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Influence of coloured shade nets and seasons on production and quality of cut foliage of leather leaf fern (*Rumohra adiantiformis*)

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ABSTRACT

Leather leaf fern [*Rumohra adiantiformis* (G forst) Ching.] was grown under red, green, white and black coloured shade nets permitting light intensities ranging from 240.50 to 370 µ mol m^{-2} s^{-1} (75% shade net), for two consecutive years from 2014-16, at ICAR-IIHR, Bengaluru. The influence of coloured nets and the season on cut foliage yield and quality were evaluated. Developmental stages of the fronds under the different coloured nets were also studied. Fronds attained the harvestable maturity stage at 33 days post emergence under red shade net, whereas it took 31.5 days under green shade net. The plants cultivated under red shade net (75% shade) resulted in higher foliage production/plant/month (6.60) while it was on par with black shade nets in terms of quality of the foliage with respect to length of lamina (24.90 cm) and frond width (17.77 cm). The vase life of the cut foliage grown under red shade net was 47.6 days. Cultivation of leather leaf fern under red shade resulted in maximum cut foliage yield, quality and post harvest life.

Key words: Coloured shade nets, Cut foliage, Leather leaf fern, Photomorphogenesis

Leather leaf fern [*Rumohra adiantiformis*. (G. Forst.) Ching.] belongs to the family Dryopteridaceae. It is a shade loving plant having long symmetrical fronds that are widely used in floral decorations and bouquets. Among the cut foliage crops, leather leaf fern is highly preferred due to its long post harvest life. Globally tropical foliage is widely traded as cut foliage, and in the United States, the leather leaf fern alone accounts for 50 million dollars with Florida accounting for 96% of all production volume (Stamps 2006). Demand for this cut foliage is increasing steadily over the years. The present area under cultivation of this crop in India is negligible but the conducive climatic conditions prevailing in the tropical zones provide immense scope for its commercial cultivation. Production of good quality marketable fronds requires the adoption of suitable cultural practices. Coloured shade net is one of the technologies that is being used to regulate the crop growth and quality. Shahak (2008) reported that the coloured nets exhibit special optical properties that allow the control of light on account of various chromophores and light dispersive and reflective elements that were introduced during manufacturing. These have a considerable influence on the microclimate to which the plant is exposed and promote desired physiological responses, which are light-regulated and provide physical protection against excessive radiation, insect pests and environmental changes. These nets are designed to screen various spectral bands of the solar radiation, and/or transform direct light into scattered light. Photomorphogenesis as a response of the plants to the quality of light is influenced by the pigment phytochrome. According to Stuefer and Huber (1998) changes in the light composition influences the development and morphogenesis. A study was conducted, to evaluate and identify the coloured net most suitable for maximising the production of superior quality cut foliage of leather leaf fern.

MATERIALS AND METHODS

An experiment was conducted in the Division of Floriculture and Medicinal Crops, ICAR- Indian Institute of Horticultural Research, Bengaluru during 2014 to 2016 on leather leaf fern grown under four coloured polypropylene shade nets (75%), *viz*. red, black, green and white to study their influence on the production and quality of cut foliage in randomised block design. Rhizomes with three fully expanded fronds and 1-2 circinate frond were planted at 45 x 45 cm spacing on raised beds made up of a substrate combination of cocopeat, soil and vermicompost in (1:1:1 v/v). Fertilizers was applied to the plants @100:30:60 kg NPK ha^{-1} per year. Entire dose of phosphorous was supplied as basal dose and nitrogen and potash were applied in six equal split doses at bimonthly intervals. Observations on

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the number of cut foliage/plant/month, length of lamina, length of stipe, length of frond, frond width and diameter of stipe were recorded. Based on the importance with regard to marketable standards, some of these parameters were assigned a factor with which it was multiplied and the weighted averages were calculated. Developmental stages of the fronds and post harvest qualities under the diffrerent coloured shade nets were recorded. The gas exchange parameters, net photosynthesis (P_N), transpiration rate (*E*) and stomatal conductance (*g*s) were recorded between 09:30 h and 11:00 h on fully expanded fourth leaf from shoot apex using portable photosynthetic system (LCpro+, ADC Bioscientific Limited, UK). Seasonal influence on the production and quality attributes of the fronds was also analysed. The pooled data was statistically analysed (Gomez and Gomez 1984) and the results have been presented.

RESULTS AND DISCUSSION

Production and quality of cut foliage as influenced by coloured shade nets

The photomorphogenic effects of the red, green, white and black shade nets on cut foliage production and the quality of the fronds of leather leaf fern are presented in Table 1. Plants grown under red shade net produced the maximum number of cut foliage/plant/month (6.60) which was on par with white shade net (6.27). Minimum yield of cut foliage/plant/month was obtained under black (5.61) and green shade nets (5.61). In *Philodendron* 'Xanadu', Stamps (2008) recorded the maximum foliage production under red shade net. Mythrong and Sudhadevi (2016) also reported increased plant height, plant spread and number of leaves of *Nephrolepis exaltata* and *Asparagus densiflorus* under red net. According to Stamps and Chandler (2008) *Aspidistra elatior* 'Variegata' recorded highest growth and yield under black netting, with netting colour having little effect on vase life. For *Philodendron* × hybrid 'Xanadu', leaf colour was lighter green under red netting, plants were taller under blue and gray netting, and vase life was similar under all colours. Netting treatments influenced *Pittosporum tobira* 'Variegata' plant growth, leaf colour, chlorophyll content, and yield, but had little effect on vase life. Similarly Meena *et al*. (2014) reported higher yield of spinach cultivated under green and red nets as compared to white and black nets. The foliage quality was also influenced by the colour of the shade nets. Black shade net recorded maximum length of lamina (26.29 cm), length of stipe (22.22 cm), length of frond (54.54 cm), frond width (18.53 cm) and number of pinnae (10.50) and red shade net was on par with black shade net for length of lamina (24.90 cm), frond width (17.77 cm) and number of pinnae (10.26). Medany *et al.* (2009) attributed the increase in growth of sweet pepper grown under black net house to better microclimate in terms of reduction in temperature, relative humidity, wind speed and light intensity.The plants grown under green shade net recorded minimum values for length of lamina (22.82 cm), length of stipe (17.61cm), length of frond (47.45 cm), frond width (16.78 cm), number of pinnae (10.09) and diameter of stipe (2.82 mm).

Seasonal influence on production and quality of cut foliage under coloured shade nets

The seasonal influence on cut foliage production and quality of cut foliage of leather leaf fern was analysed during three seasons, *viz* summer (March to June), rainy (July to October) and winter (November to February) (Tables 2 and 3). Cut foliage production was maximum under red shade net during the summer (4.78) and rainy (7.50) season. During the winter season, white shade net produced maximum number of cut foliage (7.17) which was on par with red (7.08). Among the seasons, the maximum number of cut foliage/plant/month (Table 2) was recorded during the rainy season under red and black shade nets (7.50 and 6.49, respectively) followed by winter (7.08 and 6.04, respectively) and the least during summer months (4.78 and 3.87, respectively). The cut foliage quality aspects were superior under black shade nets and it was observed that cut foliage produced under the red shade nets were on par with black shade nets with respect to the length of stipe and average width of frond. However the diameter of the stipe was maximum under red shade net. Among the seasons, winter and rainy seasons recorded superior foliage quality over summer season for all the quality attributes. In general, it was observed that the length of the lamina was maximum during the winter season (Table 2) in all the treatments followed by rainy season. The lamina was shortest during summer season for all the treatments. Similar trends were observed for length of stipe and average width of frond with respect to seasonal variations (Tables 2 and 3). Irrespective of the seasonal variations the plants grown under black

Table 1 Influence of shade net colour on the production and quality of cut foliage in leather leaf fern

Shade net colour	Number of cut foliage/pl/ month	Length of lamina (cm)	Length of stipe (cm)	Length of frond (cm)	Frond width (cm)	Diameter of stipe (mm)	Number of pinnae
Red	6.60	24.90	20.49	51.44	17.77	2.88	10.26
Green	5.61	22.82	17.61	47.45	16.78	2.82	10.09
White	6.27	23.15	20.56	48.47	17.22	3.97	10.10
Black	5.61	26.29	22.22	54.54	18.53	2.92	10.50
SEm ±	0.13	0.36	0.42	0.82	0.24	0.05	0.09
CD (P= 0.05)	0.38	1.06	1.25	2.41	0.72	0.14	0.26

Table 2 Seasonal influence of shade net colour on the number of cut foliage/ plant, length of lamina (cm) and length of stipe (cm)

Shade net colour	Number of cut foliage per plant month			Length of lamina (cm)			Length of stipe (cm)		
	Summer	Rainy	Winter	Summer	Rainy	Winter	Summer	Rainy	Winter
Red	4.78	7.50	7.08	22.79	25.39	26.00	14.85	21.16	24.06
Green	3.86	5.95	6.58	19.91	23.56	24.26	12.77	17.17	21.68
White	4.30	6.86	7.17	20.79	23.78	24.19	14.97	20.77	23.78
Black	3.87	6.49	6.04	23.64	27.05	27.78	15.94	22.95	26.20
SEm ±	0.14	0.18	0.23	0.27	0.5	0.49	0.34	0.48	0.8
CD (P= 0.05)	0.42	0.52	0.67	0.79	1.46	1.44	1.01	1.43	2.36

Table 3 Seasonal influence of shade net colour on the average width of frond (cm), diameter of stipe (mm) and number of pinnae pairs per frond

Shade net colour	Average width of frond (cm)			Diameter of stipe (mm)			Number of pairs of pinnae per frond		
	Summer	Rainy	Winter	Summer	Rainy	Winter	Summer	Rainy	Winter
Red	15.71	18.15	18.95	3.26	2.76	2.72	9.62	10.28	10.90
Green	13.92	17.06	18.63	3.00	2.72	2.78	9.65	9.83	10.73
White	14.25	17.59	19.08	3.16	2.75	2.81	9.39	9.78	11.05
Black	15.92	19.26	19.77	3.20	2.80	2.82	9.82	10.28	11.36
SEm ±	0.28	0.33	0.33	0.06	0.08	0.05	0.12	0.11	0.10
CD (P= 0.05)	0.81	0.98	NS	0.18	0.22	NS	NS	0.32	0.30

coloured shade nets had the longest lamina (27.78, 27.05 and 23.64 cm during winter, rainy and summer seasons, respectively). This was followed by plants grown under red coloured shade nets (26.00, 25.39 and 22.79 cm during winter, rainy and summer seasons, respectively). Shortest lamina was recorded in plants cultivated under green shade nets (24.26, 23.56 and 19.91cm during winter, rainy and summer seasons, respectively). Stipe length was maximum in plants grown under black coloured nets (26.20, 22.95 and 15.94 cm during winter, rainy and summer seasons, respectively). This was followed by plants grown under red coloured nets and shortest stipes was observed in plants under green coloured shade nets (21.68, 17.17 and 12.77 cm during winter, rainy and summer seasons, respectively). Frond width was maximum in plants grown under black coloured nets (19.77, 19.26 and 15.92 cm during winter, rainy and summer seasons, respectively). This was followed by plants grown under red coloured nets and shortest stipes was observed in plants under green coloured shade nets (18.63, 17.06 and 13.92 cm during winter, rainy and summer seasons, respectively). The diameter of stipe was larger during the summer months in general for all the treatments except for plants grown under white shade nets during rainy season (Table 3). Maximum stipe diameter was recorded under red shade net during summer season (3.26 mm). The stipe diameter was lower during the rainy and winter seasons as compared to the summer months. The number of pinnae pairs per frond was higher during the winter months, the highest number of pairs being under black coloured shade nets (11.36). Summer season recorded the lowest number of pinnae irrespective of the colour net treatments (Table 3).

Vase life of fronds

Vase life varied significantly among the cut foliage of leather leaf fern grown under different coloured shade nets (Fig 1). The vase life of cut foliage was evaluated under room condition (temperature 24-28 C and 50-67% RH) in distilled water. Maximum vase life of cut foliage of leather leaf fern was recorded in plants grown under red coloured shade net (47.6 days) which was on par with cut foliage grown under white shade net (42.4 days) and green net (40.2 days). Similar result was observed by Stamps and Chandler (2008) in *Pittosporum tobira* 'Variegata' foliage grown under red shade net. Minimum vase life (30.2 days) was obtained with cut foliage grown under black shade net. Cervelli *et al.* (2003) reported when the leaves of leather leaf fern grown under 72% shade were harvested in summer it had the least vase life (24 days).

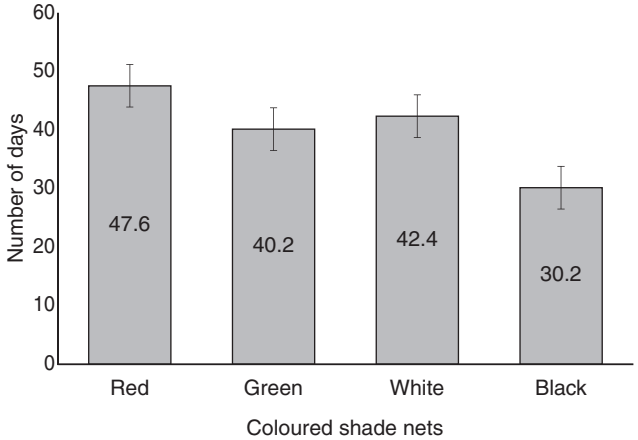

Fig 1 Influence of shade net colour on the vase life of cut foliage of leather leaf fern.

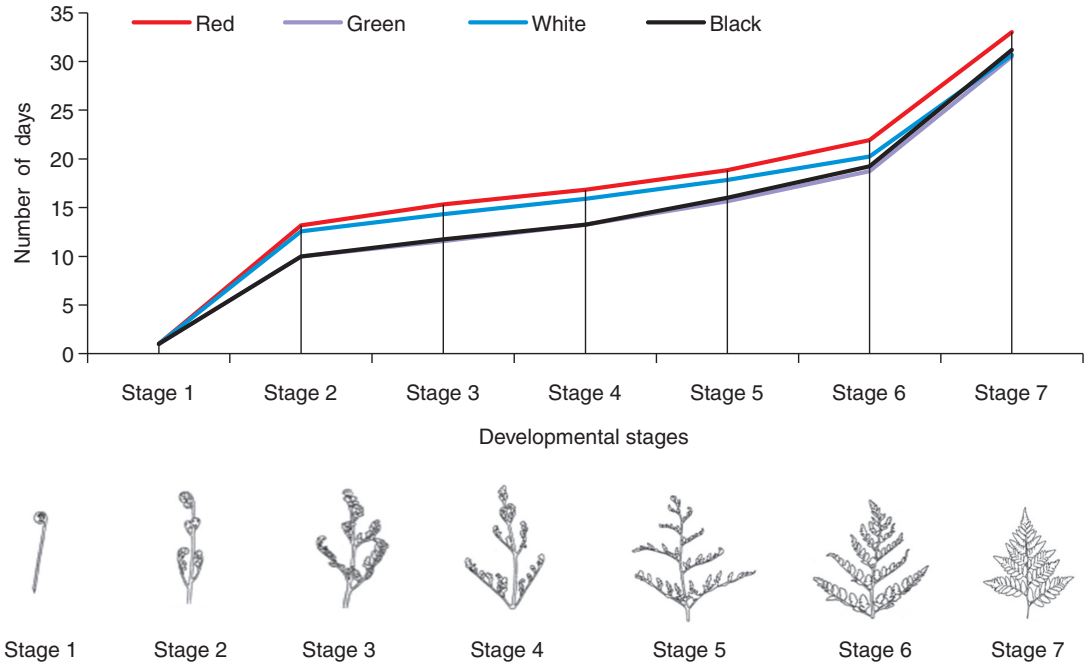

Fig 2 Influence of coloured shade net on developmental stages of leather leaf fern.

Developmental stages of the fronds

The developmental stages of ferns (Fig 2) were studied and the days taken to attain each of the seven critical stages (Strandberg *et al*. 1997) under the different coloured shade nets were recorded. Red shade net followed by white shade net was found to have increased time intervals between the different growth stages as compared to black and green shade nets. The time taken for the fronds to reach up to the fifth stage of development is the same for the plants grown under green and black coloured net. Thereafter the lamina expansion took place at a little slower pace under the green nets as compared to the black shade nets. The developmental stages up to the sixth stage in plants grown under the white shade nets were slower compared to the green and black nets. However, the days taken to attain the fully expanded mature stage was on par with the black and green shade nets. In case of the plants grown under the red coloured shade nets, the time taken to attain the second growth stage was on par with white shade net. However, under red shade net maximum time was taken for the plants from the second stage to fully developed stage. According to Strandberg (2003) the average time from leaf emergence to maturity was 22.6 days and was found to be strongly related to solar radiation and degree days.

Physiological observations: The observations on gas exchange characteristics recorded in the plants grown under different coloured shade nets showed significant differences during rainy and winter seasons (Table 4). The photosynthesis rate was highest under white shade net during rainy and winter seasons, followed by green shade net. However, during summer, though the differences were non-significant, plants grown under red shade net showed the highest photosynthesis rates followed by white shade net. Plants under black shade net showed consistently lower photosynthesis rates across the seasons. The percent PAR availability under different shade nets varied with highest available PAR under the green shade net followed by white shade net and the lowest PAR was available under the black shade net (Table 4). Though definite trend was not observed among the different shade net treatments, overall, the transpiration rate and stomatal conductance were higher during rainy season compared to summer and winter seasons. In this study we observed the significant influence of black shade on PAR availability and photosynthesis rate. Due to lower PAR availability under black shade net, compared to other colour shade nets, the photosynthesis rate was also lower.

Table 4 Seasonal influence of shade net colour on transpiration rate (m moles $m^{-2}s^{-1}$), stomatal conductance (moles $m^{-2}s^{-1}$), photosynthesis rate (μ moles (CO_2) $m^{-2}s^{-1}$) and per cent available PAR

Shade net colour	Transpiration rate (milli moles $m^{-2}s^{-1}$)			Stomatal conductance (moles $m^{-2}s^{-1}$)			Photosynthesis rate (μ moles (CO_2) $m^{-2}s^{-1}$)			Per cent available PAR		
	Summer	Rainy	Winter	Summer	Rainy	Winter	Summer	Rainy	Winter	Summer	Rainy	Winter
Red	1.76	1.84	0.98	0.03	0.18	0.06	5.41	3.01	4.67	26.58	31.69	27.58
Green	1.28	2.48	1.18	0.03	0.19	0.05	3.26	5.76	4.88	35.45	41.54	38.16
White	1.82	1.84	1.76	0.05	0.23	0.15	4.93	4.96	5.09	29.09	31.75	35.04
Black	1.50	1.70	1.32	0.03	0.15	0.07	3.27	3.58	2.05	17.12	21.75	14.80
CV(%)	17.72	11.86	12.48	10.40	11.33	12.81	23.74	17.1	21.5	5.45	10.43	9.77
CD (P= 0.05)	NS	0.47	0.33	0.007	0.04	0.21	NS	1.47	1.79	1.88	4.3	3.39

Ayala-Tafoya *et al*. (2018) in their study on the influence of coloured shade nets on photosynthesis and yield of cucumber observed that the black shade net provided more shade to the plants. The availability of PAR as well as red and blue lights were lower under black shade net compared to the other colour shade net. It was also observed that the transmission of PAR, red and blue light was 23.7, 40.3 and 36 per cent higher, respectively as compared to black net. Black and white shade nets are known to cause reduction in light quantity and provide shade, while red shade net has effect on changes in red light composition (Ayala-Tafoya *et al*. 2011; Lobos *et al*. 2012; Oliveira *et al*. 2016).

Hence, the photosynthesis rate was higher under red shade net compared to black shade net. Though the green shade net transmitted highest PAR among the shade nets, the photosynthesis rate was on par except during rainy season. The foliage production was higher under red shade nets despite lesser PAR compared to green and white shade nets. This was similar to the findings of Leite et al., (2008) in *Phalaenopsis* orchid wherein foliage biomass production was maximum under blue shade net inspite of reduced PAR.

Weighted averages were assigned for the different characters of commercial importance according to the market standards. Cut foliage grown under red shade net had the maximum weighted average (55.91) followed by white net (52.80), black net (50.64) and the least for cut foliage grown under green shade net (47.40).

Incidence of pest and diseases were monitored at weekly intervals. Plants of leather leaf fern cultivated under different coloured shade net did not record any pest and disease incidence during the period under report.

Among the different coloured shade nets evaluated, cultivation under the red coloured shade net resulted in higher cut foliage production, quality and better post harvest keeping quality of leather leaf fern. The yield of cut foliage was marginally higher during the rainy season compared to winter season under the red shade net. However for all the quality attributes of cut foliage, winter season was more favourable. It can hence be concluded that cultivation of leather leaf fern under red shade net (75%) permitting light intensities ranging from 240.50 to 370 μ mol m^{-2} s^{-1} maximised the cut foliage yield, quality and post harvest keeping quality.

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