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The Effect of Colored Shade Nets on Nutrition and Growth of *Dieffenbachia amoena* 'Starlight'

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Abstract

In order to control the sunlight in the open air and greenhouses in Iran, shade nets are essential. Using shade nets can reduce the air temperature in the covered area. The selection of shade nets with the right color has been shown to have an important role in the growth of ornamental plants under similar conditions. In order to accomplish this objective, an experiment was conducted to examine the impact of shade netting in the shades of blue, white, and green (at a shade level of 50 %) on the growth of *Dieffenbachia amoena* ornamental foliage plants. The basic design of the experiment consisted of randomized complete blocks. During the five-month economic growing period under greenhouse conditions, plant height, diameter, and chlorophyll index were measured every two weeks. At the end of growth, the leaf fresh and dry weight, stem fresh and dry weight, plant growth index, and leaf nutrients were measured. The results indicated that *Dieffenbachia* grown under blue shade nets had higher height, growth index, root dry weight, and iron than those grown under white and green shade nets. Since most Iranian greenhouses produce this ornamental plant under green shade nets, and considering that these two colored shade nets have similar prices, it is recommended that *Dieffenbachia* be produced under blue shade nets.

Keywords: Foliage plants, Greenhouse conditions, Growth factor, Growth index, Nutrients.

INTRODUCTION

The genus *Dieffenbachia*, which is native to the tropical regions of Central and South America, includes about 30 monocot species in the Araceae family (Chen *et al.*, 2003). *Dieffenbachia* is an attractive gardening and interiorscape houseplant used wide-ly throughout the world for its decorative leaves (Sakr, 2016). This plant has broad, variegated leaves with white markings or distinct de-signs with sheathing petioles, giving it a very striking appearance (Haney and Chen, 2003). Light is an important environmental factor that has a significant impact on photosynthesis and plant growth. It is also an energy source for carbon fixation in plants. Chlorophyll, as the main pigment of photosynthesis, plays an important role in light collection and light conversion processes in plants. Solar radiation, as the source of the final stimulation of photosynthesis and its important regulatory factor, can be the main source of stress for the plant at high intensities (Petrović *et al.*, 2017). *Dieffenbachia* are usually grown commercially under 1500 to 3000 foot candles (300 to 600 µmol m^{-2} s^{-1}, approximately 80 percent shade)(Henny *et al.*, 1990). Since Iran is located in a region of the world with a high ranking of solar energy input, with an estimated solar radiation rate of 220 to 1800 kW/m^2/year (Safaii *et al*., 2005). It is necessary to use shade nets to control sunlight during the process of producing indoor ornamental plants (Forghani and Kiani Abri, 2005). In order to address environmental challenges such as drought and climate change and their effects on plant growth, it is possible to consider the production of plants in greenhouse conditions, which is a protected method. Shade nets are an emerging approach for the production of ornamental products, and colored and neutral net canopies can be used for this purpose. Shade nets reduce the temperature of the air below them by physically blocking solar radiation, including photosynthetically active radiation around crops, which reduces heat energy exchange (Stamps, 2009). Arthurs *et al.* (2013) suggested that a net could be used outside or above the greenhouse to reduce the radiation load and create shade inside the greenhouse. da Silva *et al.* (2016) have shown that blue shade nets in *Physalis* species increase the number of lateral branches and decrease apical dominance due to the possible destruction of auxin through changing the ratios of infrared to red. Ribeiro *et al.* (2018) found that the Indian mint plant (*Pogostemon cablin*) produced more essential oil under blue shade nets. The results indicated that blue shade nets in the broad-leaved Aralia "*Fatsia japonica*" prevented vegetative growth and caused dwarfing of the plant, whereas the red and yellow shade nets increased vegetative growth, the length and thickness of stems, petioles, leaf dimensions, and the overall yield of commercial cuttings (Shahak, 2008; Oren-Shamir *et al.*, 2001).

Studies in Brazil showed that *Phalaenopsis* orchids usually produce larger leaves under blue shade nets than black and red shade nets, but the onset of flowering is earlier in red (Leite *et al.*, 2008). The blue light has increased photosynthesis in pepper by increasing leaf area, stimulating stomatal opening, increasing stomatal conductance and increasing chlorophyll content (Ombódi *et al.*, 2016). The results obtained from the utilization of colored nets for *Pittosporum variegatum* revealed that red shade nets induces the extension of plant branches, while blue shade nets results in shortening. Conversely, gray shade nets results in a significant increase in branching, resulting in the production of dense plants with short branches and leaves (Oren-Shamir *et al.*, 2001). Kittas *et al*. (2001) state that the roof of the greenhouse with 50% shade can be effective in reducing the internal temperature of the greenhouse by 10 ºC and can also significantly reduce the temperature of the leaf surface (Shamshiri and Ismail, 2013). Depending on the material used for shade netting, from 20 to 80 % shade, 30 to 50 % light reduction can be expected for most greenhouse applications (Glenn *et al.,* 1984).

The study examined the impact of varying colored nets, including red, green, black and white with 50% shading intensity, and a control (without net), on the production and quality of *Cordyline terminalis* ornamental plants. It was found that under colored nets, regardless of the type of color, leaves of superior quality and higher biomass were produced in comparison to the control. Furthermore, under the shade of the red and white net, the plant height, number of leaves, biomass, leaf area, photosynthesis rate, and harvest index were significantly higher than the control (Gaurav *et al.*, 2016 b). The findings of the investigation revealed that *Aspidistra* exhibited a greater density of growth under the shade of blue-red and blue nets, *Philodendron* produced a greater number of leaves under red shade nets, whereas *Philodendron* produced fewer leaves under blue shade nets, and *Pittosporum* exhibited a greater degree of internode height and length under red and gray shade nets (Rajapakse *et al.*, 1999; Stamps and Chandler, 2008). Blue-colored shade nets reduced the stem length and flower size of *Lisianthus* (Ovadia *et al.*, 2009). Studies have demonstrated that the effect of blue and red shade nets is likely due to their effect on the increase or decrease of blue spectral bands, compared to red and infrared bands. It is further stated that the effect may be due to similar effects of photos elective layers and synthetic irradiation (Rajapakse *et al.*, 1999; Kasperbauer, 1992).

MATERIALS AND METHODS

This experiment was conducted in May 2022 in greenhouses covered with colored shade nets at the Flower and Ornamental Plant Research Station, Lahijan, Iran (37° 11' 44" and 50° 01' 03"). The objective of this study was to investigate the effect of light changes from colored nets on the growth and development characteristics of ornamental foliage plants *Dieffenbachia amoena*. The design consists of randomized blocks with three treatments (blue, white and green shade nets with shade level of 50%)(Fig. 1). Each treatment consisted of three replicates and each replicate consisted of twelve plants pots. Each of the three greenhouse units was covered in blue, white, and green shade nets. *Dieffenbachia*, rooted cuttings, were selected with three leaves and planted in 4-liter pots containing peat and perlite (volume ratio 1:2). Then, they were transferred to a greenhouse.

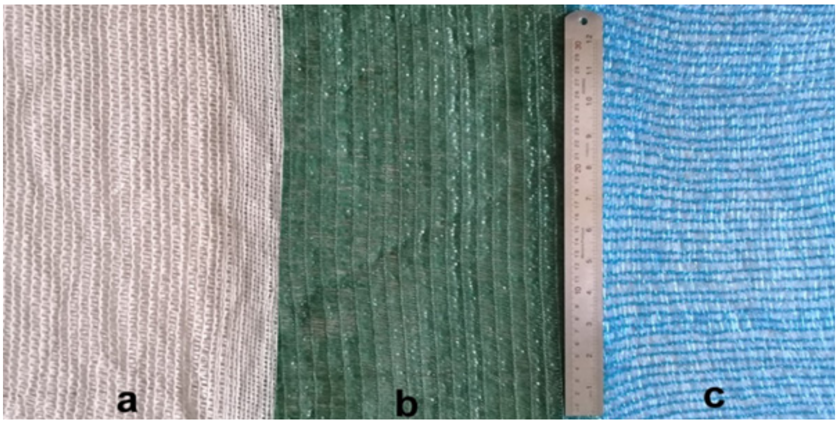

Fig. 1. Colored shade nets used in the experiment (a- White, b- Green and c-Blue shade nets).

Nutrient solution

Growth factors, including height, trunk diameter, and number of leaves, were measured before starting the solution. After measuring the mentioned traits, OMEX powder fertilizer containing 18% nitrogen, 18% phosphorus and 18% potassium was used to prepare the nutrient solution. For the solution, 4.5g of OMEX powder were dissolved in 7.2 liters of water and added to the pots (200 cc per pot) once every seven days (Chen *et al*., 1988). The irrigation requirements of the plant during the growth period were adjusted according to the cultivation beds. *Dieffenbachia* cuttings were placed in greenhouse units that were covered with colored nets. The height and diameter of *Dieffenbachia* plants during the growth period, the chlorophyll index, the fresh and dry weight of leaves, the fresh and dry weight of stem, the plant growth index, and the absorption of nutrients at the end of the growth period were measured.

Growth factors

The height, diameter, and number of *Dieffenbachia* leaves were measered every 15 days. At the end of the experiment, the dry and fresh weight of the shoot were also evaluated. The height of the plant was measured from the surface of the pot to the end of the leaf sheath using a ruler. Stem diameter was measured using a digital caliper. The number of *Dieffenbachia* leaves in each pot was counted. After removing the plants from the pot and thoroughly washing the roots, the fresh weight of both leaves and roots was independently measured using a digital scale. The leaves and roots were then placed in a cardboard envelope and dried at 75 ºC for 48 hours. The dry weight of each sample was measured using a scale.

Based on the following relationship, the plant growth index was determined.

$$\text{Growth index (GI)} = \{(\text{Plant height} + [(\text{diameter } 1^{*} + \text{diameter } 2)/2])/2\}$$

*diameter 1: In the east-west direction; diameter 2: In the north-south direction.

Photosynthetically active radiation was measured in lux using a Testo 545 light meter and then converted to μmol m^{-2} s^{-1}. The light radiation under the investigated color shade nets included an average of 100 to 1100 μmol m^{-2} s^{-1}. The SPAD-502 plus chlorophyll meter was used to measure chlorophyll in μmol m^{-2} s^{-1}. Therefore, five points of each leaf in each plant were measured and recorded their average value.

Chemical analysis

After distillation by the Kjeldahl system, nitrogen was obtained by the titration method (Goos, 1995). The potassium concentration was determined by employing a flame emission technique with a Jenway model flame photometer (Kalra, 1998) An Apel-PD-303 UV spectrophotometer was used to read plant phosphorus at a wavelength of 480 nm (Kalra, 1998). After preparing the extract from the plant, the atomic absorption device was used to measure the calcium and magnesium elements (Kalra, 1998).

Statistical Analysis

The data were analysed statistically using One-Way ANOVA using SAS 9.1 software, average treatments were compared using the LSD method, and graphs were drawn using Excel.

RESULTS AND DISCUSSION

Growth factors

Based on ANOVA (Table 1 and 2), the effect of color shade net on height, growth index, number of leaves, number of leaves, leaf chlorophyll index, fresh weight of roots, and dry weight of roots was significant at the 5% probability level.

Table 1. Analysis of variance of plant growth factors.

S.o.V	df	MS				
		Height	**Trunk diameter**	**Growth index**	**Number of leaves**	**Chlorophyll index**
Treatment (nets color)	2	69.46*	24.89ns	1851.85*	2.11*	432.18*
Error	6	6.51	19.79	180.66	0.63	44.37
Total	35	-	-	-	-	-
CV (%)		15.88	17.28	14.60	11.93	15.32

*, ** and ns: Significant at P < 0.05, P < 0.01 and insignificant based on the LSD test, respectively.

Table 2. Analysis of variance of plant growth factors.

S.o.V	df	MS			
		Fresh weight of leaves	**Dry weight of leaves**	**Fresh weight of roots**	**Dry weight of roots**
Treatment (nets color)	2	1423.15ns	24.02 ns	1182.69*	8.65*
Error	6	804.66	0.01195278	202.554167	1.72
Total	35	-	-	-	-
CV (%)		27.01	7.06	26.06	24.60

*, ** and ns: Significant at P < 0.05, P < 0.01 and insignificant based on the LSD test, respectively.

Based on the mean comparison (Fig. 2a), the highest height (13.45 cm) was found under the blue shade nets. There was a significant difference between the white and green shade nets, but no significant difference was observed between plant height under the white (8.74 cm) and green shade nets (10.27 cm). The height of *Dieffenbachia* was significantly elevated under the blue shade nets in comparison to the white and green shade nets, which is in accordance with the findings of Gao *et al.* (2021), but not with the findings of Shahak *et al.* (2016). Shahak (2008) found that there was no significant difference between the shade effect of blue and red nets on the height of ornamental sunflowers.

According to Tafoya *et al.* (2018), the utilization of shade nets in blue, red, and pearl in cucumber cultivation has resulted in the greatest alteration in either the light spectrum or quality. Additionally, they observed that blue shade nets transmit more light in the blue-green region (from 400 to 570 nm) and increase the infrared flux from 730 nm onward. The mean comparison of *Dieffenbachia* trunk diameter showed values of 9.30 mm, 7.7 mm, and 6.42 mm, respectively, in the blue, white, and green shade nets, which were not significantly different (Table 3). The research showed that there was no significant difference between the effect of blue shade and red shade nets on the diameter of ornamental sunflowers (Nascimento *et al.*, 2016).

The highest growth index (71.68) was obtained using blue shade net. The plant growth index in the blue shade net (5% probability level) was significantly different from the white (47.50) and green (54.65) shade net (Fig. 2b).

The mean comparison (Table 3) showed that the highest number of leaves were created in the white (4.58) and green (4.08) shade nets, and the lowest number was created in the blue shade net (3.75). No significant difference was observed between the white and green shade nets, but these two color shade nets had a significant difference with the blue shade net. Rajapakse *et al.* (1999) reported that the number of *Philodendron* leaves in blue shade nets was lower than in red shade nets. Nascimento *et al.* (2016) also did not observe a significant difference in the number of ornamental sunflower leaves grown in blue and red shade nets.This may be due to the effect of increasing or decreasing the blue spectral bands compared to the red and infrared bands (Rajapakse *et al.*, 1999 ; Kasperbauer, 1992).

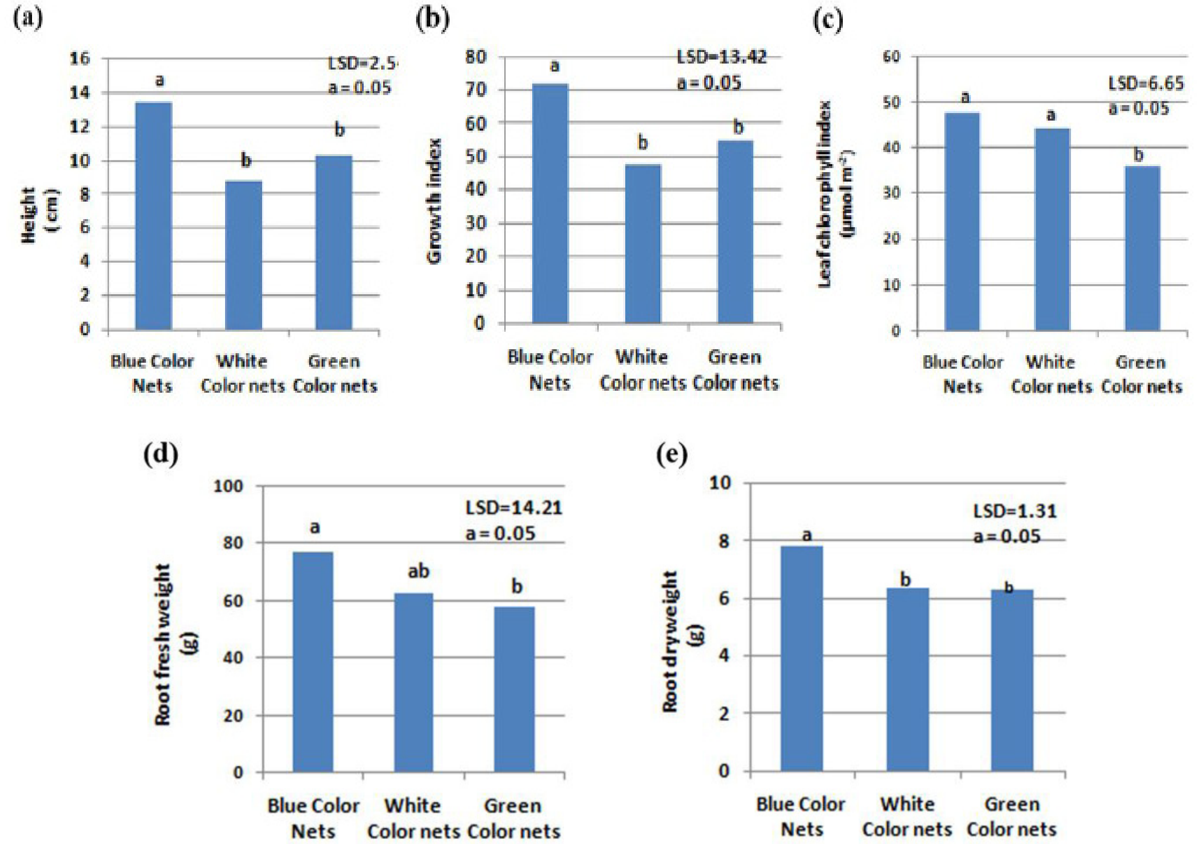

Fig. 2. The mean comparison of color shade nets effect on height (a), growth index (b), leaf chlorophyll (c), root fresh weight (d), and root dry weight (e) of *Dieffenbachia*. The means of each column with a common letter according to LSD are not significant at the 5% probability level.

Table 3. The mean comparison of the plant growth factors.

Treatment	Trunk diameter (mm)	Number of leaves	Fresh weight of leaves (g)	Dry weight of leaves (g)
Blue shade nets	9.30a	3.75b	126.96a	12.59a
White shade nets	7.70a	4.58a	107.78a	10.17a
Green shade nets	6.42a	4.08ab	108.43a	10.10a
LSD	4.44	0.79	28.33	2.65
Alpha	0.05	0.05	0.05	0.05

*In each column, means with similar letter(s) are not significantly different ($P < 0.05$) using the LSD test.

The mean comparison (Fig. 2c) showed that the highest leaf chlorophyll index was obtained in the blue (70.47 µmol/m^2) and white (44.31 µmol/m^2) shade nets. The lowest chlorophyll index (36.04 µmol/m^2) was related to the green shade nets, which had a significant difference with the blue and white shade nets. Gaurav *et al.* (2016a) observed that white and red shade nets significantly increased the leaf chlorophyll of *Dracaena fragrans*. The mean comparison (Table 3) of the fresh weight of plant leaves in blue (126.09 g), white (107.78 g), and green (108.43 g) shade nets shows no significant difference (Table 3). Gaurav *et al.* (2016a) observed that *Dracaena fragrans* grown under white, red, green, and black shade nets did not differ significantly in terms of leaves fresh weight. While Leit *et al.* (2008) observed a consistent pattern of increased leaves fresh weight for *Phalaenopsis* in blue shaded nets compared to black and red. Mean comparison showed (Table 3) that there was no significant difference in the dry weight of *Dieffenbachia* leaves under the blue (12.59 g), white (10.17 g) and green (10.10 g) shade network. Gaurav *et al.* (2016a) observed that the effect of white, red, green, and black shade nets on the dry weight of *Dracaena fragrans* leaves was not significantly different. Also, studies showed that the dry weight of red sweet pepper grown under white and green shade nets did not differ significantly (Ombódi *et al.*, 2016). The mean comparison (Fig. 2d) that the highest fresh weight of plant roots was obtained under the blue (76.80 g) and white (62.75 g) shade nets. which had a significant difference with green shade nets (57.62 g). The mean comparison (Fig. 2e) showed that the highest dry weight of *Dieffenbachia* roots was obtained under the blue shaded nets (7.82 g), which was significantly different from the white shaded nets (6.37 g) and green (6.33 g).

Nutrients in leaves

Based on ANOVA (Table 4 and 5), the effect of color shade net on N, P, K, Ca, Mg, Fe, Zn, Mn and Cu was significant at the 5% probability level.

Table 4. Analysis the variance of nutritional elements in plant leaves.

		MS				
S.o.V	**df**	**N**	**P**	**K**	**Ca**	**Mg**
Treatment (nets color)	2	1.21*	0.15**	0.40**	2.76^{ns}	19.10*
Error	6	0.21	0.007	0.01	3.58	4.21
Total	35	-	-	-	-	-
CV		8.79	24.35	7.06	19.60	24.45

*, ** and ^{ns}: Significant at P < 0.05, P < 0.01 and insignificant based on the LSD test, respectively.

Table 5. Analysis the variance of nutritional elements in plant leaves.

		MS			
S.o.V	**df**	**Fe**	**Zn**	**Mn**	**Cu**
Treatment (nets color)	2	34300.47*	2.46^{ns}	288.31^{ns}	1604.03*
Error	6	4571.49	26.07	364.31	352.98
Total	35	-	-	-	-
CV (%)		31.98	15.71	34.55	23.65

*, ** and ^{ns}: Significant at P < 0.05, P < 0.01 and insignificant based on the LSD test, respectively.

The greatest amount of plant leaves nitrogen is under the green shade nets (2.87%), which had a significant difference with other shade nets (Table 6). In terms of leaf nitrogen, no significant difference was observed between blue (2.39%) and white (2.26%) shade nets. Jokar *et al.* (2021) observed the highest amount of nitrogen in figs under blue shade nets. The mean comparison shows that the plant leaves phosphorus under blue (0.42%) and white shade nets (0.41%) was significantly more than green shade nets (0.22%), but no significant difference was observed between blue and white shade nets (Fig. 3a). According to Jokar *et al.* (2021), the color shade nets used significantly increase the amount of phosphorus in the figs of the green variety with the sequence of yellow net > blue net > without net. The mean comparison (Fig. 3b) showed that under white (1.07%) and green (1.03%) shade nets, plant leaves potassium was significantly higher than blue shade nets (0.73%), but between white and green shade nets no significant difference was observed. Jokar *et al.* (2021) found that the highest concentration of potassium in the green variety of figs is obtained under the cover of blue shade nets. The mean comparison (Table 6) showed that the calcium of *Dieffenbachia* leaves under blue, white, and green shade nets was not statistically significant. the mean comparison (Table 6) of plant leaves magnesium under white (6.49 ppm) and green shade nets (6.69 ppm) was significantly higher than the blue shade net (4.41 ppm). Jokar *et al.* (2021) observed that magnesium in the two fig cultivars significantly increased under blue and yellow shade nets, compared to the control. However, no significant difference was observed between yellow and blue shade nets.The mean comparison of Fig. 3c, showed that the highest plant leaves iron was obtained under the blue shade net (287.7 ppm), which had a significant difference with other color shade nets. However, there was no significant difference between white (195.9 ppm) and green shade nets (194.2 ppm). The mean comparison of table 6, showed that manganese in *Dieffenbachia* leaves in blue (82.43 ppm), white (89.37 ppm) and green shade nets (79.91 ppm) is not significantly different. The mean comparison (Table 6) showed that zinc in *Dieffenbachia* leaves in blue (28.19 ppm), white (28.42 ppm) and green shade nets (29.06 ppm) are not significantly different.The mean comparison (Table 6) showed that copper was found to be higher in *Dieffenbachia* leaves under white (99.98 ppm) and green shade nets (87.25 ppm), which had a significant difference with blue shade nets (76.90 ppm). However, no significant difference was observed between the white and green shade nets.

Table 6. The mean comparison of nutrient elements in plant leaves.

Treatment	N (%)	Ca (ppm)	Mg (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)
Blue shade nets	2.39b	6.26a	4.41b	28.19a	82.43a	76.90b
White shade nets	2.26b	5.31a	6.49a	28.42a	89.37a	99.98a
Green shade nets	2.87a	5.64a	6.69a	29.06a	79.91a	87.25ab
LSD	0.46	1.89	2.05	5.10	19.06	18.76
Alpha	0.05	0.05	0.05	0.05	0.05	0.05

*In each column, means with similar letter(s) are not significantly different (P < 0.05) using the LSD test.

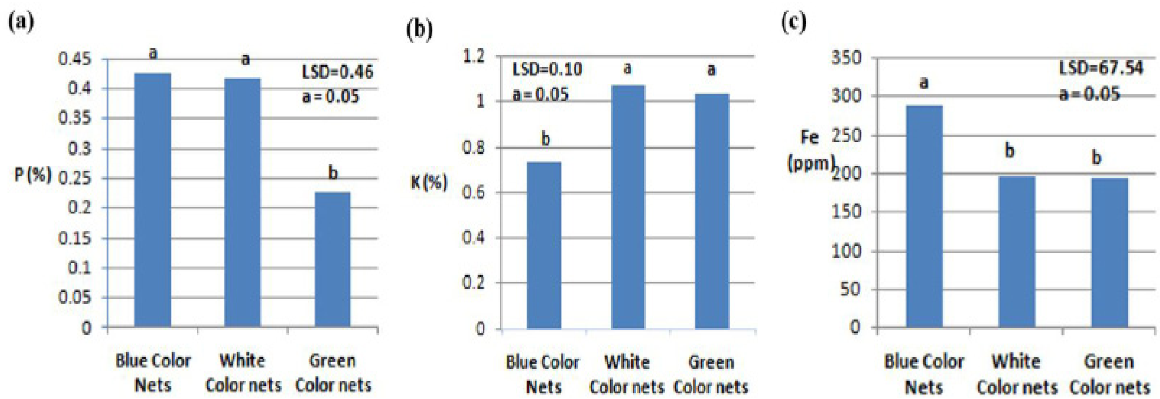

Fig. 3. The mean comparison of color shade nets effect on phosphorus (a), potassium (b) and iron (c) in *Dieffenbachia* leaves, under the influence of the type of color shade nets. The means of each column with a common letter according to LSD are not significant at the 5% probability level.

The height change process

Height changes recorded every 15 days during the growth period of *Dieffenbachia* under colored shade nets (Fig. 4) showed an upward trend, and the highest average slope of height increase occurred between the 15th and 60th days. The highest increment in height was observed in the shade nets of blue, green, and white, respectively.

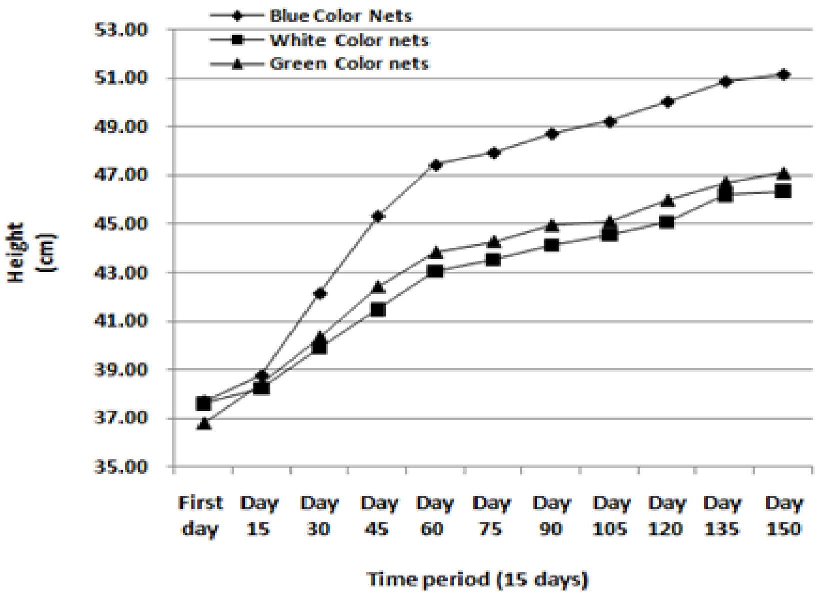

Fig. 4. The trend of *Dieffenbachia* height changes, under the influence of color shade nets in a period of 15 days during the growth period.

The collar diameter change process

The changes in the collar diameter of *Dieffenbachia* (Fig. 5) that were observed under color shade nets every 15 days revealed gradual changes with a slight slope, and the highest amount was obtained in blue, green, and white shade nets, respectively.

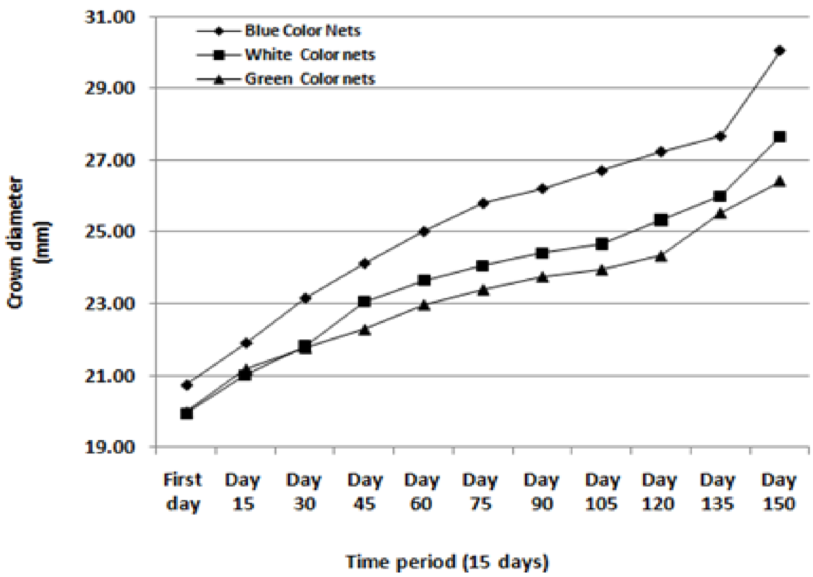

Fig. 5. *Dieffenbachia* trunk diameter changes, under the influence of color shade nets in a period of 15 days during the growth period.

Changes in growth index

The changes in the growth index of *Dieffenbachia* (Fig. 6) were measured under the colored shade net curtains every 15 days. The results indicated that the highest elevation gain was observed between the 15th and 60th day, respectively, in the shade nets of blue, white, and green.

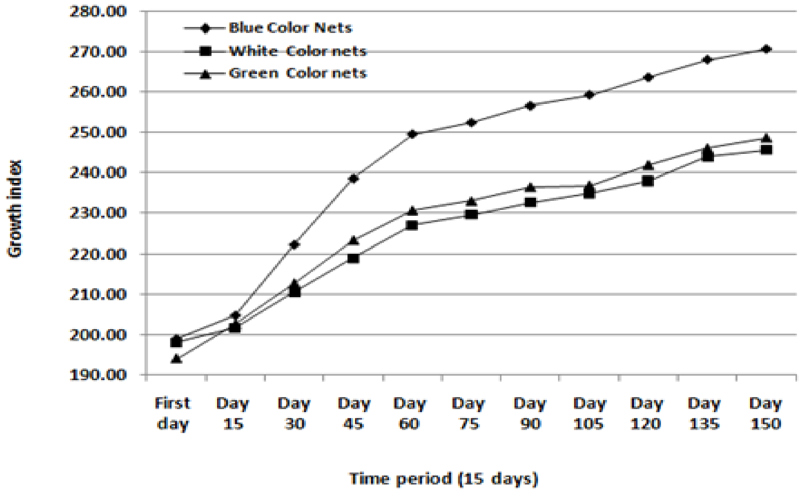

Fig. 6. *Dieffenbachia* growth index changes under the influence of color shade nets at 15-day intervals during the growth period.

Changes in maximum and minimum temperature

This graph depicts (Fig. 7) that in all three color shade nets, the maximum temperature fluctuation range is significantly greater than the minimum temperature fluctuation range. This is possible because the quality of the light changes under the influence of the blue, white, and green shade nets during the day. During the night, the range of minimum temperature fluctuations under blue, white, and green shade nets is in close proximity to each other. This disparity may be attributed to the absence of light and the minor variance in density and texture between the three types of color shade nets.

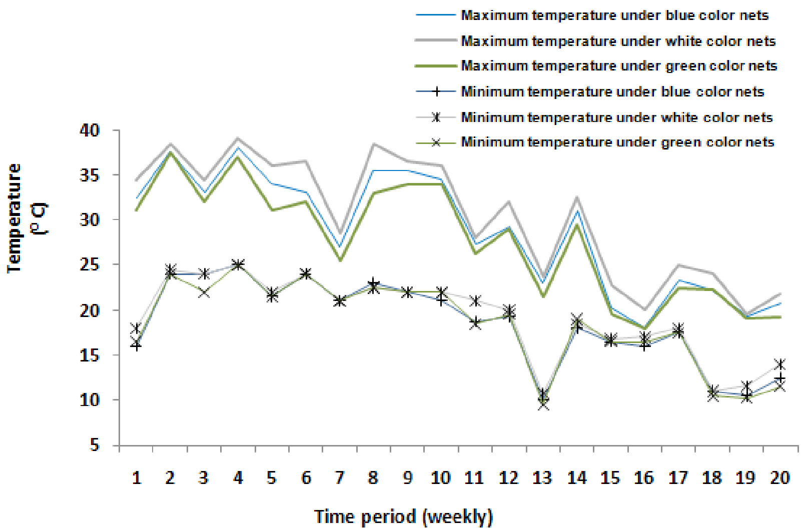

Fig. 7. Changes of the maximum and minimum temperature of the *Dieffenbachia* growth environment. under the influence of color shade nets on a weekly basis during the growth period.

Changes in photosynthetically active radiation

The quantity of photosynthetic active radiation was determined on a weekly basis under various shade nets at the hours of 9:00 and 14:00 (see Fig. 8).The results indicated that the highest levels of photosynthetic active radiation were measured at 9:00 and 14:00 hours, respectively in white, blue and green shade nets. The highest fluctuation in the amount of radiation occurred from the first to the thirteenth week and from the 13th to the 12th week, and amount of radiation decreased and became close to each other at 09:00 and 14:00. Abul-Soud *et al.*, (2014) found that the amount of radiation under white shade nets is higher than under blue shade nets.Al-Helal and Abdel-Ghany (2010) found that dark green shade nets had the highest net absorption, while white shade nets had the lowest. It appears that photosynthetically active radiation under shade nets is sufficient for plant growth during the spring and summer months, but low levels in the early fall can be limiting. Researchers believe that the use of shade in autumn and winter may reduce the growth of some ornamental plants (Baloch *et al.*, 2009; Fletcher *et al.*, 2005).

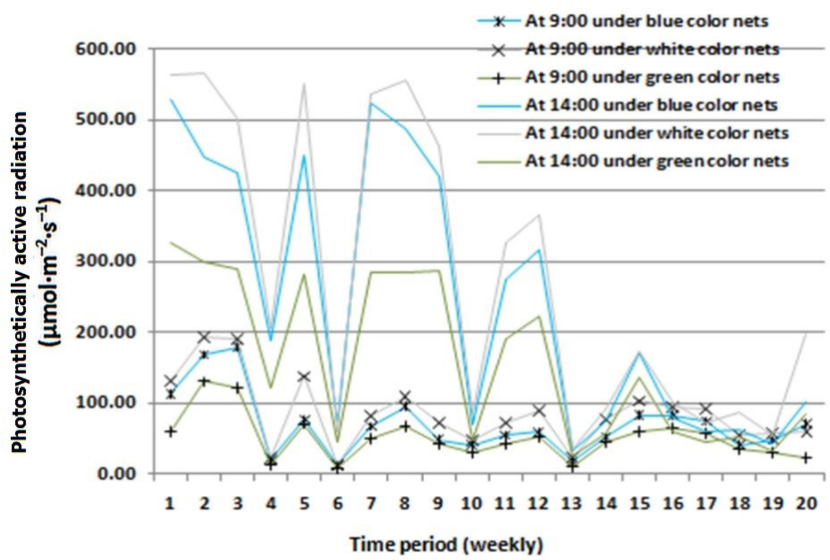

Fig. 8. Changes in the amount of photosynthetically active radiation in the *Dieffenbachia* growth environment at 9:00 and 14:00 under the influence of color shade nets weekly، during the growth period.

CONCLUSION

The beneficial effects of color shade nets on certain growth factors of ornamental foliage plants have been extensively investigated and verified in greenhouse conditions and during the hot seasons of the year. Based on the findings of this experiment, which demonstrate that the blue shade nets are more effective in maintaining the ornamental foliage plant *Dieffenbachia amoena* than the white and green shades, it is recommended to utilize the blue shade net.

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