of the leaf discs, may be a mechanism that prevents tissue desiccation, given the decrease in the osmotic component of leaf water potential (James, Lawn, & Cooper, 2008).

Relative water content is a parameter that characterizes the degree of leaf hydration (Pimentel, Sarr, Diouf, Abboud, & Roy-Macauley, 2002). Relative water content is related to stress conditions; that is, in environments with high temperatures and drought, among others, and plants have decreased leaf water content. Because no significant difference in relative water content occurred among treatments Table 4 demonstrates that the different types of

shade nets and the control treatment did not affect relative water content, indicating that the control plants did not experience this stress.

**Table 4.** Relative water content (RWC) of Jelly palm (*Butia capitata*) leaves under shade nets (Lavras, 2016).

Treatments	RWC (%)
Control	37.00 a
Red	39.10 a
White	36.86 a
Black	33.76 a
Silver	41.27 a
CV	17.43

\*Averages followed by the same letters in columns belong to the same group, according to the Scott-Knott test ( $p \leq 0.05$ ).

## Conclusion

Red shade nets increased the growth and biomass of *Butia capitata* plants.

The use of shade nets had no effect on the physiological characteristics of *Butia capitata* plants.

The red shade net is the most suitable for the production of seedlings of *Butia capitata* in the southern conditions of Minas Gerais.

## Acknowledgements

We thank the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and Fundação de Amparo a Pesquisa do Estado de Minas Gerais (FAPEMIG) for funding this project.

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Received on February 9, 2017.

Accepted on June 20, 2017.

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