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Paladugu Chakradhar
Department of Floriculture and Landscaping, Dr. YSRHU, Anantharajupeta, Andhra Pradesh, India

M Raja Naik
Associate Professor, Department of Floriculture and Landscaping, Dr. YSRHU, Anantharajupeta, Andhra Pradesh, India

K Swarajyalakshmi
Professor, Department of Floriculture and Landscaping, Dr. YSRHU, Anantharajupeta, Andhra Pradesh, India

Y Sireesha
Assistant Professor, Department of Plant Pathology, Dr. YSRHU, Anantharajupeta, Andhra Pradesh, India

V Umamahesh
Professor, Department of Crop Physiology, College of Agriculture, Naira, Andhra Pradesh, India

P Lavanyakumari
Assistant Professor & Head, Department of Statistics and Computer Applications. SV AG College, Tirupati, Andhra Pradesh, India

N Vinod Kumar
Assistant Professor, Department of Plant Pathology, Dr. YSRHU, Anantharajupeta, Andhra Pradesh, India

Corresponding Author:
Paladugu Chakradhar
Department of Floriculture and Landscaping, Dr. YSRHU, Anantharajupeta, Andhra Pradesh, India

Effect of colored shade nets on biochemical and quality parameters of different ornamental plants

Paladugu Chakradhar, M Raja Naik, K Swarajyalakshmi, Y Sireesha, V Umamahesh, P Lavanyakumari and N Vinod Kumar

Abstract
The present research was conducted to find out the Effect of different colored shade nets on biochemical and quality of various ornamental plants. The experiment was carried out at Floriculture and Landscaping Block at College of Horticulture, Anantharajupeta during February-August of 2022. The experiment consists of 25 treatments with three replications which were laid out in Factorial Randomized Complete Block Design. The treatments were formed with two factors *viz*. Factor I (Colour shade nets (50% shade), Green net (C_1), White net (C_2), Black net (C_3), Red net (C_4) and Open (C_5) condition and plants (Factor II, *Pandanus veitchii* (P_1), *Epipremnum aureum* (P_2), *Sansevieria trifasciata* (P_3), *Aglaonema commutatum* var. Redgold (P_4), *Rhoeo spathacea* (P_5) were taken. The experiment revealed that the maximum ascorbic acid (2.50 mg g^{-1}) Chlorophyll (5.50 mg g^{-1}) were recorded at 180 DAP under black net. Highest carotenoid content (4.39 mg g^{-1}) and leaf pH were recorded under red net at 180 DAP. The maximum shelf life (23.24 days) at 180 DAP also reported under red net.

Keywords: Colour shade nets, ornamental plants, carotenoids, ascorbic acid, leaf pH

Introduction
The floricultural sector relies heavily on ornamental foliage plants, which are mostly used as fillers in flower arrangements for decoration. Cut foliage gives arrangements and bouquets freshness, colour, and diversity. In recent years, India has begun the commercial producing of cut foliage plants, which are in high demand on the market. The cut foliages may be produced all year round with little upkeep and expenditure.

Generally, Plants with attractive foliage thrive in light shade and produce leaves all year round. Some decorative, vegetable, and even fruit crops have previously been tested using the coloured shade netting method of covered agriculture. Regardless of colour, providing shade nets will lower radiation that reaches the crops below and is directly correlated to the shade factor and change the microenvironment.

Cordyline, Pandanus, Chlorophytum, Ixora, Aglaonema, Sansevieria, Rhoeo, Pothos, Pedilanthus, Asparagus and Dracaena are important ornamental plants in the world trade and used worldwide for their beautiful foliages. High grade quality foliage and healthy ornamental plants fetches more price and demand in the market. Today's lucrative industry is ornamental plant nurseries, which include a wide variety of nurseries based on wholesale or retail, indoor/shade-loving plants, tissue culture plants, commercial flowering plants, shrub, climber, and tree seedlings for landscaping, annual plants, bulbous flowers, etc. These nurseries are doing well across the nation. Efficient and affordable shade structures facilitate the nurserymen in production of quality planting material so that they can get more profit. Use of different coloured shade nets improves the quality and production of cut greens and indoor plants. According to above studies the present investigation was carried out the 'Effect of different colored shade nets on growth and quality of various ornamental plants'

Material and methods
The present investigation was carried out during the year 2022 for 6 months at Dr. YSRHU-College of Horticulture, Anantharajupeta with 5 types of ornamental plants under four types of color shade nets *viz*, Green (C_1), White (C_2), Black (C_3), Red nets (C_4) and Open (C_5). The details of materials used, methods adopted and experimental techniques employed during the study are outlined here. The five plant species Pandanus veitchii (P_1), *Epipremnum aureum* (P_2), *Sansevieria trifasciata* (P_3), *Aglaonema commutatum* var. Redgold (P_4), *Rhoeo spathacea* (P_5) of same height and aged plants were taken and prepared in 12/15-inch black polybags.

There were 12 poly bags in each treatment and among them 6 plants were selected randomly for recording the observations. The data on biochemical parameters like Ascorbic acid, total chlorophyll, carotenoids, leaf extract pH and relative water content, quality parameters like shelf life was taken at the end of the season. Ascorbic acid was estimated by using the methodology of Ranganna (1986) [22] and expressed as mg g-1. Carotenoids and total chlorophyll analysis was done with DMSO method and then estimated by spectrophotometric observation. The leaf pH was determined according to protocol of Prasad and Rao (1982) [21]. Relative water content of the samples was estimated using the method proposed by Singh (1977) [26]. Shelf life was recorded at 180 days till the leaves began to show yellowing or at least 5% or more of the leaves were desiccated. The data of 6 months were analysed statistically at 0.05% level of significance with the help of OPSTAT software.

Result and Discussion

The various observations of biochemical and quality attributes are presented in Table. 1 to 6.

Table 1: Effect of different color shade net and ornamental plants on Ascorbic acid (mg g-1) at 180 DAP

Shade net colour (C)	Ascorbic acid (mg g^{-1}) at 180 DAP					Mean
	Pandanus veitchii (P_1)	*Epipremnum aureum* (P_2)	*Sansevieria trifasciata* (P_3)	*Aglaonema commutatum* var. Red gold (P_4)	*Rhoeo spathacea* (P_5)	
Green (C_1)	1.20	1.57	1.77	1.41	3.51	1.89
White (C_2)	1.32	2.13	3.51	1.52	2.61	2.22
Black (C_3)	2.11	2.80	1.83	3.12	2.62	2.50
Red (C_4)	1.85	2.72	3.07	1.83	2.22	2.34
Open (C_5)	1.13	2.52	2.12	0.87	1.64	1.65
Mean	1.52	2.35	2.46	1.75	2.52	
Source	Colour (C)		Plant (P)		C x P	
S.Em±	0.02		0.02		0.04	
CD (*P*=0.05)	0.05		0.05		0.11	

(Table.1.) At 180 DAP, among multiple coloured shade nets, plants grown under C_3 had highest ascorbic acid (2.50 mg g-1) which was followed by C_4 (2.34 mg g-1), C_2 (2.22 mg g^{-1}) and C_1 (1.89 mg g^{-1}). The lowest ascorbic acid reported under C_5 (1.65 mg g^{-1}). Findings for means of ascorbic acid, P5 (2.52 mg g^{-1}) recorded the greatest ascorbic acid it is followed by P_3 (2.46 mg g^{-1}), P_2 (2.35 mg g^{-1}) and P_4 (1.75 mg g^{-1}). Lowest ascorbic acid recorded in P_1 (1.52 mg g^{-1}). Ascorbic acid showed significance among interactions. Maximum ascorbic acid (3.51 mg g^{-1}) was recorded in the interaction of *Sansevieria trifasciata* x white and it is on par with *Rhoeo spathacea* x green (3.51mg g^{-1}) and followed by Aglaonema x black (3.12 mg g^{-1}). The lowest ascorbic acid (0.87 mg g^{-1}) was recorded in open x Aglaonema.

The maximal ascorbic acid content under a black net was related to light intensity, according to the data. The ascorbic acid content of pepper fruits increased by 31.1% from the unshaded control to 35% shading treatments in prior research (Caruso, 2020) [5], which found a favourable correlation between shading degree and ascorbic acid content.

Table 2: Effect of different color shade net and ornamental plants on Carotenoids (mg g^{-1}) at 180 DAP

Shade colour(C)	Carotenoids (mg g^{-1}) at 180 DAP					Mean
	Name of Ornamental foliage plant (P)					
	Pandanus veitchii (P_1)	*Epipremnum aureum* (P_2)	*Sansevieria trifasciata* (P_3)	*Aglaonema commutatum* var. Red gold (P_4)	*Rhoeo spathacea* (P_5)	
Green (C_1)	3.44	9.03	1.18	2.92	1.42	3.60
White (C_2)	2.56	4.16	2.17	5.94	2.97	3.56
Black (C_3)	1.84	5.75	2.66	5.28	1.48	3.40
Red (C_4)	3.82	5.19	2.14	5.95	4.84	4.39
Open (C_5)	2.02	3.79	1.57	1.29	3.46	2.43
Mean	2.74	5.59	1.94	4.28	2.83	
Source	Colour (C)		Plant (P)		C x P	
S.Em±	0.00		0.00		0.00	
CD (P=0.05)	0.001		0.001		0.001	

(Table 2.) At 180 DAP, among multiple shade colours, plants grown under C_4 had highest carotenoids (4.39 mg g^{-1}) which followed by C_1 (3.60 mg g^{-1}), C_2 (3.56 mg g^{-1}) and C_3 (3.40 mg g^{-1}). The lowest carotenoids reported under C_5 (2.43 mg g^{-1}). Findings for means of carotenoids, P_2 (5.59 mg g^{-1}) recorded the greatest carotenoids followed by P_4 (4.28 mg g^{-1}), P_5 (2.83 mg g^{-1}) and P_1 (2.74 mg g^{-1}). The lowest carotenoids reported in P_3 (1.94 mg g^{-1}). Carotenoids showed significance among interactions. Maximum carotenoids (9.03 mg g^{-1}) was recorded in the interaction of Epipremnum x green and followed by Aglaonema x red (5.95 mg g^{-1}). The lowest Carotenoids (1.18 mg g^{-1}) was recorded in *Sansevieria trifasciata* x green.

Carotenoids were more abundant in the plants cultivated under the red netting. Both Tinyane *et al.* (2013) [32] and Selahle *et al.* (2014) [25] found that tomatoes' carotenoid content rose when grown under red and pearl shade nets. According to Kong *et al.* (2012) [16], the yellow net caused

morphological alterations and a rise in leaf carotenoid levels in peppers compared to the red net, which may be related to the yellow net's increased exposure to green light. Carotenoids have the ability to absorb energy, which may cause the excited chlorophyll molecules to split open and release free oxygen. According to Bergquist (2007) [2], carotenoids may also break down the free oxygen molecules produced during photosynthesis. Ili *et al*. (2017) [13] found lettuces grown under coloured shade nets had greater leaf carotenoid concentration than controls (no net), which is in agreement with our findings.

Table 3: Effect of multiple shade colors and ornamental plants on Total chlorophyll content at 180 DAP

Shade colour(C)	Total chlorophyll content (mg g^{-1})at 180 DAP					Mean
	Name of Ornamental foliage plant (P)					
	***Pandanus veitchii* (P_1)**	***Epipremnum aureum* (P_2)**	***Sansevieria trifasciata* (P_3)**	***Aglaonema commutatum* var. Red gold (P_4)**	***Rhoeo spathacea* (P_5)**	
Green (C_1)	4.31	11.61	1.72	4.21	1.76	4.72
White (C_2)	2.24	4.76	2.42	5.88	3.50	3.76
Black (C_3)	3.70	8.38	4.38	9.06	1.96	5.50
Red (C_4)	4.80	5.61	2.34	9.95	1.09	4.76
Open (C_5)	2.50	3.37	1.12	2.86	4.76	2.92
Mean	3.11	6.75	2.40	5.99	2.62	
Source	Colour (C)		Plant (P)		C x P	
S.Em±	0.03		0.03		0.07	
CD (P=0.05)	0.09		0.09		0.20	

(Table 3.) Among multiple shade colours, plants grown under C_3 net recorded highest total chlorophyll content (5.50 mg g^{-1}) which was followed by C_4 (4.76 mg g-1) and it is on par with C_1 (4.72 mg g^{-1}) and followed by C_2 (3.76 mg g^{-1}). The lowest total chlorophyll content was reported under C_5 (2.92 mg g^{-1}).
Findings for means of total chlorophyll content, P_2 (6.75 mg g^{-1}) recorded the greatest total chlorophyll content it is on par with P_4 (5.99 mg g^{-1}) followed by P_1 (3.11 mg g^{-1}) and it is on par with both P_5 (2.62 mg g^{-1}) and P_3 (2.40 mg g^{-1}). Total chlorophyll content showed significance among interactions. Maximum total chlorophyll content (11.61 mg g^{-1}) was recorded in the interaction of P_2 x C_1 and followed by P_4 x C_4 (9.95 mg g^{-1}). The lowest total chlorophyll content (1.12 mg g^{-1}) was recorded in C_5 x P_3.
Chlorophyll concentration is at its highest in some shade situations (Brand, 1997) [4] because the synthesis of chlorophyll is limited by high light intensities (Taiz and Zeiger, 2002) [29], while the breakdown of chlorophyll is extremely active under high light intensities. This suggests that some shading levels could be advantageous in everyday situations. In begonia, plants cultivated in sunshine had lower chlorophyll contents than those grown under 76% shade (Hamerlynck *et al*., 2000) [11]. Plants grown under 76% shading had the greatest chlorophyll contents. Similar outcomes were seen in the current study. This is likely because plants in the shadow require less light for photosynthesis (Hosseini *et al*., 2014) [12], therefore they grow more leaves and alter their photosynthetic pigments to make up for the lack of light.

Table 4: Effect of multiple shade colors and ornamental plants on leaf extract pH at 180 DAP

Shade colour(C)	Leaf extract pH at 180 DAP					Mean
	Name of Ornamental foliage plant (P)					
	***Pandanus veitchii* (P_1)**	***Epipremnum aureum* (P_2)**	***Sansevieria trifasciata* (P_3)**	***Aglaonema commutatum* var. Red gold (P_4)**	***Rhoeo spathacea* (P_5)**	
Green (C_1)	6.42	6.93	5.35	6.00	6.76	6.29
White (C_2)	6.42	7.23	5.12	6.63	6.74	6.43
Black (C_3)	6.62	7.17	5.15	6.57	6.93	6.49
Red (C_4)	6.48	7.33	5.27	6.64	6.88	6.52
Open (C_5)	6.43	7.21	5.44	6.62	6.83	6.51
Mean	6.47	7.17	5.27	6.49	6.83	
Source	Colour (C)		Plant (P)		C x P	
S.Em±	0.03		0.03		0.07	
CD (P=0.05)	0.09		0.09		0.20	

(Table 4.) At 180 DAP, among multiple shade colours, plants grown under C_4 had highest leaf extract pH (6.52) which is on par with C_5 (6.51), C_3 (6.49) and C_2 (6.43). The lowest Leaf extract pH reported under C_1 (6.29). Findings for means of Leaf extract pH, P_2 (7.17) recorded the greatest leaf extract pH followed by P_5 (6.83) and P_4 (2.83) and it is on par with P_1 (6.47). The lowest Leaf extract pH reported in P_3 (5.27). Leaf extract pH showed no significance among interactions. Maximum Leaf extract pH (7.33) was recorded in the interaction of P_2 x C_4 and it is on par with P_2 x C_2 (7.23). The lowest Leaf extract pH (5.12) was recorded in P_3 x C_2.

Table 5: Effect of multiple shade colors and ornamental plants on relative water content (RWC, %) at 180 DAP

Shade colour(C)	Relative water content (RWC, %) at 180 DAP					Mean
	Name of Ornamental foliage plant (P)					
	Pandanus veitchii (P_1)	*Epipremnum aureum* (P_2)	*Sansevieria trifasciata* (P_3)	*Aglaonema commutatum* var. Red gold (P_4)	*Rhoeo spathacea* (P_5)	
Green (C_1)	84.83	93.99	95.35	121.62	92.89	97.73
White (C_2)	89.60	103.37	100.84	94.38	98.73	97.38
Black (C_3)	83.20	100.15	104.06	98.72	97.03	96.63
Red (C_4)	74.92	100.46	65.48	131.45	101.00	94.66
Open (C_5)	85.69	102.70	82.37	97.39	96.65	92.96
Mean	83.65	100.13	89.62	108.71	97.26	
Source	Colour (C)		Plant (P)		C x P	
S.Em±	3.04		3.04		6.80	
CD (P=0.05)	NA		8.67		19.40	

(Table 5.) Among multiple shade colours, plants grown under C_1 had highest relative water content (97.73%) which was followed by C_2 (97.73%), C_3 (96.63%) and C_4 (94.66%). The relative water content reported lowest under C_5 (92.96%). Findings for means of relative water content, P_4 (108.71%) recorded the greatest relative water content is on par with P_2 (100.13%) it is on par with P_5 (97.26%) and it is on par with P_3 (89.62%). Lowest relative water content recorded in P_1 (83.65%). Relative water content showed no significance among interactions. Maximum relative water content (131.45%) was recorded in the interaction of C_4 x P_4 and it is on par with C_1 x P_4 (121.62%). The lowest relative water content (65.48%) was recorded in C_4 x P_3.

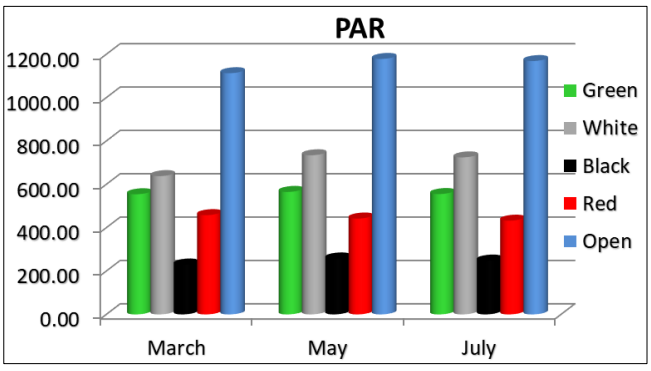
According to Souri *et al*. (2009) [27], the transpiration rate and leaf RWC are influenced by the root system and water absorption properties. Important elements in this respect include any variations in the gradient of water potential from the root to the leaves and on the stomata openings. Reduced transpiration as a result of shade treatments has increased RWC records. Additionally, there may be a strong relationship between relative water content (RWC) and light intensity. The relative water content (RWC) of leaves is always influenced by light intensity, and in the current study, plants treated with green nets had the greatest RWC levels. It has been demonstrated that leaves on the light side may contain higher RWC than those on the shadow side (Mc Cain, 1995) [19]. According to research by Zhou *et al*. (2007) [31], the RWC in rice tissues dropped linearly as light intensity increased. Leaf relative water content is greater when shade is provided by a net than when no shade is provided. The relative water content of the leaves decreased when the quantity of irrigation was reduced (Hamdani *et al*. 2017) [10].

Table 6: Effect of multiple shade colors and ornamental plants on Shelf life (days) at 180 DAP

Shade colour(C)	Shelf life (days) at 180 DAP					Mean
	Name of Ornamental foliage plant (P)					
	Pandanus veitchii (P_1)	*Epipremnum aureum* (P_2)	*Sansevieria trifasciata* (P_3)	*Aglaonema commutatum* var. Red gold (P_4)	*Rhoeo spathacea* (P_5)	
Green (C_1)	22.35	11.24	26.47	7.59	24.54	18.44
White (C_2)	21.46	10.56	27.47	7.23	19.91	17.33
Black (C_3)	24.01	13.63	30.13	22.03	19.04	21.77
Red (C_4)	21.45	19.55	29.53	17.63	28.00	23.24
Open (C_5)	27.54	10.48	21.53	13.69	21.87	19.03
Mean	23.36	13.09	27.03	13.64	22.67	
Source	Colour (C)		Plant (P)		C x P	
S.Em±	0.09		0.09		0.20	
CD (P=0.05)	0.25		0.25		0.56	

(Table 6.) At 180 DAP, among the different color treatments, the C_4 showed highest shelf life (23.24 days) followed by C_3 (21.77 days), C_5 (19.03 days) and C_1 reported 18.44 days. The lowest shelf life was reported under C_2 (17.33 days). The maximum shelf life was found in P_3 (27.03 days) followed by P_1 (23.36 days), P_5 (22.67 days) and P_4 (13.64 days). The lowest shelf life (13.09 days) was reported in P_2. In the interactions, the maximum shelf life (30.13 days) was observed in C_3 x P_3 followed by C_4 x P_3 (29.53 days). The lowest shelf life was recorded under C_5 x P_2 (11.58 days).

In hot, sunny countries, shade nets are especially important since they lower both the amount of light and the amount of heat that is produced during the day. This might be due to the improvement of chlorophyll content and healthy foliage under shade nets. Longest shelf life of pepper was found under black net with 30% shade (Ilic *et al*., 2018) [14]. The shelf life was increased in pepper grown under pearl and yellow nets (Goren *et al*. 2012) [9].



Graph 1: Effect of multiple shade colors on PAR (µmol $m^{-2}s^{-1}$) values

Among the shad nets highest PAR values were found under open at 60 (March), 120 (May) and 180 (July) DAP respectively compared to all the shade nets. This is might be due to the high light intensity under open. Lowest PAR values recorded under black shade net. Usually shade nets reduce the light intensity so that there was a low intensity of light might be observed.

Conclusion

In comparison to other colour shade nets, black and red shade nets were shown to be more effective in improving the majority of plant characteristics. Therefore, it might be advised to use a black or red net instead of a commercially available green shade net and to produce cut greens and potted plants in an open environment.

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