Effects of colored shade nets on various quality aspects of pansy *(Viola x wittrockiana)*

Abstract

Garden pansies (*Viola x wittrockiana* Gams ex Nauenburg & Buttler) are a greenhouse crop commonly grown under black shade net, and often require the use of chemical plant growth regulators to maintain a compact growth habit. Non-chemical efforts to alter plant morphology, like height, would provide a more sustainable solution than chemical application. The objective of these studies was to evaluate the effects of different colors of shade nets on growth and flowering of pansies. In the first experiment, pansies ('Clear Yellow', 'Buttered Popcorn', and 'Deep Orange') were placed under 30% blue or black shade net, or a control with no shade net. In the second experiment, pansies of the same three cultivars were grown under 50% black, red, pearl, or Aluminet™ shade net. Data were collected on plant height, plant width, flower number, plant survival, SPAD readings, and light quality. In experiment one, the blue shade net reduced height to flower and height to leaves, but also decreased flower number and plant survival as compared to black shade net. All plants under no shade died. In experiment two, SPAD, an indicator of plant quality, was found to be lower under black shade net, while pearl shade net led to a decrease in plant height and no effect on number of flowers. Light quality, including R:FR ratio, varied among shade treatments, while light intensity was reduced under Aluminet™, black (50%), and red shade nets compared to other shade treatments. Blue and pearl shade nets both reduced plant height, but blue shade net also reduced plant survival and flowering.

Introduction

Garden pansies are one of the most popular annual bedding plants in the United States, due to their continuous colorful blooms during the fall and winter months when little else is flowering (Kessler et al., 1998). Oftentimes in greenhouse production, pansies are grown from plugs in mid to late August in order to reach market size by late September-early October. In many parts of the United States, temperatures inside of greenhouses can easily reach over 38°C during this time. However, pansies are best produced at temperatures below 18°C, as multiple cultivars of pansies have shown a decrease in growth and flowering as temperatures increase (Carlson, 1990; Niu et al., 2000; Warner et al., 2006). Thus, pansies are often grown under shade nets to reduce greenhouse temperatures, but lower light levels can lead to plant stretching. The use of plant growth regulators (PGRs) in pansy production is also commonplace in order to reduce stretching of the pansy. Weekly foliar applications of A-Rest (ancymidol) at 12 ppm, B-Nine (daminozide) at 5000 ppm, or Bonzi (paclobutrazol) at 3 ppm have been recommended (Kessler et al., 1998; Collado et al., 2021).

Shade nets reduce air and canopy temperatures by physically blocking solar radiation including photosynthetic active radiation (PAR) around the crops and thus lowering thermal energy exchange (Stamps et al., 2009). Shade nets can be used outside over the top of greenhouses to reduce whole-house radiation load, as well as inside greenhouses to create targeted shade (Arthurs et al., 2013). Traditional black shade net is made from woven opaque high-density polyethylene plastic with shading percentages typically ranging from 30-70% shade

(Shahak et al., 2004). These black shade nets serve only to provide shade proportional to their porosity and do not modify the spectral quality of radiation (Castellano et al., 2008).

Recently, several companies have begun to produce shade nets in an array of different colors. These colored nets are designed to manipulate plant development and growth physiology by affecting light quality via light spectrum modification upon filtering through the net (Stamps et al., 2009). The manufacturers of one such brand, ColorNets, have described the nets ability to modify either ultraviolet (UV) light, visible light, or red:far red light ratios based on the colors of the netting and that light fraction hitting the colored threads becomes spectrally modified and scattered, while the light passing through the holes of the net remains unmodified in spectrum (Shahak et al., 2004). Arthurs et al. (2013) found no significant alterations in red:far red light ratios under red, blue, pearl, and black shade nets as compared to ambient light, but blue shade net had consistently lower red:far red light ratio of all the nets. There have also been Aluminet™ nets developed primarily for thermal screening that are made from reflective metalized high-density polyethylene, but can also serve as dispersive shade nets that diffuse light to penetrate inside dense plant canopies without altering spectral quality (Oren-Shamir et al., 2001; Nascimento et al., 2016). Pearl shade nets, which also do not alter the visible light spectrum but have been thought to alter ultraviolet A and B levels, have light-scattering properties attributed to them as well (Nissim-Levi et al., 2007).

There has been a multitude of studies conducted investigating the unique effects these colored shade nets have on plant growth. Use of red shade net greatly increased tomato (*Solanum lycopersicum* L.) fruit yield as well as increased lycopene production in the fruits;

increased stem elongation in lisianthus (*Eustoma* Salisb.), increased branch length in sunflower (*Helianthus annuus* L.) and snapdragon (*Antirrhinum* L.), led to longer seedling length across multiple groundcherry (*Physalis* L.*)* species potentially due to varied R:FR light ratios, greater plant height and internode length in *Dracaena fragrans* (L.) Ker Gawl and several other species of flowering plants, less shoot growth due to increased zeatin levels and lessened abscisic acid concentration in salinized pepper (*Capsicum annuum* L.) plants; and increased total dry weight, leaf thickness, and essential oil quantity and quality (increased patchoulol percentage) in patchouli (*Pogostemon cablin* (Blanco) Benth.) (Gálvez et al., 2020; Ilic et al., 2012; Li et al., 1970; Oren-Shamir et al., 2001; Ovadia et al., 2009; Gaurav, 2014; McElhannon, 2007; da Silva et al., 2016; Ribeiro et al., 2018).

Blue shade net has been found to decrease length of ornamental foliage branches while increasing leaf variegation, as well as decrease stem length and flower size of sunflower and lisianthus (Oren-Shamir et al., 2001; Ovadia et al., 2009). In addition, blue shade net was also found to increase the number of side shoots in *Physalis* species and reduce apical dominance, reportedly due to potential degradation of auxin via altered R:FR ratios (da Silva et al., 2016). Blue shade net also increased essential oil production in patchouli (Ribeiro et al., 2018).

Pearl shade net has been found to reduce ultraviolet-A and ultraviolet-B levels (280-400 nm) without significantly altering the spectral composition in the visible range (Arthurs et al., 2013). Nissim-Levi et al. (2007) found that myrtle (*Myrtus communis* L.) and waxflower (*Crowea* Sm.) flowering shrubs grown under pearl shade net exhibited more compact growth habit with more branches comparable to that achieved when using a chemical PGR, as well as a higher number of flowers per plant, as compared to those under black shade net. It was also found to significantly increase fruit yield in tomato crops (Ilic et al., 2012). The objective of the present study was to evaluate the effects of different colors of shade nets on growth and flowering of pansies.

Materials and Methods

Location and greenhouse conditions

The research was conducted in two greenhouses at the Research Greenhouse facility at Oklahoma State University, Stillwater campus (36°08'09.9"N 97°05'10.9"W). No supplemental light was used in the greenhouse. Daily light integral levels (DLI) ranged from 12.4 to 22.7 DLI. The greenhouse temperatures were set 27/24° C (day/night), but day temperatures often exceeded set points by as much as 10° C (Table 1).

Plant material and treatments

Seedlings of three different pansies (Delta Premium™ 'Buttered Popcorn', Majestic Giants II 'Clear Yellow', and Matrix® 'Deep Orange') were obtained from Ball Horticulture (West Chicago, IL) in 288 cell trays. The plants were received on 19 August 2021 and were potted on 23 August 2021. The pansies were individually transplanted into 1801 cell trays filled with growing media (BM-7 45% bark, Berger, Sulphur Springs, TX). Trays were spaced approximately 30 cm apart. Polyvinyl chloride (PVC) pipes of 2.5 cm diameter were used to make frames of 0.762 m height to hold shade nets above the canopy. For experiment one, blue ChromatiNet® (30% shade) and black (30% shade) shade nets were purchased from Gothic Arch Greenhouses, Inc. (Mobile, AL). Treatments included each of these nets plus one control treatment with no shade net. For experiment two, ChromatiNet® and Aluminet™ shade nets were purchased from Green-Tek, Inc. (Clinton, WI). Treatments included red ChromatiNet® (50% shade), pearl ChromatiNet® (50% shade), Aluminet™ (50% shade), and black (50% shade). Plants were hand-watered throughout the experiment as needed, and fertigation using a 15-5-15 water-soluble fertilizer (Jack's, Allentown, PA) at a rate of 200 ppm was applied with each watering.

Data collection

Data were collected 6 weeks after transplanting for plant height to top of flower, plant height to top of leaves, widths, flower number, flower length, flower width, dry weight, SPAD, leaf area, plant quality, and plant survival. For dry weights, plant material was oven-dried for 2 days at 54° C. SPAD chlorophyll concentrations were taken using a Minolta SPAD-502 chlorophyll meter (Spectrum Technologies, IL, USA) by scanning the middle of the two bottom-most leaves of each leaf. Quality ratings (1: green, active growth, 2: some leaf browning and showing signs of stress, 3: dying or dead) were taken. Plant survival was recorded as either alive or dead. Leaf area was measured using a Li-Cor L1-3100C Area Meter (LI-COR Biosciences, Lincoln, NE), selecting two leaves from the bottom and averaging the values. Spectral data for reflectance was measured 2 weeks after transplanting in the middle of the day using an Ocean Optics reflectance spectrometer (model FLAME-S-VIS-NIR-ES, Ocean Optics, Florida, USA) with a range of 350-1000 nm. Illuminance, temperature, and humidity were recorded by Illuminance UV recorder TR-74Ui (TANDD, Matsumoto, Japan).

Data analysis

Both experiments were arranged as a randomized complete block design. Each treatment had 18 plants with six replications randomized in flats for experiment one and 18 plants with four replications in experiment two. Data were analyzed using SAS 9.4 (SAS Institute, Cary, NC). Percentages were calculated for plant survival among cultivars and shade net treatment. Tests of significance were reported at the 0.05, 0.01, and 0.001 levels. The data was analyzed using generalized linear mixed models methods. Tukey multiple comparison methods were used to separate the means.

Results and Discussion

The control (no shade net) treatment had the greatest daily light integral (DLI) and temperature, measuring an average of 19 DLI and 27° C, respectively (Table 1). Gaurav (2014) also found the control had the greatest light intensity and temperature measurements compared to the shade net treatments. In experiment one of the present study, none of the plants grown under the control survived (Table 2), which may have been due to light intensity, temperature, or a combination of both. General overall quality of pansies has been shown to increase linearly as DLI increases up to a DLI of 12 mol m^{-2} d^{-1} after which growth slows (Pramuk et al., 2005; Torres et al., 2009). Previous studies have shown similar quality decreases in pansy crops as temperatures increase across several cultivars (Warner et al., 2006; Torres et al., 2009). For both experiments one and two, black (30% shade), blue, and pearl shade net treatments were greater than any other shade net for DLI (Table 1), and according to Torres and Lopez (2010) within minimum acceptable quality range for pansy. Temperature was greatest in blue, pearl, and red among shade nets. Humidity was greatest in Aluminet™ and black (50%) shade net treatments at 65.73% and 65.77% respectively, while lowest in red at 21.32% humidity. Low humidity in the red treatments may have been influenced by table drainage or malfunctioning sensors. Among shade treatments, blue shade net had a lower survival rate than any other shade net (Table 2).

Light spectral reflectance percentage was altered under all shade nets except the control (Figures 1 and 2). All shade nets were found to allow some UVA radiation. Arthurs et al. (2013) found pearl nets were most effective at reducing the transmittance of both UVB radiation (280–315 nm) and UVA radiation (315–400 nm), while red nets reduced transmittance of UV radiation the least. In this study, black appeared to reduce transmittance the most, while red shade net appeared to have slightly greater transmittance of UVA than pearl or Aluminet™ (Figure 1).

Among 30% shade nets, black transmitted 10-40% light in the PAR region of 400-700 nm and blue 30-80% with a peak of 400-425 nm, while no reduction was seen in the control (Figure 1). Among the 50% shade treatments, black reduced PAR by 90%, while Aluminet™ was reduced 60%, pearl 80%, red 20-75% (Figure 2). Red shade net allowed ~25-40% transmittance from 450-575 nm then 60-90% between 600-725 nm. These findings support Arthurs et al. (2013) who reported red nets allowed approximately 50% transmittance around 400 nm wavelength but produced over 70% transmittance at wavelengths beyond 590 nm, and blue nets peaks in transmittance in the blue waveband (defined as 450–495 nm) and far-red wavelengths beyond 750 nm. Blue, Aluminet™, pearl, and red shade nets had less than 1.0 R:FR ratios, defined as 660/730 nm according to Deitzer et al., (1979), while black 50% and no shade nets were near 1.0 (Figures 1 and 2). Arthurs et al. (2013) reported pearl, black and red nets gave R:FR ratios similar to ambient (R:FR ratio approaches 1.0), whereas blue nets lowered the R:FR ratio to around 0.8, and blue and red nets alter spectral quality more in the PAR/visible range. In our study, red and blue also had greater altered spectral quality in the PAR/visual range and the R:FR ratio was 0.6 (Figure 1).

Blue shade net resulted in decreased plant height (Table 5). Overall, increasing the blue light fraction decreases growth mainly through its effect on plant morphology and light interception (Kalaitzoglou et al., 2021). da Silva et al. (2016) reported plants grown under blue shade net (under less red light) have shown lower biomass accumulation, possibly due to its effect on auxin synthesis. Pearl shade net, while having a lower R:FR ratio, may have instead decreased plant height via scattering of light rather than direct alteration of the light spectrum as part of a decrease in plant shade-avoidance response (Kasperbauer et al., 1994). The shade-avoidance response is exacerbated by the spectrum of light changing as it passes through foliage towards the center of the plant, like when light is scattered as it is under pearl shade net, a less-altered spectrum of light can more evenly penetrate the inner parts of the plant (Nissim-Levi et al., 2015).

There was a significant shade X cultivar interaction for leaf area in experiment one (Table 3). ‘Clear Yellow’ had the greatest leaf area under blue shade net, but was not different from any other treatment except ‘Buttered Popcorn’ under black shade net and ‘Deep Orange’ under blue shade net (Table 4). Leite et al. (2008) also found that blue shade net increased leaf area of *Phalaenopsis amabilis* Blume. No significant differences occurred between black or blue shade nets within a cultivar. Leaf area has been observed to increase in conditions of lower light intensity (Buisson et al., 1993).

There were significant treatment effects for height to flower, height to leaves, and flower number (Table 3). Blue shade net resulted in lower height to flower, height to leaves, and flower number as compared to black shade net (Table 5). Our findings support those of Oren-Shamir (2001) where blue shade net caused a dwarfing effect in ornamental branches of Australian laurel (*Pittosporum tenuifolium* variegatum Banks & Solander ex Gaertn.) as compared to red and Aluminet™ shade nets. This effect was also observed by Ovadia et al. (2009) where lisianthus and sunflowers grown under blue shade net had decreased flower stem length as compared to red shade net. This plant growth regulating effect was also seen where *Physalis* seedlings grown under blue shade net had more side shoots and less apical dominance than those grown under red shade net (da Silva et al., 2016). It was hypothesized in da Silva's experiment that this effect was due to the degradation of auxins via the light spectrum modifications resulting in an altered R:FR ratio. Blue shade net resulting in decreased height to flower was contradicted by Nascimento's 2016 study, where blue shade net led to an increase in height to flower in sunflowers as compared to red, but it was not found to be significantly different.

Significant cultivar effects were seen for height to leaves, flower length, and flower width (Table 3). 'Deep Orange' had the greatest height to leaves but was not different from 'Buttered Popcorn' (Table 6). 'Clear Yellow' had the greatest flower length and flower width but was not different from 'Buttered Popcorn'. A larger flower diameter than average is a known trait of the Majestic Giants II series of pansies; however, while the flower diameter was larger, the average plant height and width of the Majestic Giants II series was not significantly different from most other pansy cultivars (Kelly et al., 2005).

In experiment two, plant survival was greatest under 50% black shade net (Table 2). There was a significant shade X cultivar interaction for leaf area (Table 6). ‘Buttered Popcorn’ had the greatest leaf area when grown under pearl shade net, but was only different from plants grown under black shade net (Table 8). ‘Clear Yellow’ had the greatest leaf area under the Aluminet™ shade net, but was not different from the red shade net. ‘Deep Orange’ had the greatest leaf area under the red shade net, but was only different from black shade net. Gaurav (2014) also found that red shade net increases leaf area, but in contrast to our findings, black shade net had the greatest leaf area.

In experiment two, there were significant treatment effects for height to flower, height to leaves, and SPAD (Table 7). Height to flower was greatest under red shade net but not significantly different from Aluminet™ or black (Table 9). Height to leaves was also greatest under red, but was not found to be significantly different from black; this supports da Silva’s (2016) findings of red shade net resulting in the greatest stem length of several *Physalis* species but not being significantly different from black. The lack of significant differences between red and black treatments contradicts what Li et al. (1970) found with snapdragons where red shade net resulted in significantly longer flower stems as compared to black and blue shade net. It also contradicts the findings of Ovadia et al., (2009) who observed a significant increase in sunflower and lisianthus stem length under red shade net as compared to black and blue shade net and Oren-Shamir (2001) experiment growing Australian laurel where red shade net resulted in the greatest overall stem length compared to black. The significant differences may be attributed to a species effect. Pansy heights were lowest under pearl shade net (Table 9), which is similar to results seen with Nissim-Levi et al. (2008) who found that myrtle plants grown under pearl shade net were shorter than those grown under black shade net by as much as 25%. The difference was attributed not to an alteration of light spectrum, but to a more even dispersal of light throughout the canopy of the plant, thus reducing the shade-avoidance effect seen when a plant is not getting enough light or only getting sunlight on the outside of the canopy. Shade-avoidance is known to elicit plant elongation and greater biomass (Nissim-Levi et al., 2008). SPAD was found to be lower under black shade net (Table 9). This supports Gaurav (2014) who found red shade net had a greater SPAD reading than black. This was attributed to increased PAR transmittance under red shade net as compared to black, thus resulting in improved photosynthetic rate and chlorophyll content. There was a significant cultivar effect for flower length, flower width, and SPAD (Table 7). 'Clear Yellow' was the greatest for all, but was not different from 'Buttered Popcorn', which was consistent with what was seen in experiment one under black and blue shade net (Table 10).

Conclusion

Blue and pearl shade nets both led to a decrease in plant height, but blue shade net also reduced plant survival and flowering, so pearl shade net showed the most overall potential for an alternative to chemical height control in pansy. Greater altered light spectral quality with greater amounts of blue light likely reduced plant growth. Pearl shade net had greater light intensity than red, Aluminet™, and black that could have resulted in reduced plant stretching. Light quality and quantity are known to affect plant growth (Oren-Shamir et al., 2001). In both experiments, black shade net resulted in cool temperatures, but Aluminet™ was not different than black at 50%, making them better for cooler season crops as evident with greater plant survival than other colored shade nets. Future research should evaluate different cultivars of pansy, shade net percentages, and direct comparisons of pearl shade net with chemical plant growth regulators as a potential sustainable alternative.

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Table 1. Environmental data of all treatments in a greenhouse in Stillwater, OK during fall 2021 across both experiments.

Shade net	Daily light integral (mol m^{-2} d^{-1})	Temperature (°C)	Humidity (%)
Control	19.49a[z]	26.83a	54.52e
Black (30%)	6.82b	24.95c	59.52c
Blue (30%)	7.46b	25.57b	57.77d
Aluminet™ (50%)	4.67c	24.33d	65.77a
Black (50%)	3.92c	23.90d	65.73a
Pearl (50%)	7.88b	25.28bc	63.63b
Red (50%)	4.77c	25.23bc	21.32f

[z] Indicates significant at or non-significant (NS) at $*P \leq 0.05$, $**P \leq 0.001$, or $***P \leq 0.0001$.

Table 2. Shade net and cultivar effects on plant survival on pansies grown in the greenhouse in Stillwater, OK in 2021.

Shade/Cultivar	Percent survival
Aluminet™ (50%)	82.81
Black (50%	84.38
Pearl (50%)	75.00
Red (50%)	79.69
Blue (30%)	54.63
Black (30%)	71.76
No shade	0.00
Clear Yellow	74.58
Buttered Popcorn	64.22
Deep Orange	70.00

Table 3. Tests of effects for pansy cultivars (‘Buttered Popcorn’, ‘Clear Yellow’, and ‘Deep Orange’) grown under blue (30%) and black (30%) shade nets at the OSU Research Greenhouses in Stillwater, OK in fall 2021.

	Shade	Cultivar	Shade × Cultivar
Height to flower	***[z]	NS	NS
Height to leaves	**	*	NS
Width	NS	NS	NS
Flower number	*	NS	NS
Flower length	NS	*	NS
Flower width	NS	*	NS
SPAD	NS	NS	NS
Leaf area	NS	NS	*
Dry weight	NS	NS	NS
Quality rating	NS	NS	NS

[z] Indicates significant at or non-significant (NS) at *$P \leq 0.05$, **$P \leq 0.001$, or ***$P \leq 0.0001$.

Table 4. Least squares means for pansy cultivars (‘Buttered Popcorn,’ ‘Clear Yellow,’ and ‘Deep Orange’) grown under blue and black (30%) shade nets for leaf area of pansies grown at OSU Research Greenhouses in Stillwater, OK in fall 2021.

Cultivars	Shade	Leaf area (cm^2)
Buttered Popcorn	Black	2.00b[z]
	Blue	2.21ab
Clear Yellow	Black	2.11ab
	Blue	2.29a
Deep Orange	Black	2.21ab
	Blue	2.03b

[z] Means (n = 16) within a column followed by same lowercase letter are not significantly different by pairwise comparison in mixed model ($P \leq 0.05$).

Table 5. Least squares means for pansy cultivars (‘Buttered Popcorn,’ ‘Clear Yellow,’ and

‘Deep Orange’) grown under blue (30%) and black (30%) shade nets at OSU research greenhouses in Stillwater, OK in fall 2021.

Shade	Height to flower (cm)	Height to leaves (cm)	Flower number
Black	2.68a	2.25a	0.92a
Blue	2.46b	2.09b	0.69b

[z] Means (n = 16) within a column followed by same lowercase letter are not significantly different by pairwise comparison in mixed model ($P \leq 0.05$).

Table 6. Least square means for growth and flower effects of pansy cultivars (‘Buttered Popcorn,’ ‘Clear Yellow,’ ‘Deep Orange’) grown under blue (30%) and black (30%) shade nets at OSU Research Greenhouses in Stillwater, OK in fall 2021.

Cultivar	Height to leaves (cm)	Flower length (cm)	Flower width (cm)
Buttered Popcorn	2.16ab	1.60a	1.50ab
Clear Yellow	2.11b	1.62a	1.54a
Deep Orange	2.24a	1.39b	1.31b

[z] Means (n = 16) within a column followed by same lowercase letter are not significantly different by pairwise comparison in mixed model ($P \leq 0.05$).

Table 7. Tests of effects for pansy cultivars (‘Buttered Popcorn’, ‘Clear Yellow’, and ‘Deep Orange’) grown under 50% colored shade nets (red, pearl, Aluminet™, black) at the OSU Research Greenhouses in Stillwater, OK in fall 2021.

	Shade	Cultivar	Shade × Cultivar
Height to flower	***[z]	NS	NS
Height to leaves	***	NS	NS
Width	NS	NS	NS
Flower number	NS	NS	NS
Flower length	NS	***	NS
Flower width	NS	***	NS
Leaf area	***	***	**
SPAD	**	**	NS
Dry weight	NS	NS	NS
Quality rating	NS	NS	NS

[z] Indicates significant at or non-significant (NS) at $*P \leq 0.05$, $**P \leq 0.001$, or $***P \leq 0.0001$.

Table 8. Least squares means for pansy cultivars (‘Buttered Popcorn’, ‘Clear Yellow’, and ‘Deep Orange’) grown under colored shade nets for leaf area of pansies grown at OSU Research Greenhouses in Stillwater, OK.

Cultivars	Shade	Leaf area (cm^2)
Buttered Popcorn	Red	2.28bcd[z]
	Pearl	2.52abc
	Aluminet™	2.50abc
	Black	1.72ef
Clear Yellow	Red	2.53ab
	Pearl	2.37bcd
	Aluminet™	2.72a
	Black	1.67f
Deep Orange	Red	2.24bcd
	Pearl	2.13cde
	Aluminet™	2.03def
	Black	1.75ef

[z] Means (n = 16) within a column followed by same lowercase letter are not significantly different by pairwise comparison in mixed model ($P \leq 0.05$).

Table 9. Least squares means for pansy cultivars (‘Buttered Popcorn’, ‘Clear

Yellow', and 'Deep Orange') grown under red, pearl, Aluminet™, and black shade nets (50%) at OSU Research Greenhouses in Stillwater, OK in fall 2021.

Shade	Height to flower (cm)	Height to leaves (cm)	SPAD (unitless)
Red	2.89a	2.77a	3.90ab
Pearl	2.62b	2.44c	3.96a
Aluminet™	2.81a	2.62b	3.90ab
Black	2.79a	2.64ab	3.83b

[z] Means (n = 16) within a column followed by same lowercase letter are not significantly different by pairwise comparison in mixed model ($P \leq 0.05$).

Table 10. Least square means for effects of pansy cultivars ('Buttered Popcorn', 'Clear Yellow', 'Deep Orange') grown under red, pearl, Aluminet™, and black shade nets (50%) at OSU Research Greenhouses in Stillwater, OK in fall 2021.

Cultivar	Flower length (cm)	Flower width (cm)	SPAD (unitless)
Buttered Popcorn	1.60a	1.50ab	3.89ab
Clear Yellow	1.62a	1.54a	3.95a
Deep Orange	1.39b	1.31b	3.86b

[z] Means (n = 16) within a column followed by same lowercase letter are not significantly different by pairwise comparison in mixed model ($P \leq 0.05$).

Figure 1. Reflectance percentage of solar light under a. black (30%) shade net, b. blue (30%) shade net, and c. no shade net. Percentages were measured using the Ocean Optics reflectance spectrometer FLAME-S-VIS-NIR-ES under each net at the OSU Research Greenhouses in Stillwater, OK, on a clear day in September 2021.

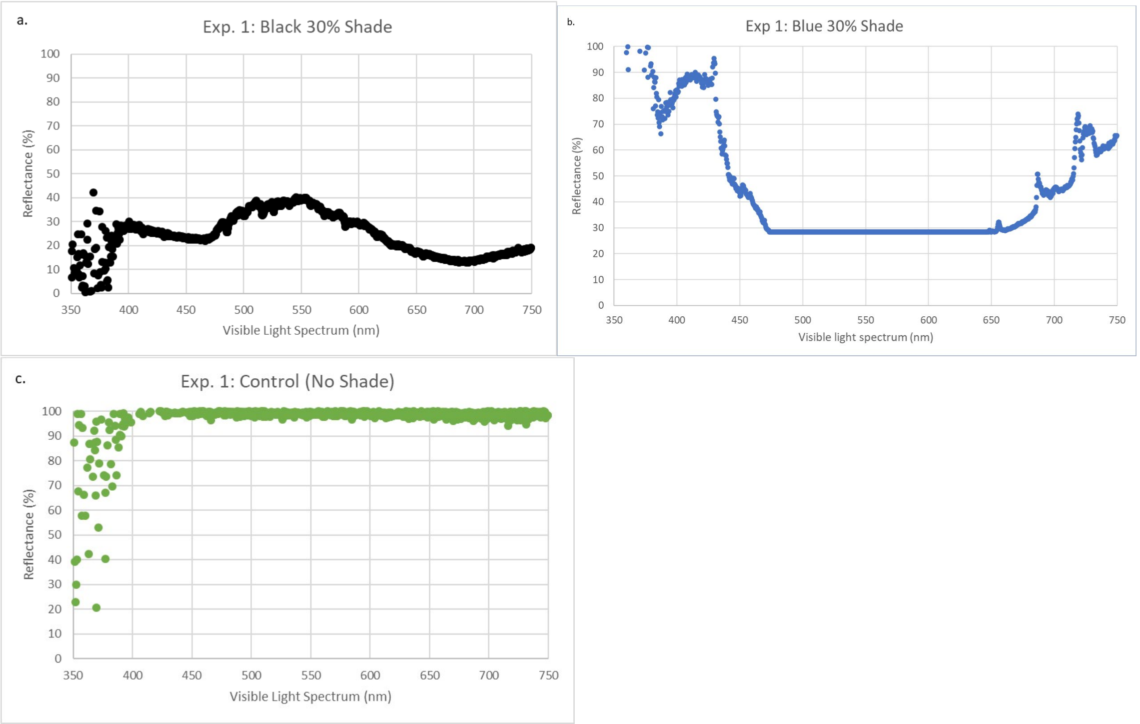
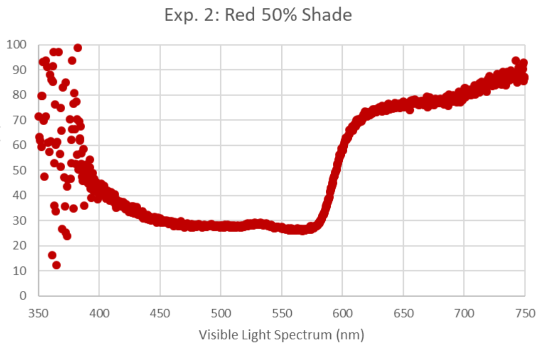
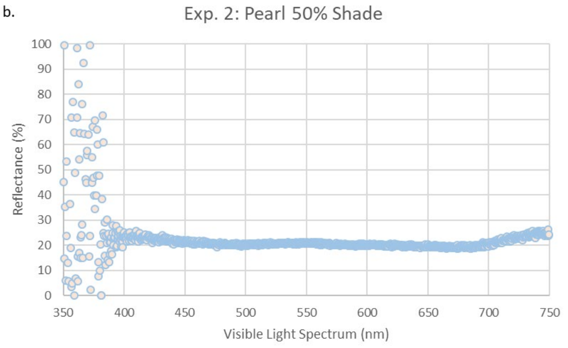


Figure 2. Reflectance percentage of solar light under (a.) red, (b.) pearl, (c.) Aluminet™, and (d.) black shade net (all 50%). Percentages were measured using the Ocean Optics reflectance spectrometer FLAME-S-VIS-NIR-ES under each net at the OSU Research Greenhouses in Stillwater, OK, on a clear day in September 2021.

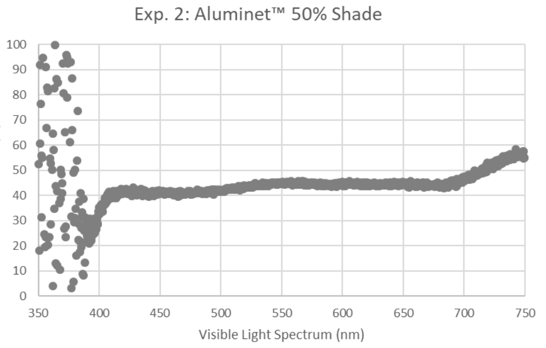
a.


Exp. 2: Red 50% Shade
Reflectance (%)
0
10
20
30
40
50
60
70
80
90
100
350
400
450
500
550
600
650
700
750
Visible Light Spectrum (nm)

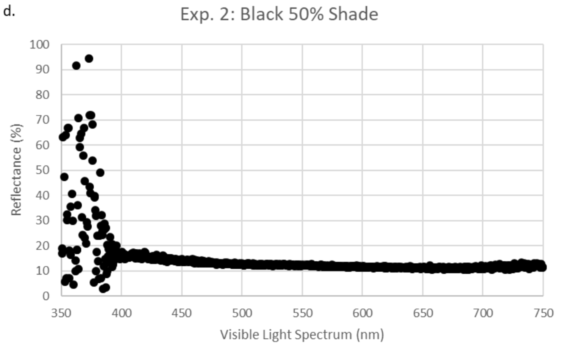
b.


Exp. 2: Pearl 50% Shade
Reflectance (%)
0
10
20
30
40
50
60
70
80
90
100
350
400
450
500
550
600
650
700
750
Visible Light Spectrum (nm)

c.


Exp. 2: Aluminet™ 50% Shade
Reflectance (%)
0
10
20
30
40
50
60
70
80
90
100
350
400
450
500
550
600
650
700
750
Visible Light Spectrum (nm)

d.


Exp. 2: Black 50% Shade
Reflectance (%)
0
10
20
30
40
50
60
70
80
90
100
350
400
450
500
550
600
650
700
750
Visible Light Spectrum (nm)