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The effect of different colored netting on quantitative and qualitative traits of two foliage plant species (*Codiaeum variegatum* and *Aglaonema commutatum*)

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Abstract: Photoselective netting is a new group of colored netting developing in the past few decades. The effect of colored (red, green, and yellow) netting was studied on physiological traits of *Codiaeum* and *Aglaonema* in a trial in Flowers and Ornamental Plants Research Station of Lahijan, north of Iran. The trial was based on a split-plot experiment with two factors. The first factor was devoted to colored netting at four levels (no netting, green, yellow, and red) and the second factor was devoted to plant species at two levels of *Codiaeum* and *Aglaonema* based on a randomized complete block design with three replications. The results showed the positive effect of yellow netting on improving the vegetative capability of the plants, so that the highest plant height, shoot and root fresh and dry weight, and leaf area were observed in the plants grown under the yellow netting. Also, the highest anthocyanin, carotenoid contents, and catalase activity were obtained from the red netting and the highest Brix° and total chlorophyll from the red and yellow netting. According to the results, the highest vegetative growth rate was related to *Codiaeum*. The application of the colored nets provided the plants with more optimal growth conditions.

1. Introduction

The average number of sunny days in Iran annually amounts to a significant value of 280 days, making it unavoidable to use shading to control incident radiation during sunlight exposure (Forghani and Kiani Abri, 2005). The concept of photo-selective shade netting was first devised in Israel and was tested on ornamental plants, vegetables, and fruit trees. Then, the idea gradually spread to the whole world to be applied to various plants, climatic regions, and agronomic practices (Shahak, 2008). So far, black netting has mostly been used for shading and transparent netting has been employed for protection against environmental or pest damages. A whole new group of protective nettings has been developed to manipulate both the quality and quantity of radiation intercepted by plants and simultaneously protect them optimally (Shahak *et al.,* 2004 a, b).

The technology of colored nets that selectively filters sunlight and physically protects crops is based on specific nets in which color elements are used during fabrication. This technology seeks to absorb ultraviolet, blue, green, yellow, red, far-red, or near-infrared spectra. The direct light is intended to change into scattered light too. Colored nets can only alter the components of sunlight that penetrates through their plastic strings whereas solar rays that go across the holes are not manipulated (Shahak *et al.,* 2016). It has been documented that yellow and red, as well as grey, netting can significantly increase the productivity of *Capsicum annuum* versus black netting. These results were attributed to the increased number of fruits in a season in plants subjected to the netting (Shahak *et al.,* 2008). In another study by Shahak *et al.* (2016), it was revealed that yellow netting outperformed red netting in stimulating the vegetative growth of *Pittosporum* and among the studied nets, yellow netting exhibited much stronger strengthening effects than red netting. Other studies have also shown that blue netting reduced vegetative growth and induced dwarfness in leafy ornamental plants and cut flowers whereas red and yellow nets that reduced the intensity of blue light induced vegetative growth in plants (Shahak *et al.,* 2016). Photoselective nets can, according to studies, alter shade quality by scattering light and changing its spectral composition (Shahak *et al.,* 2008). Wang and Folta (2013) reported that the colored nets had a significant effect on increasing vegetative growth rate in foliage plants as compared to the black nets with a similar coefficient of shading (Oren-Shamir *et al.,* 2001). The results showed that the red and white nets increased the yield of Cordyline with respect to plant height, leaf number, biomass, leaf area, photosynthesis rate, and harvest index as compared to control. Also, plants under the colored nets exhibited a longer vase life than those in the open air, but there was no significant difference between nets with different colors. According to the results, white and red nets were better for the growth of Cordyline (Kumar Gaurav *et al.,* 2016). Since few studies have addressed the effect of colored netting on vegetative and physiological traits of foliage plants, the present paper explores the impact of color netting on vegetative traits of ornamental *Codiaeum variegatum* and *Aglaonema commutatum* plants in Flower and Ornamental Plant Research Station of Lahijan, Iran.

2. Materials and Methods

The effect of colored (red, green, and yellow) netting was studied on vegetative traits of *C. variegatum* and *Aglaonema commutatum* in Flowers and Ornamental Plants Research Station of Lahijan, north of Iran in the spring and of 2018. The trial was based on a split-plot experiment with two factors. The first factor was devoted to colored netting at four levels (no netting, green, yellow, and red) and the second factor was devoted to plant species at two levels of *C. variegatum* and *A. commutatum* based on a RCBD with three replications. Each experimental plot was composed of four plants. The light intensity in cloudy days was in the range of 4000-5000 lux, No shade net of 6000 lux and on sunny days in the range of 20,000-28,000 lux and No shade net of 30,000-35000 lux.

The recorded vegetative parameters included plant growth rate, plant height, shoot and root fresh and dry weight and leaf area. Dry weight was obtained oven-dried at 105°C for 24 h. To determine leaf area, the leaves length (L) and widest width (W) were measured, and the leaf area (A) was calculated by the following equation (Moll and Kamparth, 1997):

$$A = L \times W \times 0.75$$

The physiological traits included °Brix, chlorophyll *a*, *b* and total, carotenoid, anthocyanin, flavonoid, antioxidant capacity, catalase and peroxidase. The Brix° of the leaves was measured with an N-1α hand-held refractometer (ATAGO Co., Japan). To measure chlorophyll contents of the treatments, 0.5 g of sample was weighed and ground in a mortar containing 50 ml 80% acetone. Then, the extract was infiltrated, adjusted to 50 ml, and poured into cuvettes. To determine chlorophyll content, it was read at 643 and 660 nm with a spectrophotometer. Chlorophyll *a* and *b* and total chlorophyll contents were estimated by the following equations (Mazumdar and Majumder, 2003):

$$\text{Total chlorophyll (mg/ml)} = 7.12(A_{660}) + 16.8\,(A_{643})$$
$$\text{Chlorophyll a (mg/ml)} = 993(A_{660}) - 0.777(A_{643})$$
$$\text{Chlorophyll b (mg/ml)} = 17.6(A_{643}) - 2.81(A_{660})$$

To measure the carotenoid level, the treatments were sampled. Then, 0.5 g was weighed from the sample and was ground in a mortar containing 50 ml 80% acetone. Then, it was infiltrated, adjusted to 50 ml , and poured into cuvettes. The extracts were read at 645, 663, and 660 nm and were placed in the following equation, denoted by *A*, to determine carotenoid levels of the treatments (Mazumdar and Majumder, 2003):

$$\text{Carotenoid level} = 4.69(A_{660}) - 0.268(A_{643}) + 8.02(A_{663})$$

To measure anthocyanin content, 0.5 of the sample was taken and ground in a Chinese mortar containing 50 ml of hydrochloric-ethanol acid (85% ethanol 95% + 15% hydrochloric acid). Then, it was infiltrated, adjusted to 50 ml , and poured into cuvettes. They were placed in a refrigerator at 4°C for 24 hours followed by 2 hours in darkness. The extract was read at 535 nm with a spectrophotometer and was placed in the following equation to determine anthocyanin content (Mazumdar and Majumder, 2003):

$$\text{Total absorption} = \frac{e \times b \times c}{d \times a}$$

where a = sample weight (0.5 g), b = the volume taken for the measurement (5 ml), c = total volume (50 ml), d = the fraction taken for the sample 0.1, and e = absorption read at 535 nm.

$$\text{Total anthocyanin content of sample} = \frac{\text{Total absorption of sample}}{98.2}$$

To measure flavonoid content, 0.1 g of the sample was taken and ground in a mortar containing 85% methanol and was centrifuged at 8000 rpm for 5 minutes. Then, it was infiltrated and the supernatant was placed in a hot bath at 80°C for 10 minutes. Then, it was cooled down and its absor was read at 270, 300, and 330 nm with a spectrophotometer (Humadi and Istudor, 2008).

$$A=\varepsilon bc$$

where: A= absorption rate, ε= extinction coefficient 33000 $m.cm^{-1}$, b= width of the cuvette (1 cm) and c= total flavonoid content.

In order to estimate antioxidant capacity, 1 g of the plant was wrapped in foil and was placed in liquid nitrogen for 2-3 minutes. Then, it was ground with 10 ml methanol 85% and the samples were placed in room temperature for one hour. Next, their extract was infiltrated and centrifuged for five minutes. Then, 150 ml was taken from it and was added with 850 µl DPPH. The solution was stirred fast and was kept in room temperature at the dark for 20 minutes. After placing the blank and resetting the instrument, first only DPPH was poured into the cuvette and it was read. Then, the sample was read at 517 nm by a spectrophotometer. The antioxidant capacity of the extracts was calculated by the following equation in terms of % inhibition in DPPH (Ramandeep and Savage, 2005):

$$\%DPPH = \frac{A_{cont} - A_{samp}}{A_{cont}} \times 100$$

where %DPPH = percent inhibition, A_{cont} = absorption rate of DPPH, and A_{samp} = absorption rate (sample + DPPH).

The activity of catalase (CAT) was measured through the following stages (Dazy *et al.*, 2008): 1 g of plant tissue that had been ground in 4 ml ethanol was added with (i) 0.01 mol phosphate buffer (pH = 7), (ii) 0.5 ml H_2O_2 0.2 mol, and (iii) 2 ml acid reagent (dichromate/acetic acid mixture). Then, its absorption was read at 610 nm with a spectrophotometer. To measure the enzymatic activity of peroxidase (POD), the extract was prepared as described above. Then, the variations of OD at 430 nm were read with a spectrophotometer once thirty seconds for two minutes (Chance and Maehly, 1955). Data were statistically analyzed with MSTATC Software Package, and the means were compared with the LSD test.

3. Results

According to the results of analysis of variance (ANOVA; Tables 1, 2), the simple effect of netting type and plant species and their interactions were significant ($p<0.01$) on plant height. The tallest plants were obtained from the yellow netting and the shortest from no net exposure. Also, means comparison for the interaction of 'netting type × plant species' revealed that the highest plant height was related to 'yellow net × *A. commutatum*' and the lowest to 'no net × *A. commutatum*'.

According to ANOVA (Table 1), plant growth rate was significantly ($p<0.01$) affected by shade netting, plant species, and 'shade netting × plant species'. Means comparison revealed that the highest growth rate was obtained from the yellow netting (Table 3) and the lowest from no-netting treatment. Means comparison for the interactive effect of 'shade netting × plant species' on plant growth rate showed that 'yellow netting × *C. variegatum*' had the utmost plant growth rate and 'no netting × *A. commutatum*' had the lowest one. According to ANOVA, leaf number was significantly influenced by netting type ($p<0.05$) and plant species ($p<0.01$), but the interaction of these two parameters was insignificant for this trait (Table 1). Means comparison revealed that the highest number of leaves was observed in the plants treated with the yellow net and the lowest in the plants not treated with the nets (Table 3).

The effect of netting type and plant species was significant (p<0.01) on leaf size (leaf length and width), but the interaction of 'net type × plant species' was insignificant (Table 1). The yellow net was related to the highest leaf length and width and the control to the lowest leaf size (Table 3). As well, means comparison for the effect of plant species on leaf size indicated that *C. variegatum* produced the largest leaves (Table 4). ANOVA shows the significant (p<0.01) influence of netting type and plant species on leaf area, but the insignificant effect of 'netting type × plant species' on this trait (Table 1). The highest leaf area of 138.4 cm^2 was associated with the application of the yellow net, but control treatment (in which no net was applied) showed the lowest leaf area of 72.19 cm^2 (Table 3). Means comparison for the effect of plant species on leaf area revealed that *C. variegatum* had the highest leaf area (Table 4).

ANOVA revealed the significant (p<0.01) effect of shade netting type and plant species on shoot fresh and dry weight, but their interaction was significant

Table 1 - Analysis of variance for the effect of experimental factors on the studied morphological traits

Source of Variables	df	Means of squares											
		Final height	Growth	Initial leaf no.	Final leaf no.	Leaf no. Increase	Leaf length	Leaf width	Leaf area	Shoot fresh weight	Shoot dry weight	Root fresh weight	Root dry weight
Replication	2	4.76 NS	6.74 *	0.58 NS	21.15 NS	14.86 NS	0.97 NS	0.51 NS	264.38 NS	25.99 NS	0.13 NS	1.26 NS	0.006 NS
Netting (A)	3	202.24 **	160.65 **	4.20 NS	189.84 *	153.79 **	41.01 **	7.09 **	4813.22 **	3492.35 **	17.12 **	35.24 **	0.173 **
Error	6	5.54	0.97	5.57	37.95	15.81	0.76	0.58	226.36	85.45	0.42	1.32	0.006
Plant (B)	1	1536.00 **	997.82 **	348.84 **	2095.34 **	734.27 **	173.35 **	19.26 **	16949.00 **	28295.47 **	138.67 **	0.39 NS	0.002 NS
AB	3	42.36 **	50.11 **	3.75 NS	22.95 NS	11.98 NS	13.57 NS	1.89 NS	1448.57 NS	529.42 *	2.59 *	6.80 *	0.032 *
Error	8	1.43	2.28	4.95	25.25	10.24	5.60	0.69	517.91	82.94	0.41	1.01	0.005
C.V. (%)		3.62	14.13	26.23	25.40	28.32	12.93	11.71	22.42	18.07	18.06	21.51	21.79

NS= insignificant difference; **= significant difference at the p<0.01 level; *= significant difference at the p<0.05 level.

Table 2 - Analysis of variance for the effect of experimental factors on the studied morpho-chemical traits

Source of Variables	df	Means of squares									
		Brix	Catalase	Peroxidase	Anthocyanin	Chlorophyll a	Chlorophyll b	Total chlorophyll	Carotenoid	Flavanoid	Antioxidant capacity
Replication	2	0.29 NS	0.001 NS	0.015 NS	1170.53 NS	1.81 NS	0.31 NS	1.62 NS	0.45 NS	0.001 NS	0.003 NS
Netting (A)	3	15.49 *	0.005 **	0.014 NS	16243.31 **	2.63 NS	0.95 NS	6.56 *	5.68 **	0.000 NS	0.008 **
Error	6	1.74	0.000	0.005	721.97	1.10	0.39	1.04	0.41	0.000	0.001
Plant (B)	1	532.04 **	0.000 NS	0.032 NS	6699.06 **	3.06 NS	0.06 NS	1.66 NS	0.36 NS	0.000 NS	0.003 *
AB	3	0.49 NS	0.000 NS	0.037 **	48512.77 **	2.80 NS	0.28 NS	2.13 NS	1.09 NS	0.001 **	0.007 **
Error	8	0.37	0.001	0.003	5179.48	1.19	0.27	1.92	0.47	0.000	0.000
C.V. (%)		6.97	48.63	13.11	28.83	75.90	56.85	57.60	31.23	10.53	36.02

NS= insignificant difference; **= significant difference at the p<0.01 level; *= significant difference at the p<0.05 level.

Table 3 - Means comparison for the effect of netting type on the studied traits

Netting	Final height (cm)	Growth (cm)	Leaf no.	Shoot fresh weight (g)	Shoot dry weight (g)	Root fresh weight (g)	Root dry weight (g)	Leaf length (cm)	Leaf width (cm^2)	Leaf area	Sugar content (%)	Catalase (UNIT)[1]	Anthocyanin (mg/100 g)	Total chlorophyll (mg/g)	Carotenoid (mg/L)	Antioxidant capacity (DPPH%)
No netting	25.25 c	3.92 c	13.50 b	23.52 c	1.65 c	2.11 c	0.14 c	14.92 c	6.04 b	72.19 c	6.66 b	0.04 b	1.37 b	0.85 b	0.77 b	9 a
Yellow	39.33 a	16.50 a	27.17 a	82.05 a	5.75 a	7.89 a	0.55 a	21.17 a	8.50 a	138.4 a	9.68 a	0.04 b	2.62 b	2.90 a	2.60 a	2 b
Red	33.92 b	11.50 b	19.63 ab	50.25 b	3.52 b	4.82 b	0.34 b	19.17 b	7.33 ab	106.5 b	10.33 a	0.10 a	4.77 a	3.09 a	2.94 a	5 ab
Green	33.33 b	10.88 b	18.83 ab	45.74 b	3.20 b	3.84 bc	0.27 bc	18.00 b	6.46 b	88.92 bc	8.50 ab	0.03 b	1.20 b	2.77 ab	2.50 a	9 a

Similar letter(s) in each column show insignificant differences according to the LSD test.
[1] Peroxidase enzyme unit in µM /H_2O_2 consumed/min/mg.

Table 4 - Means comparison for the effect of plant species on the studied traits

Plant species	Final height (cm)	Growth (cm)	Leaf no.	Shoot fresh weight (g)	Shoot dry weight (g)	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	Sugar content (%)	Antho-cyanin (mg/100 g)	Antioxidant capacity (DPPH%)
Codaeum variegatum	40.96 a	17.15 a	29.13 a	84.72 a	5.93 a	21 a	8.98 a	128.08 a	13.50 a	3.02 a	5 b
Aglaonema commutatum	24.96 b	4.25 b	10.44 b	16.05 b	1.12 b	15.63 b	6.19 b	74.93 b	4.08 b	1.97 b	7 a

Similar letter(s) in each column show insignificant differences according to the LSD test.

for this trait ($p<0.05$) (Table 1). The highest shoot fresh and dry weight was obtained from the yellow netting (Table 3) as means comparison for the effect of shade net type indicated. Likewise, means comparison for the interaction of netting type and plant species showed that 'yellow netting × *C. variegatum*' produced the highest shoot fresh and dry weight without any significant differences from that of 'red netting × *C. variegatum*' and 'green netting × C. variegatum'. The lowest shoot fresh and dry weight was obtained from 'no netting × *A. commutatum*' and 'green netting × *A. commutatum*' (Table 5). The effect of net type was significant on root fresh and dry weight at the $p<0.01$ level and the interaction of 'net type × plant species' was significant for these traits at the $p<0.05$ level (Table 1). Means comparison indicated that the highest root fresh and dry weights were obtained from the yellow netting and the lowest were obtained when the plants were barely exposed to radiation (Table 3). According to means comparison for the interactive effect of the treatments, 'yellow net × *A. commutatum*' produced the highest root fresh and dry weight whilst the lowest root fresh and dry weights were obtained from 'no net × *C. variegatum*', 'no net × *A. commutatum*', and 'green net × *A. commutatum*' (Table 5).

ANOVA indicated that degree Brix (°Bx) was significantly influenced by net type at the $p<0.05$ level and by plant species at the $p<0.01$ level, but the interaction of 'net type × plant species' was insignificant for this trait (Table 2). The highest degree Brix was related to the red net (10.33%) and yellow net (9.68%) and the lowest to control (6.66%) (Table 3). Means comparison for the effect of plant species indicated that *C. variegatum* had higher Brix of 13.50% (Table 4).

The effect of net type was significant ($p<0.01$) on catalase enzyme, but this enzyme content was not influenced by plant species and 'net type × plant species' (Table 2). The highest catalase enzyme content was obtained from the red netting showing insignificant differences from other treatments (Table 4). ANOVA showed that the interactive effect of 'net type × plant species' was significant ($p<0.01$) on peroxidase enzyme, but the effect of shading net and plant species was not significant (Table 1). The highest peroxidase enzyme content was obtained from 'no net × *A. commutatum*' and the lowest from 'red net × *C. variegatum*', 'green net × *A. commutatum*', 'green net × *C. variegatum*', 'yellow net × *A. commutatum*', and 'no net × *C. variegatum*' (Table 5).

Anthocyanin content was significantly ($p<0.01$) influenced by net type, plant species, and 'net type × plant species' (Table 2). Means comparison indicated

Table 5 - Means comparison for the interactive effect of 'netting type × plant species' on the studied traits

Plant species	Final height (cm)	Growth (cm)	Shoot fresh weight (g)	Shoot dry weight (g)	Root fresh weight (g)	Root dry weight (g)	Peroxidase (UNIT)[1]
'No netting × *Codaeum variegatum*'	29.33 c	6.33 cd	44.32 bc	3.10 b	2.09 c	0.15 c	0.34 b
'No netting × *Aglaonema commutatum*'	21.17 d	1.50 d	2.72 d	0.19 c	2.14 c	0.15 c	0.61 a
'Yellow netting × *C. variegatum*'	49.33 a	25.33 a	118.2 a	8.27 a	6.68 ab	0.47 ab	0.43 ab
'Yellow netting × *A. commutatum*'	29.33 c	7.67 c	45.93 b	3.22 b	9.10 a	0.64 a	0.40 b
'Red netting × *C. variegatum*'	42.83 b	17.83 b	88.31 a	6.18 a	5.20 bc	0.36 bc	0.33 b
'Red netting × *A. commutatum*'	25.00 d	5.17 cd	12.19 cd	0.85 c	4.43 bc	0.31 bc	0.45 ab
'Green netting × *C. variegatum*'	42.33 b	19.08 b	88.10 a	6.17 a	5.21 bc	0.36 bc	0.39 b
'Green netting × *A. commutatum*'	24.33 d	2.67 cd	3.38 d	0.24 c	2.49 c	0.18 c	0.33 b

Similar letter(s) in each column show insignificant differences according to the LSD test.

[1] Peroxidase enzyme unit in µM /H_2O_2 consumed/min/mg.

that the highest anthocyanin content was obtained from the red net (Table 3), but the other treatments did not differ significantly to one another. According to means comparison for the effect of plant species on anthocyanin content, the highest content was observed in *C. variegatum* (Table 4). Also, means comparison for the interactive effect of 'net type × plant species' on anthocyanin content indicated that 'red net × *A. commutatum*' had the highest anthocyanin content and 'green net × *A. commutatum*' and 'no net × *A. commutatum*' exhibited the lowest one (Fig. 1).

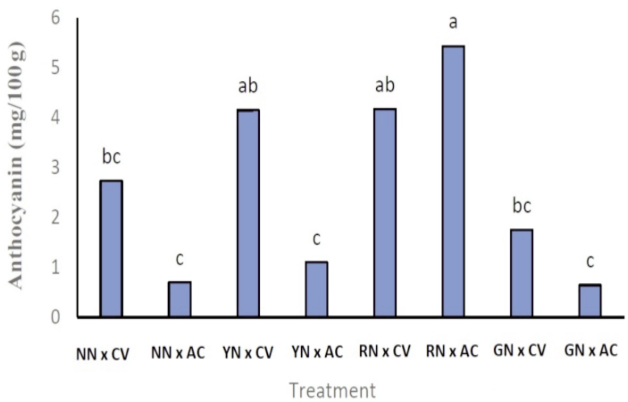

Fig. 1 - The effect of 'netting type × plant species' on anthocyanin content. NN= no netting, YN= yellow netting, RN= red netting, GN= green netting, CV= *Codaeum variegatum*, AC= *Aglaonema commutatum.*

The results of ANOVA showed that the effect of net type was significant (p<0.05) on total chlorophyll content, but the effect of plant species, net type, and 'net type × plant species' was insignificant on chlorophyll a and b and so was the effect of plant species and 'net type × plant species' on total chlorophyll (Table 2). Means comparison for the effect of net type on total chlorophyll (Table 3) indicated that the highest total chlorophyll was related to the red and yellow nets and the lowest to no-net treatment.

Shading net type influenced carotenoid content of plants significantly (p<0.01), but the trait was not significantly affected by plant species and 'net type × plant species' (Table 1). Means comparison showed that the plants grown under the red nets had a higher carotenoid content but without any significant differences from those grown under the yellow and green nets. The lowest carotenoid content was related to control (Table 3). The results of ANOVA showed that the interaction of 'net type × plant species' was significant (p<0.01) for flavonoid content, but the effect of net type and plant species was insignificant on this trait (Table 2). The highest flavonoid content was obtained from 'green net × *C. variegatum*' and the lowest from 'red net × *C. variegatum*' (Fig. 2).

Antioxidant capacity was significantly influenced by netting type and 'netting type × plant species' at the p<0.01 level and by plant species at the p<0.05 level (Table 2). *A. commutatum* plants grown under the yellow net and control plants had the highest antioxidant capacity, while the lowest capacity was related to the yellow net (Table 3). Also, it was found that *A. commutatum* had a higher antioxidant capacity than *C. variegatum* (Table 4). Means comparison for 'net type × plant species' revealed that the highest antioxidant capacity was related to 'no net × *A. commutatum*' and the lowest to 'yellow net × *C. variegatum*' and 'yellow net × *A. commutatum*' (Fig. 3).

4. Discussion and Conclusions

Based on our results the highest plant height was related to 'yellow net × *A. commutatum*'. In a study on the effect of colored nets on Cordyline, Kumar

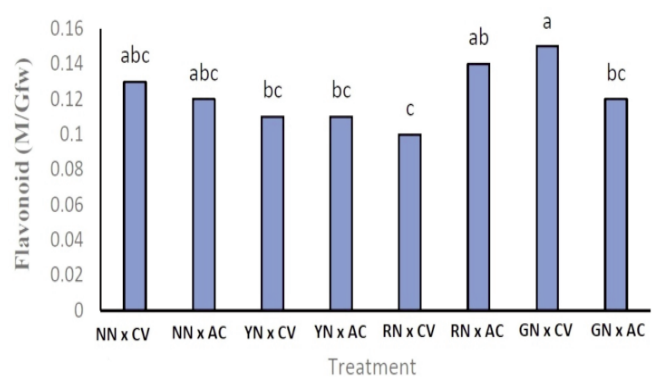

Fig. 2 - The effect of 'netting type × plant species' on flavonoid content. NN= no netting, YN= yellow netting, RN= red netting, GN= green netting, CV= *Codaeum variegatum*, AC= *Aglaonema commutatum.*

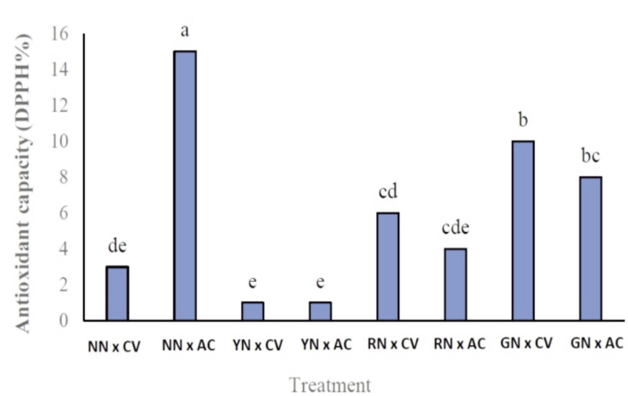

Fig. 3 - The effect of 'netting type × plant species' on antioxidant capacity. NN= no netting, YN= yellow netting, RN= red netting, GN= green netting, CV= *Codaeum variegatum*, AC= *Aglaonema commutatum.*

Gaurav *et al.* (2016) stated that plants grown under colored shade nets exhibited variable growth due to the spectral effect on plant growth. They reported that the Cordyline plants grown under white and red shade nets were taller than the control plants (not exposure to shade nets). It has been reported that both red and yellow shade nets enhanced the vegetative traits of Aralia including stem length and thickness, petals, and leaf dimensions and generally increased the yield of commercial cut flowers (Oren-Shamir *et al*., 2001; Shahak, 2008). Shahak *et al.* (2016), also, found that the yellow shading net induced vegetative growth of Pittosporum. The highest growth rate was observed in the plants exposed to the yellow nets. It has been argued that yellow nets outperform red nets in inducing vegetative growth, probably because of the inductive effect of supplementary artificial green light (Oren-Shamir *et al.*, 2003; Kim *et al.*, 2004). In a four-year research study on cut flowers in Besor Research Station (2000-2003), an increase was reported in stimulatory capacity and in growth under yellow and red nets (Shahak, 2008; Ovadia *et al*., 2009). There is a report that lettuce produced the highest number of leaves under colored nets (pearl and red nets) and the lowest number in control (no net application) (Ilić et al., 2017). It can be concluded that different plant species differ in their growth and development responses to the spectra generated by different colored nets. Leaf area is a crucial parameter for growth. It is defined as a plant's capacity to synthesize dry matter in terms of radiation use rate and photosynthesis rate. Kumar Gaurav *et al*. (2016) showed that leaf area of Cordyline was higher under colored shade netting than control (no shade net application). Colored nets influenced both the length of growth period and morphological traits of lettuce so that they enhanced leaf area index and shortened the length of growth period significantly (Ilić *et al.*, 2017).

In the present study, the yellow net resulted in higher fresh weight than the other nets and control. In addition, the highest plant growth was related to the yellow net, implying the impact of yellow nets on quantitative and qualitative traits of plants. This leads us to the conclusion that colored shade nets, especially yellow nets, can enhance plant biomass. In Kumar Gaurav *et al.*'s study (2016), the highest leaf fresh weight (85.88 percent higher in the red net than in the control) and leaf dry weight were obtained from the red net and overall, the colored nets had the strongest impact on this trait when compared to control (no net application).

Brix is a measure of sugar content of the solution and depends on radiation diffraction. It represents the percentage of solid material weight of a solution to the total weight of the solution. Our results revealed that flowers grown under the red and yellow shade nets had higher degree Brix and this may be related to the stimulatory effect of artificial green light under the yellow nets (Kim *et al*., 2004). Hydrogen peroxide is the most stable form of reactive oxygen species. It has been suggested that hydrogen peroxide is toxic to cells. Catalase and peroxidase play a crucial role in inhibiting the accumulation of hydrogen peroxide. These enzymes are abundant in aerobic microbes, but anaerobic microbes lack them (Singh, 2003). It has been documented that peroxidases are involved in many cell processes such as auxin metabolism, wood formation, traverse linkages in plant cell walls, response to environmental stresses, and so on (Yamasaki *et al.*, 1997). Thus, the higher catalase and peroxidase enzyme content in plant species plays a considerable role in inhibiting the accumulation of hydrogen peroxide in plants.

A laboratory trial has shown that three properties of light color, intensity and duration affect plant growth so that red/infra-red ratio is dictated by the duration and photo flux of radiation treatments and influences anthocyanin development and synthesis significantly (Mancinelli, 1990). Lefsrud *et al*. (2008) reported that anthocyanin content of lettuce was increased in plants exposed to red LED light. In the present study, plants grown under the red shade nets exhibited the highest anthocyanin content.

At intense radiation, chlorophyll degradation rate in plant leaf exceeds its synthesis rate, resulting in the loss of chlorophyll content due to the inhibition of chloroplast formation (Gonçalves *et al.*, 2001; Fu *et al.*, 2012). It has been documented that colored nets increase chlorophyll content in plants. For example, Alkalai-Tuvia *et al*. (2014) studied the effect of colored nets on peppers and reported that the chlorophyll content of the peppers grown under the pearl nets was significant higher than that of the peppers grown under the black nets.

The plants grown under the red nets had a higher carotenoid. It has been reported by Tinyane *et al.* (2013) and Selahle *et al.* (2014) that carotenoid content of tomatoes was increased under red and pearl shade nets. Kong *et al.* (2012) reported that the yellow net resulted in morphological changes and leaf carotenoid increase in peppers versus the red net, which may relate to the increase in green light content under the yellow net. Leaf carotenoid content was higher in lettuces grown under colored shade nets than control (no net) in Ilić *et al.*'s study (2017), which is consistent with our findings.

Phytochemical biosynthesis mostly depends on light quantity and quality as was observed in lettuce plants grown under black nets. In a study, plants grown under pearl nets had significantly higher total phenol content, flavonoids, and antioxidant properties than those grown under other nets (Ilić *et al*., 2017). In another study, an increase was observed in post-harvest flavonoid content in oregano, marjoram, and coriander under pearl nets (Buthelezi *et al*., 2016). Although phytochemical content decreases slightly after harvest, a high level of post-harvest phytochemical accumulation enables plants to maintain phytochemical quality in post-harvest period (Buthelezi *et al.*, 2016). The accumulation of antioxidant compounds in green plants depends on many parameters such as temperature, light quantity and quality, cultivar, growing season, and metabolic factors (Miller *et al*., 2010). The control of radiation quality by the red and pearl photo-selective netting resulted in keeping post-flowering antioxidant activity in vegetables (Kong *et al*., 2013). Kong *et al*. (2013) reported that peppers exhibited an elevated level of antioxidants under yellow nets implying that yellow and pearl nets were likely to enhance plant resistance to biotic stresses. It seems that plants respond differently to different light spectra and plant response to the elevated level of antioxidant capacity depends on the type of colored nets.

The results show that among the studied colored shade nets, the yellow net outperformed the other nets in improving the vegetative capacity of the studied plants. Also, the highest anthocyanin, carotenoid, and catalase contents were obtained from the red net and the highest degree Brix and total chlorophyll from the red and yellow nets. Overall, the application of the colored nets was more desirable for the plants than their non-application. It has been documented that the absorption rate of yellow-colored glass is higher in 360-200 nm (blue and violet) range that is lowly important radiation for photosynthesis than in 560-760 nm range that is photosynthetically important (Haghshenas and Ghiabaklou, 2009) because the latter range is severely intercepted by chlorophyll and increases photosynthesis. This can be a reason for the higher efficiency of the yellow netting. The absorption rate of violet to yellow range of visible light (360-600 nm) by red glass is very similar to yellow glass (Haghshenas and Ghiabaklou, 2009). This explains the change in plants' behavior to the radiation passing through the red net because it seems that the penetration of photosynthetically active radiation through red nets (i.e. red and orange portions of visible light) contributes to important plant functions such as photosynthesis and increases biomass.

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