PRODUCTION OF AMARYLLIS CULTIVAT ED UNDER PHOTOCONVERTER SHADING NETS

PRODUÇÃO DE AMARYLLIS CULTIVADAS SOB TELAS FOTOCONVERSORAS DE SOMBREAMENTO

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ABSTRACT

Plant growth and development are influenced by biotic and abiotic factors. Considering the abiotic factors, light intensity can be manipulated using shading screens in order to induce better plant performance. Thus, the objective of this study was to evaluate how different shading conditions affect growth and development, starting from *Hippeastrum* plantlets, and plant flowering, after vernalization. Seedlings produced *in vitro* and acclimatized were transferred and covered with different shading nets (black, red, blue and, as a control, full sun). Agronomic and physiological analyses were performed. At the end of the cycle, the bulbs were collected, sanitized and went through vernalization in a cold chamber at 13 °C for 40 days. After this period, the bulbs with diameters between 50 mm and 60 mm were planted under the same conditions of shading and full sun; agronomic and physiological parameters were also analyzed. In the initial development stage, plants grown under black and blue shading nets showed higher chlorophyll content, in addition to fresh and dry matter of bulbs and leaves. A greater accumulation of fresh and dry matter was observed in plants grown under red shading nets. After the vernalization period, similarity was observed in initial cultivation, in which leaf growth and chlorophyll content were higher in plants grown in blue shading net and flowering was stimulated in the red shading net. Thus, the use of blue shading nets stimulates *Hippeastrum* leaf growth. However, with the objective of flower production, it is recommended to use red shading nets to accelerate the flowering process.

KEYWORDS: *Hippeastrum*; Shading; Floriculture; Ornamental Plants.

RESUMO

O crescimento e o desenvolvimento das plantas são influenciados por fatores bióticos e abióticos. Considerando os fatores abióticos, a intensidade da luz pode ser manipulada usando telas de sombreamento para induzir melhor desempenho da planta. Assim, o objetivo com este trabalho foi avaliar como diferentes

condições de sombreamento afetam o crescimento e desenvolvimento, a partir de plântulas de *Hippeastrum*, e a floração das plantas, após a vernalização. Mudas produzidas *in vitro* e aclimatadas foram transferidas e cobertas com diferentes redes de sombreamento (preto, vermelho, azul e, como controle, pleno sol). Foram realizadas análises agronômicas e fisiológicas. Ao final do ciclo, os bulbos foram coletados, higienizados e passaram por vernalização em câmara fria a 13 ºC por 40 dias. Após esse período, os bulbos com diâmetros entre 50 mm e 60 mm foram plantados nas mesmas condições de sombreamento e pleno sol; parâmetros agronómicos e fisiológicos também foram analisados. Na fase inicial de desenvolvimento, as plantas cultivadas sob sombreamento preto e azul apresentaram maior teor de clorofila, além de matéria fresca e seca de bulbos e folhas. Maior acúmulo de matéria fresca e seca foi observado em plantas cultivadas sob redes de sombreamento vermelho. Após o período de vernalização, observou-se similaridade no cultivo inicial, no qual o crescimento foliar e o teor de clorofila foram maiores nas plantas cultivadas em rede de sombreamento azul e a floração foi estimulada na rede de sombreamento vermelho. Assim, o uso de redes de sombreamento azul estimula o crescimento foliar de *Hippeastrum*. No entanto, com o objetivo de produção de flores, recomenda-se o uso de redes de sombreamento vermelhas para acelerar o processo de floração.
PALAVRAS-CHAVE: *Hippeastrum*; Sombreamento; Floricultura; Plantas Ornamentais.

INTRODUCTION

Hippeastrum sp. or amaryllis is an ornamental species produced and marketed as cut flowers, potted flowers and landscaping plants. An interesting market corresponds to the commercialization of propagation material, consisting of an important product for export(1-3). The propagation of amaryllis is frequently carried out through bulb scaling(4) or by micropropagation The commercial production is carried out in protected cultivation, under shading nets, which can induce a relatively fast growth with larger inflorescences(1).

Among the technologies for protected cultivation, the use of shading nets, in addition to attenuating incident radiation, can select light at certain wavelengths, causing different physiological effects on plants(5,6). Among the different wavelength ranges that comprise the visible spectrum, red light acts on the development of the photosynthetic apparatus and can increase starch accumulation and, consequently, induce plant growth. Red light has the greatest influence on photomorphogenesis and phytochrome is the photoreceptor responsible for the absorption of this spectrum. This photoreceptor occurs in two photoconvertible forms, one for red light absorption (active form), and the other for distant red light (inactive form)[7].

Blue light, on the other hand, can alter both growth and development, and it is responsible for helping plants acclimate to adverse environmental conditions[8]. There is a wide range of physiological responses of the plant to blue light, which are translated into electrical, metabolic and genetic processes that lead to changes in growth and development, in order to allow the plants to adapt to changes in environmental conditions. The absorption of blue light by chlorophylls results in a higher energy state due to the excitation of the chlorophyll molecule that can be used in the photochemical step be lost in the form of heat or even cause damage to the photosynthetic apparatus, such as the formation of free radicals. Blue light plays a crucial role in water relations and gas exchange, influencing plant growth[7].

The reaction to the quality and intensity of light influences and reflects on plant growth and development, varying for each species. These particularities that each species reveals are study tools under controlled conditions in which the optimization of cultivation is sought, as well as the best growth and accumulation of phytomass of *Salvia officinalis* cultivated in red and blue meshes with 50% shading was observed[8]. Through growth analysis, it is possible to understand how plants respond to abiotic factors such as the selection of the light spectrum and how they are involved in the physiological aspects of the growth process[9]. The influence of the use of photoconverter nets on production, growth and development has been the object of study of some species such as parsley, which was recommended to be grown in red and black screens with 50% shading[10], alpines cultivated under red or blue screens, also with 50% shading[11], ornamental sunflower, which had better development in full sun and under Aluminet®[12], among others. In general, studies indicate that photoconverter shading nets comprising the blue spectrum stimulate the vegetative phase and the red color spectrum stimulates faster flowering, as well as better flower stem development.

Given the above, the objective of this study was to evaluate the growth and development of *Hippeastrum* plants arising from micropropagation and after vernalization, under different shading net conditions.

MATERIAL AND METHODS

INITIAL DEVELOPMENT

Hippeastrum 'Apple Blossom' seedlings were obtained from micropropagation of scales and acclimatization of shoots for four weeks. After acclimatization, the seedlings were placed under full sun conditions (control), and meshes with 50% shading in black (980 µmol m^{-2} s^{-1}), blue (1010 µmol m^{-2} s^{-1}) and red (1030 µmol m^{-2} s^{-1}), in beds, with spacing of 0.25 m between rows and 0.10 m between plants, totaling 90 plants. The beds were prepared with the incorporation of 6 kg/m^2 of the organic fertilizer Provaso® (sugarcane bagasse, peat, limestone, class A agro-industry organic waste, manure and poultry litter, ash and vegetable cake), 40 g of KCl and 48 g of monoammonium phosphate.

Evaluations of the effect of different shading nets on initial development were carried out after 3 and 6 months, selecting 5 plants from each treatment. The number of roots, number of shoots, bulb diameter (cm), number of leaves and leaf length (cm) of the plants were measured, as well as fresh (g) and dry (g) matter of bulbs and leaves. In a non-destructive way, 10 plants of each treatment were randomly selected to obtain the total chlorophyll content, using a chlorophyll meter (TYS) positioned in the middle portion of the second pair of expanded leaves of each plant, It was conducted at 7:00 am.

POST-VERNALIZATION PRODUCTION

After 6 months, the bulbs were collected, sanitized and underwent vernalization in a cold chamber at 13°C for 40 days. After this period, the bulbs with a diameter between 50 mm and 60 mm were selected, and 41 bulbs were planted in each treatment in three beds, with a spacing of 35 cm in length between the bulbs. Fertilization with NPK (04-14-08), 3 g/m^2 per plant, was carried out 6 days after planting. Irrigation was performed manually and weed control was carried out mechanically.

Analyses started 9 days after planting, when the first leaves began to appear, and repeated every 15 days, evaluating leaf length, number of leaves per plant and chlorophyll content, using a chlorophyll meter (TYS) positioned in the middle portion of the second pair of expanded leaves of each plant, at 7:00 am. From the emergence of the first flower stem, the size of the stem was measured and, from flower opening, the diameter of the flower, the number of flowers per stem, number of stamens and carpel size were evaluated.

STATISTICAL ANALYSIS

The experimental design in both experiments was completely randomized. Data were subjected to analysis of variance - ANOVA ($p < 0.05$) and the Tukey test, at 5% significance using the sisvar 5.6 statistical program (Ferreira, 2014)[13].

RESULTS AND DISCUSSION

Analyzing the initial seedling development, no differences were observed for the number of roots, with an average of 14 roots per bulb being observed. All plants had a single sprouting, with an average of 5 leaves and the formed bulbs had an average diameter of 21.92 mm. Meirelles et al.[14] evaluated the initial development of *Rhapis excelsa*, also cultivated on different shading nets, and concluded that there was no difference between the cultivated plants and that the cultivation of this species can be carried out using the shading nets regardless of color spectrum selection.

Chlorophyll content was not influenced by collection periods, but by different shading nets. Plants grown under the black and blue shading nets had

21.74% more chlorophyll compared to plants grown in full sun and 17.73% compared to plants grown under the red shading net (Fig. 1).

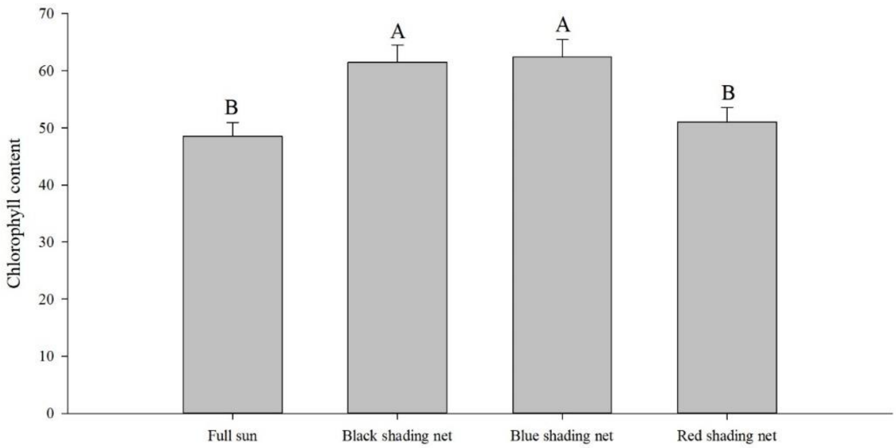

Figure 1. Chlorophyll content at the initial developmental stage of *Hippeastrum* cultivated in full sun and different colors of photoconverter shading nets, measured after 6 months of cultivation. Same letters do not differ by Tukey test at 5% significance; bars represent the standard error.

The use of shading nets is a methodology used to promote changes in the radiation spectrum available to the plant, providing metabolic adjustments in its photosynthetic system. In addition, plant species have different ways of behaving to light variations in the environment, with some species growing more with a high light intensity, and others being more adapted to low light[14,15]. The excess of radiation in *Hippeastrum* plants cultivated in full sun was sufficient to damage the leaves and, consequently, reduce the chlorophyll content. Unlike plants grown in full sun, those grown in the blue colored shading net increased the chlorophyll content, which may have occurred due to changes such as stomatal density, thus increasing the number of chloroplasts and, therefore, the content of chlorophyll produced[11].

There was no difference in the fresh matter of bulbs (Figure 2A) after 3 months of cultivation but, at 6 months, the fresh matter of bulbs cultivated in the red shading net had higher averages, differing from others. These shading nets transfer more spectrum light in red and far-red waves (590 to 750 nm) and diffuse the light that passes through the screen, being efficient in plant development(16). In relation to bulbous, the bulbification process is carried out by a relationship between two bands, the far red and the red. For bulbification occur is necessary to involve the phytochrome system, which changes regulated by this system begin with the absorption of light by the pigment(17). The absorbed light alters the molecular properties of phytochrome and can induce a sequence of cellular reactions that will result in changes in the growth and development of bulbous plants(17).

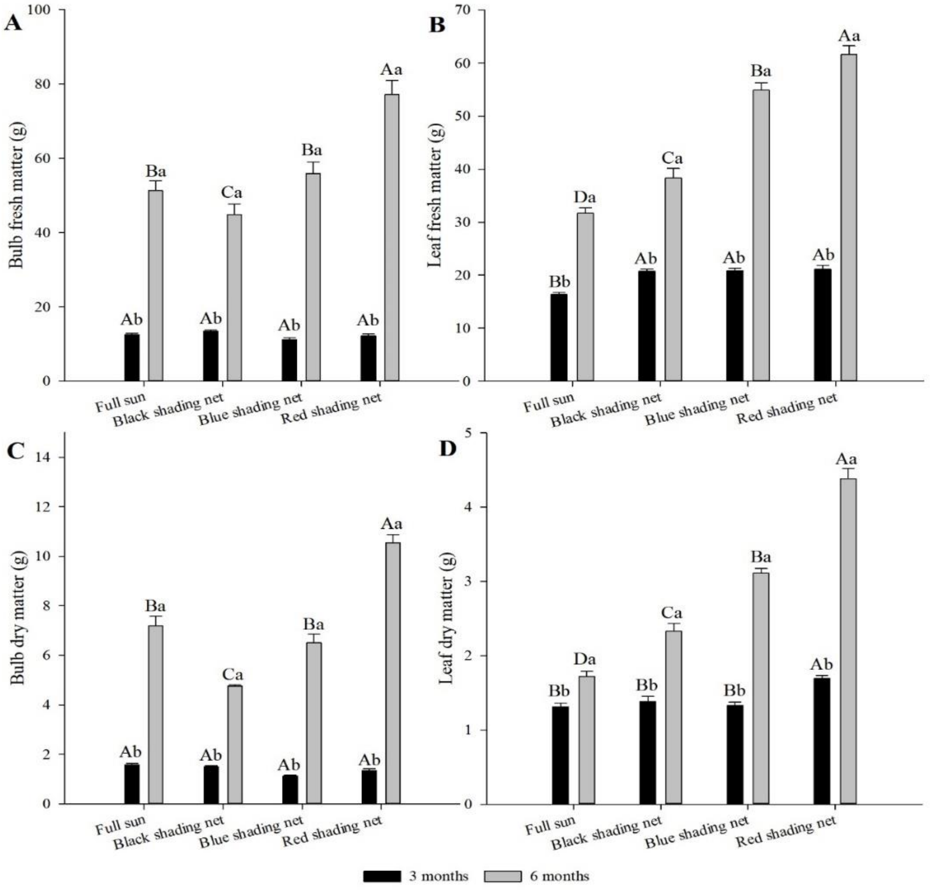

Figure 2. Fresh matter (g) of bulb (A) and leaf (B); Bulb dry matter (C) and leaf dry matter (D) in the initial development stage of *Hippeastrum* cultivated in full sun and different colors of photoconverter shading nets, collected at 3 and 6 months of cultivation. Same capital letters do not differ between treatments and lowercase between collections by the Tukey test at 5% significance; bars represent the standard error.

The bulbs cultivated in the black shading net had the lowest average fresh matter. The fact may be related to the level of shading that, in production, causes competition for assimilates, nitrogen, chloroplast pigments and biomass between leaves and bulbs and implies less bulb development, as observed for *Hippeastrum*[8].

At 3 months, there was no difference for the fresh matter of leaves (Figure 2B) of plants cultivated under the different types of spectra provided by the shading nets; however, the averages obtained in these treatments were higher when compared to the fresh matter of leaves of plants cultivated in full sun. At 6 months, this difference in fresh matter is more visible, keeping the red shading net with higher means, differing from the other treatments.

It was possible to observe a similar behavior of bulb dry matter (Figure 2 C) in relation to its fresh matter. At 3 months, there was no difference between the treatment under full sun and the others using shading nets. At 6 months, plants grown in the red shading net had higher averages than the others and plants grown in the black screen showed the lowest averages. There was no difference in the initial development of *Hippeastrum*: it may be related to the fact that young leaves do not have a well-developed photosynthetic apparatus and the distribution of assimilates is the responsibility of the root at this early stage and, since this organ is not affected by light, their physiological functions are not affected by the different waves of the light spectrum[17].

At 3 months, the dry matter of leaves (Figure 2 D) collected from plants grown in the red shading net was superior to the other treatments. Still at 6 months, plants cultivated in the red shading net had higher dry matter allocation, followed by those grown in the blue, black shading nets and full sun, proving that the intensity and spectral quality of radiation interfere in the morphological development of *Hippeastrum*, in order to increase its photosynthetic efficiency[15].

Hippeastrum plants cultivated in full sun had lower leaf dry matter and leaf length compared to plants grown in awnings, which indicates a low adaptation to this type of cultivation since, in plants under full sun, the leaves tend to have characteristics that allow better control of temperature increase and radiation exposure(15). In addition, the evaluation of *Hippeastrum* leaf dry matter is an excellent parameter for the plant response to the different incidences of the light spectrum selected by the photoconverter shading nets due to the fact that the leaves represent the main part of the assimilating apparatus(8).

The height and mass measurements of the plant are directly related to the diameter and, therefore, the bigger and heavier the plant, the greater its nutritional reserves, providing more vigorous growth(18). In this sense, it was possible to observe that *Hippeastrum* plants cultivated under a red shading net had higher average dry matter of leaves and bulbs, indicating greater plant growth and vigor in this environment, which possibly favored accelerated flowering in relation to the other treatments. Earlier flowering is related to the allocation of biomass which, consequently, indicates allocation of assimilates that are involved in the plant reproductive processes(8,19).

After the vernalization period, the average number of leaves per bulb remained 4 (four). However, the length of leaves (Figure 3A) in plants grown under blue and black shading nets was were greater than that of plants grown in full sun, even though they did not differ from each other. Plants grown under a red shading net had intermediate length.

The same leaf length behavior was observed for chlorophyll content (Figure 3B), highlighting the result obtained in plants under full sun, which induced a lower content of this pigment. *Hippeastrum* plants produce higher levels when cultivated under a blue shading net, which provides spectrum light at a wavelength of 440-490 nm, responsible for intensifying phototropism and photosynthesis(7).

The use of blue shading nets has a positive and coordinated influence on the plant genome and on the plastid, influencing the development of chloroplasts in plant cells, thus resulting in an excitation of chlorophyll, leaving it at a higher energetic stage and, due to this fact, it also leaves it in an unstable condition, releasing part of the energy in the form of heat, resulting in better results related to plant development(7), as observed in the length of *Hippeastrum* leaves cultivated under these shading nets.

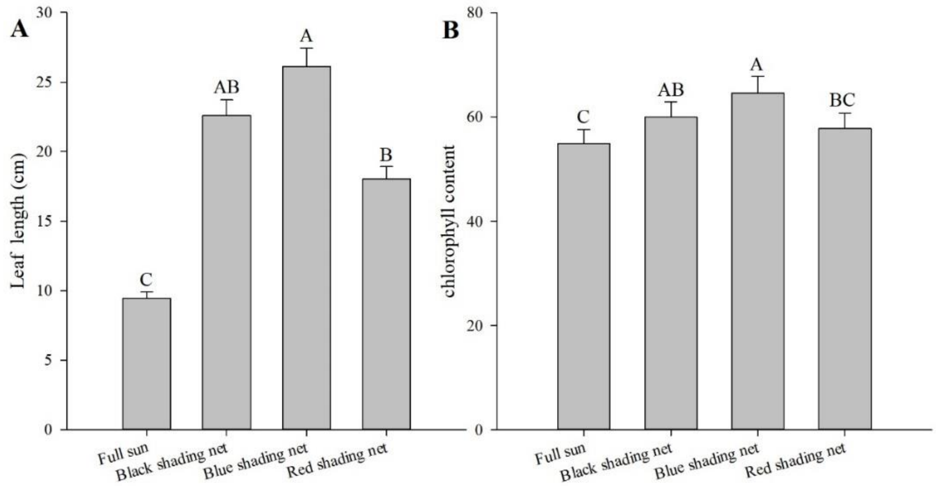

Figure 3. Leaf length (cm) and chlorophyll content after vernalization of *Hippeastrum* cultivated in full sun and different colors of photoconverter shading nets. Same letters do not differ from each other by the Tukey test at 5% significance; bars represent the standard error.

The reduction in chlorophyll content may be associated with the dilution of this content due to the greater expansion of leaves when associated with shading nets(11). Differently from what was observed in *Hippeastrum*, in which the largest leaf expansion also presented higher chlorophyll content, this dilution possibly did not occur, but a stimulus in production by chloroplasts. In studies with citrus, 50% shading provides greater plant development, as well as better performance related to chloroplast contents(20).

In the analysis of chlorophyll, the identification of lower contents in leaves exposed to full sun is related to the arrangement and number of chloroplasts, as full sun allows the occurrence of oxidative stress, in which the absorbed energy is not dissipated, degrading the chlorophyll(20,19). The low chlorophyll contents in *Hippeastrum* plants grown in full sun indicate the occurrence of photoinhibition;

this phenomenon is caused by high irradiance and consequent overproduction of electrons, leading to the formation of reactive oxygen species in the photosystem II complex, causing membrane disruption and destruction of chloroplasts[17].

Stem height (Figure 4) was influenced by cultivation under different shading nets and periods of analysis. Plants under full sun showed no change in growth at this flowering stage. As for the plants grown under the awnings, the stem showed a similar behavior between them, differing between the times of analysis, with the highest averages obtained at 45 and 60 days after planting the bulbs.

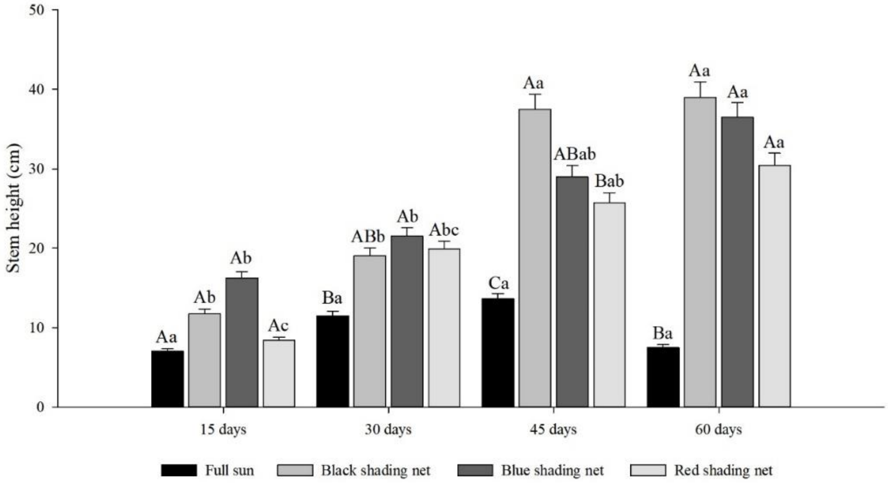

Figure 4. Stem height (cm) after vernalization of *Hippeastrum* cultivated in full sun and different colors of photoconverter shading nets measured at 15, 30, 45 and 60 days. Same capital letters do not differ between treatments and lowercase between assessments by the Tukey test at 5% significance; bars represent the standard error.

At 15 days, the treatments did not differ from each other; at 30 days, the nets differed from full sun, which presented plants with lower stem height. However, for the black shading net, this difference was not so evident. At 45 days, the stem under the screens differed from those under full sun, which, again, presented plants with lower stem height. Comparing between the shading nets, plants cultivated under the red color have lower stem height, black color have greater height and blue do not differ statistically between the two. At 60 days, plants in full sun maintained smaller stems while, among the shading nets, there was no statistical difference.

In general, netting influences the growth parameters providing greater increments in the height of the flower stem. Experiments with lisianthus, plants cultivated under the red-colored awnings showed a greater size in the lengths of the flower stems[(21)]. In cases of shading, there is a possible transfer of plant resources for a rapid development and growth of leaves and stems, trying to reach a part of the solar radiation, being a phytochrome response (frequently mediated by hormones), reducing the leaf area and branches; in addition, treatments exposed directly to the sun have lower growth values, which can be related to the stress that the plant is exposed to, reducing the photosynthetic rate and the allocation of photoassimilates to the different plant organs[(22)]. In the experiment with *Hippeastrum*, the treatment with full sun also showed a lower stem growth average when compared to shading nets, corroborating other authors.

The floral morphology parameters (Fig. 5) were evaluated two months after the implantation of the bulbs in the field. It is noteworthy that this was the first flowering obtained after acclimatization of the micropropagated seedlings. The first evaluations started with the red shading nets, as it was the first treatment to show an apparent flower after 30 days and the other treatments after 48 days. The number of flowers per stem did not differ, with an average of four flowers per stem.

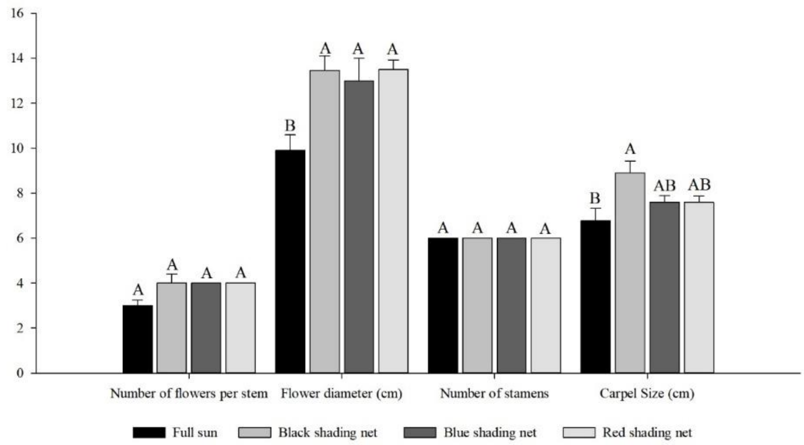

Figure 5. Floral morphology parameters after vernalization of *Hippeastrum* cultivated in full sun and different colors of photoconverter shading nets. Same capital letters do not differ from each other by the Tukey test at 5% significance; bars represent the standard error.

Flower diameter had statistical differences when compared to the cultivation condition under shading nets and full sun; the latter had a smaller diameter. The number of stamens was not changed in cultivated plants, regardless of treatment, with an overall average of 6 stamens per flower. On the other hand, the size of the carpels for plants cultivated in the black shading net and full sun differed statistically, whereas the plants cultivated in full sun had smaller carpels.

The effects of different wavelengths of the visible spectrum were studied in several ornamental plant species and the results presented indicate a stimulus to the vegetative growth rate and vigor. Early development in the treatment with red shading net was also observed in lisianthus plants, whose production may be related to phytochrome responses to the increased incidence of extreme red in plants, which stimulates development and flowering(21).

The acceleration in development may be related to the higher level of energy available for photosynthetic activity, in the microenvironment created under the red shading net. According to Almeida et al.(21), the development of the early flower stem demonstrated under the red shading net, which also occurred for *Hippeastrum*, represents a yield gain for the producer, which should be considered as a significant benefit when investing in this technology. The results found for

Hippeastrum are species-specific responses and, according to Costa et. al.[22], it is not possible to generalize this behavior, since the influence of luminosity through the shading net, on growth and development, is associated with the specificities of each plant.

CONCLUSIONS

In view of the results, *Hippeastrum* plantlets grown in shading nets performed better than those grown in full sun, regardless of wavelength selection.

The blue shading net provided better development of *Hippeastrum* leaves. However, as the objective of production is aimed at the bulb and flowers, the best development and reduction in vegetative time, starting the flowering phase faster, occurred in shading nets that select the wavelength red; this is, therefore, the recommended screen for the production of *Hippeastrum*.

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