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Bell Pepper (*Capsicum annum* L.) under Colored Shade Nets: Fruit Yield, Postharvest Transpiration, Color, and Chemical Composition

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***Abstract*. Colored shade nets may affect plant growth and fruit yield of horticultural crops. The understanding of how colored shade nets influence plants, however, is far from complete. The objective of this study was to determine the effects of colored shade nets on bell pepper fruit yield, postharvest transpiration, color, chemical composition, and antioxidant capacity. The experiment was conducted in Tifton, GA, during the spring of 2015 and 2016. The experimental design was a randomized complete block with four replications and five colored shade net treatments (black, red, silver, and white nets, and an unshaded control). The nets were placed on the top of wooden rectangular structures (15 m wide × 6 m long × 5 m high), leaving the sides of the structures uncovered. Results showed that in both 2015 and 2016, marketable and total fruit number, yield, and individual fruit weight were reduced under the unshaded treatment. There were inconsistent differences in marketable and total fruit number, yield, and individual fruit weight among colored shade nets. Postharvest fruit transpiration and skin permeance were also reduced in unshaded conditions, and no differences were found among colored shade nets. Fruit color L* and b* values were highest, and a* value was lowest in unshaded conditions. Fruit soluble solids, total phenols, flavonoids, and antioxidant capacity [Cupric Reducing Antioxidant Capacity (CUPRAC) and Trolox Equivalent Antioxidant Capacity (TEAC)] responded differently among colored shade nets in the 2 years. Total phenols, flavonoids, and TEAC, however, were among the highest in unshaded conditions. In conclusion, results of the present study support previous findings that shade nets increase fruit yield and quality in bell pepper compared with fruit produced in unshaded conditions. Nevertheless, there were no consistent differences in fruit total and marketable yield and postharvest fruit transpiration and chemical composition of fruit produced under colored shade nets.**

Chilies or peppers (*Capsicum annuum* L.) originated in Mexico, Central America, and northern South America (Wien, 1997). Bell pepper or sweet pepper is a nonpungent group of the species *C. annuum*. Bell pepper grows well in warm conditions, but fruit set, yield, and quality may be severely affected under high temperatures and solar radiation. The optimal mean air temperature for bell pepper is 21 to 23 °C and mean root zone temperature must be less than 27.5 °C for optimal fruit yield (Díaz-Pérez, 2010).

Shade nets are widely used to protect horticultural crops from excessive radiation, wind, hail, and birds. Black shade nets have shown to improve bell pepper marketable fruit yield by increasing fruit size and reducing the incidence of physiological disorders, such as sunscald (Díaz-Pérez, 2014; Ilic et al., 2011; Kong et al., 2013; Rylski, 1986). Although black nets are most commonly used, there has been increasing interest on utilization of colored nets.

Colored shade nets have been found to improve plant growth and fruit yield in horticultural crops (Stamps, 2009). In bell pepper, colored shade nets have shown to increase fruit yield and quality, such as reduction in incidences of physiological disorders (Ilic et al., 2017; Ombódi et al., 2015; Shahak, 2008). Colored shade nets can influence plant morphology and physiology by affecting plant photoreceptors, such as phytochromes (Cerny et al., 2003; Stamps, 2009). Effects of colored shade nets on crops are not always consistent and may vary depending on environmental conditions and crops (Stamps, 2009). The effects of colored shade nets on microclimate and plant growth and physiological responses are reported in a companion study (Díaz-Pérez and St. John, 2019). There is limited information on the effects of colored shade nets on fruit chemical composition and antioxidant activity (Ilic et al., 2017). The objectives of the present study were to determine the effects of colored shade nets on bell pepper fruit yield, postharvest transpiration, color, chemical composition, and antioxidant activity.

Materials and Methods

The study was conducted at the Horticulture Farm, University of Georgia (UGA), Tifton, GA, during the spring seasons of 2015 and 2016. The soil was a Tifton Sandy Loam (a fine loamy-siliceous, thermic Plinthic Kandiudults) with a pH of 6.5. Before laying mulch with a mulch-laying machine, the soil was fertilized with nitrogen (N), phosphorus (P), and potassium (K) at 50.0, 22.0, and 46.1 kg·ha^{-1}, respectively, using 10–10–10 granular fertilizer. At the same time plastic film mulch [black, low density polyethylene with a slick surface texture, 1.52 m wide and 25 µm thick (Intergro, Clearwater, FL)] was laid, drip irrigation tape [30 cm emitter spacing and a 12.6 mL·min^{-1} emitter flow at 0.55 bar of pressure (Toro, Aqua traxx, Abilene, TX)] was placed 5 cm deep in the center of the bed.

Bell pepper ('PS 09979325') transplants were produced in a greenhouse using peat-based medium (Pro-Mix, Quakertown, PA) and polystyrene 200-cell (2.5 × 2.5-cm cell) trays. Six-week-old transplants were planted on 12 Apr. 2015 and 20 Apr. 2016 on two rows per bed, with a 30-cm separation between plants and 36-cm separation between rows. Plants were established on individual raised beds (formed on 1.8-m centers; 0.76-m wide). The length of the field experimental plot was 6 m. Approximately 240 mL of starter fertilizer solution (555 ppm N; 821 ppm P; 0 ppm K) was applied directly to the base of each transplant. Starting 3 weeks after transplanting, plants were fertilized weekly through the drip system. Total major nutrients applied were 200 kg·ha^{-1} N, 22 kg·ha^{-1} P, and 194 kg·ha^{-1} K. The crop was grown following the recommendations of the UGA Extension Service.

Experimental design was a randomized complete block with four replications and five colored shade treatments (four colored nets and an unshaded control). Colored nets were black (47% shade), red (42% shade), silver (40% shade), and white (41% shade) (Fig. 1). Shade factors are as reported by the manufacturer (Green-tek, Janesville, WI) and are within the optimal shade level (30% to 46% shade) for bell pepper (Diaz-Pérez, 2014). Nets were placed on the top of wooden rectangular structures (15 m wide × 6 m long × 5 m high), leaving the sides of the structures uncovered.

Plants were irrigated with an amount of water equivalent to 100% of the crop evapotranspiration (ETc), which was calculated by multiplying the reference evapotranspiration (ETo) by the crop factor (dependent on the crop stage of development). Water was applied when cumulative ETc was 12 mm, which corresponded to approximately every 2 to 3 d in mature plants (mean ETo was 5 mm·d^{-1}).

Microenviroment. Air temperature and relative humidity were measured periodically during the season (both in 2015 and 2016) with dataloggers (HOBO, MX2301A; Instrumart, Burlington, VT). Data for white treatment were not collected due to datalogger malfunction. Root zone temperature (8 cm deep) was measured manually at midday with a digital thermometer. The ETo and rainfall data were obtained from a nearby UGA weather station (less than 300 m). Leaf temperature was measured with the copper constantan thermocouple of an infrared (IR) gas analyzer [LI-COR 6400 IRGA with an integrated 6400–40 leaf chamber fluorometer (LI-COR, Inc., Lincoln, NE)]. Measurements were conducted in developed plants on clear days [photosynthetically active radiation (*PAR*) > 1900 μmol·m^{-2}·s^{-1} in unshaded conditions] at 1200–1500 HR Eastern Standard Time using two developed and fully exposed leaves.

Harvest. Bell pepper fruit was harvested and graded according to US Department of Agriculture (USDA) standards as marketable and nonmarketable (USDA, 2005). Number and weight of marketable, nonmarketable, and total (marketable + nonmarketable) fruit were determined and expressed on a per hectare basis. Average fruit weight was derived mathematically from the marketable fruit weight and the number of marketable fruit. There were seven harvests in 2015 (15 June–31 July) and four in 2016 (21 June–6 July).

Fruit transpiration. Fruit transpiration or water loss rate was measured by placing fruit on trays (15 fruit per treatment) and kept in a controlled-temperature room (20 °C, vapor pressure difference of 1.50 kPa and air velocity of < 0.2 m·s^{-1}). Fruit water loss was measured gravimetrically by weighing individual fruit daily for 7 d. The rate of water loss (*WLR*) was determined as a daily percent weight loss of the fruit with respect to the fruit weight the day before each measurement. The fruit *WLR*, surface area (SA), and transpiration ratio or permeance to water vapor (P_{H2O}) were calculated as follows (Díaz-Pérez et al., 2007):

$$WLR\left(\%\,loss\,day^{-1}\right) = (\Delta FW/FW_o)(100/t) \quad [1]$$

$$SA = -0.0026\,x\,FW_o^2 + 1.797\,x\,FW_o + 23.06 \quad [2]$$

$$P_{H2O}\left(\mu mol\,m^{-2}s^{-1}kPa^{-1}\right) = \left[WLR\,x\,FW_o x\left(6.43x10^{-3}\right)\right]/(SAxVPD) \quad [3]$$

where ΔFW is the change in fruit *FW* (g) and *t* is the time period (day) between two consecutive fruit *FW* determinations; FW_o is fruit *FW* at the beginning of the weighing period; 6.43×10^{-3} μmol·m^{-2}·s^{-1} is a conversion factor; *SA* is whole-fruit surface area (m^2); and *VPD* is water vapor pressure deficit (kPa) under storage. Mean values of *WLR*, *SA*, and P_{H2O} were calculated for individual fruit from measurements made over a 7-day period. The mean fruit weights (FW_o) used were 125.2 g (unshaded), 128.5 g (black), 150.1 g (red), 161.3 (silver), and 165.4 (white).

Fruit color. Postharvest attributes (except transpiration) were measured in 20 mature green fruit per treatment (five fruit per plot). Fruit skin color was measured (four readings per fruit) with a CR-400 (8 mm aperture, D65 illuminant) handheld colorimeter (Konica Minolta, Ramsey, NJ). Color was measured as L*, a*, b*. Lightness (L* value) goes from 0 (white) to 100 (black); a* value from –a (green) to +a (red); b* value from –b (blue) to +b (yellow) (McGuire, 1992).

Fruit chemical attributes. A fruit juice sample was obtained from individual fruit by manually squeezing a portion of the fruit pericarp and filtering the juice through two layers of cheesecloth. Eight fruit were evaluated per shade net treatment. Soluble solids content (SSC) was measured using a Brixstix digital handheld refractometer (3810

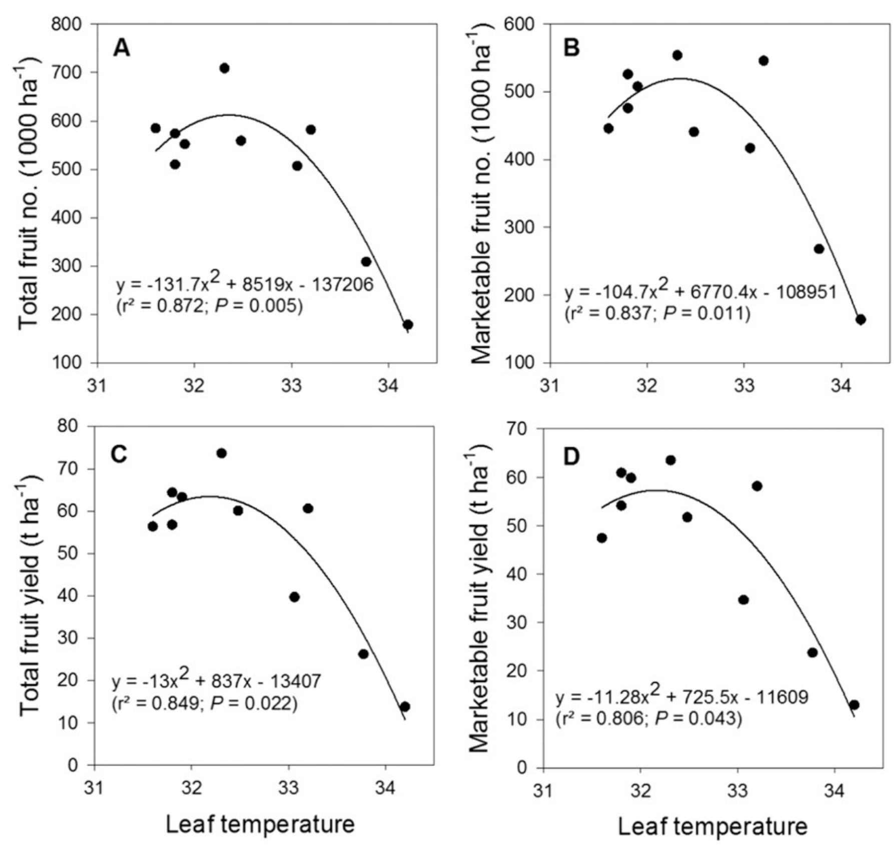

Fig. 1. Relationship between total fruit number (**A**), marketable fruit number (**B**), total fruit yield (**C**), and marketable fruit yield (**D**) with midday leaf temperature (°C) in bell pepper under colored shade nets. Fruit harvested at the mature green stage, Tifton, GA.

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PAL-1; Atago, Livermore, CA), which was calibrated with distilled water. Total phenols were determined as a measure of total antioxidant capacity following the Follin-Ciocalteau method (Singleton et al., 1999) and data were expressed as gallic acid equivalents. Total flavonoid concentrations were determined using a methanolic extract and expressed as quercetin equivalents (Rawat et al., 2014). Antioxidant capacity was determined by the TEAC and the CUPRAC methods (Barros et al., 2007; Castro-Concha et al., 2014).

Statistical analysis. Data were analyzed using the General Linear Model and Regression Procedures from SAS (SAS version 9.4; SAS Institute, Inc., Cary, NC). Data means were separated by Fisher's protected least significant difference test at 95% confidence. Percentages were transformed to arcsin values before analysis. For clarity, nontransformed percentage means were used for presentation in tables and figures. Data are presented by year because there were significant treatment by year interactions.

Results

Microclimatological factors. Seasonal air temperature and relative humidity and midday leaf and root zone temperature and *PAR* for both 2015 and 2016 seasons are shown in Tables 1 and 2.

Fruit yield. In 2015, marketable fruit number and yield, total fruit yield, and weight of individual fruit were reduced in unshaded conditions (Table 3). There were no differences in fruit yield or individual fruit weight among colored shade nets. In 2016, marketable yield was highest in silver net and lowest in unshaded conditions and under white net (Table 4). Individual fruit weight was lowest in unshaded conditions in both years. Although fruit number and yield responses to colored shade nets varied by year, overall reduction in fruit number and yield in unshaded conditions was consistent in both years. Midday leaf temperature under shade net treatments was related to fruit yield of bell pepper plants. Midday leaf temperature between 31.5 and 32.5 °C had little effect on fruit yield. Marketable and total fruit number and yield decreased with increasing midday leaf temperature above 32.5 °C (Fig. 1).

Postharvest fruit transpiration. Fruit water loss rate and skin permeance were the lowest in fruit from unshaded conditions (Fig. 2). There were no differences in fruit *WLR* and skin permeance between colored shade nets.

Fruit skin color. Fruit skin color values were affected by shade treatments (Fig. 3). Fruit L* value was highest in unshaded treatment and lowest under black and silver nets. Fruit a* value was the lowest (most negative) in unshaded treatment and the highest (least negative) under black and red nets. Fruit b* value was the highest in unshaded conditions and the lowest under black net.

Fruit chemical attributes. In 2015, SSC was highest under red net and lowest under black net (Table 5). In general, total phenols, flavonoids, CUPRAC, and TEAC values were among the highest in unshaded treatment and under white net and among the lowest under black net. In 2016, SSC was unaffected by shade treatments, although, as in 2015, SSC showed reduced values under black net (Table 6). Similar to 2015, in 2016, total phenols, flavonoids, and TEAC values were the highest in unshaded treatment. CUPRAC was lowest in 2015 and highest in 2016 under black net.

Discussion

Shade nets affect the quality and quantity of solar radiation received by the crop as well as the air and soil temperature under the net, resulting in improvements of plant growth and fruit yield and quality (Arthurs et al., 2013). In Florida, shade-house structures

Table 1. Effect of colored shade nets on seasonal air temperature and relative humidity and midday leaf and root zone temperature (RZT) and photosynthetically active radiation (*PAR*) in bell pepper, Tifton, GA, Spring 2015.

	Seasonal air temp (°C)			Seasonal relative humidity (%)					
Shade	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Midday RZT (°C)	Midday leaf temp (°C)	Midday *PAR* ($\mu mol \cdot m^{-2} \cdot s^{-1}$)
Black	22.32 a[z]	27.0 c	33.1 b	49.5 a	69.9 a	87.0 b	34.0 b	31.8 b	985 d
Red	22.28 ab	27.1 b	33.1 b	46.8 c	65.9 d	82.8 c	34.9 b	31.8 b	1064 c
Silver	22.26 b	27.1 b	33.0 c	48.3 b	68.8 b	87.3 a	34.9 b	31.9 b	1102 bc
White	nd[y]	nd	nd	nd	nd	nd	35.2 b	33.2 a	1135 b
Unshaded	22.17 c	27.2 a	33.9 a	45.7 d	67.6 c	86.9 b	37.1 a	34.2 a	1851 a
P	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

[z]Means followed by the same letter are not significantly different based on Fisher's protected least significant difference test at 95% confidence.
[y]nd = not determined.

Table 2. Effect of colored shade nets on seasonal air temperature and relative humidity and midday leaf temperature and photosynthetically active radiation (*PAR*) in bell pepper, Tifton, GA, Spring 2016.

	Seasonal air temp (°C)			Seasonal relative humidity (%)				
Shade	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Midday leaf temp (°C)	Midday *PAR* ($\mu mol \cdot m^{-2} \cdot s^{-1}$)
Black	20.52 b[z]	26.2 c	31.8 c	43.2 a	62.5 a	82.7 a	32.48 bc	1051 c
Red	20.49 c	26.3 b	32.1 b	39.7 c	58.4 c	79.0 b	31.60 c	1204 b
Silver	20.56 b	26.4 b	31.9 c	40.9 b	60.5 b	81.9 a	32.31 bc	1200 b
White	nd[y]	nd	nd	nd	nd	nd	33.06 ab	1066 c
Unshaded	20.66 a	26.6 a	32.6 a	41.3 b	56.0 d	71.5 c	33.77 a	1991 a
P	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001

[z]Means followed by the same letter are not significantly different based on Fisher's protected least significant difference test at 95% confidence.
[y]nd = not determined.

Table 3. Effect of colored shade nets on fruit yield and individual fruit weight in bell pepper, Tifton, GA, Spring 2015.

	Marketable		Total		
Shade	($1000 \cdot ha^{-1}$)	($t \cdot ha^{-1}$)	($1000 \cdot ha^{-1}$)	($t \cdot ha^{-1}$)	Fruit wt (g)
Black	526 a[z]	61.0 a	574	64.4 a	117 a
Red	476 a	54.2 a	510	56.8 a	113 a
Silver	508 a	59.9 a	552	63.3 a	119 a
White	546 a	58.2 a	582	60.6 a	106 a
Unshaded	164 b	13.0 b	179	13.8 b	65 b
P	0.049	0.0002	0.062	0.0003	<0.0001

[z]Means within the same column followed by the same letter are not statistically different according to Fisher's protected least significant difference test ($P \leq 0.05$).

Table 4. Effect of colored shade nets on fruit yield and individual fruit weight in bell pepper, Tifton, GA, Spring 2016.

	Marketable		Total		
Shade	(1000·ha^{-1})	(t·ha^{-1})	(1000·ha^{-1})	(t·ha^{-1})	Fruit wt (g)
Black	441 b[z]	51.8 ab	559 b	60.1 ab	115 a
Red	446 b	47.5 bc	585 b	56.4 b	103 ab
Silver	554 a	63.6 a	709 a	73.7 a	113 a
White	417 b	34.7 cd	507 b	39.7 c	81 bc
Unshaded	268 c	23.8 d	309 c	26.2 c	90 c
P	<0.0001	<0.0001	<0.0001	<0.0001	0.0002

[z]Means within the same column followed by the same letter are not statistically different according to Fisher's protected least significant difference test ($P \leq 0.05$).

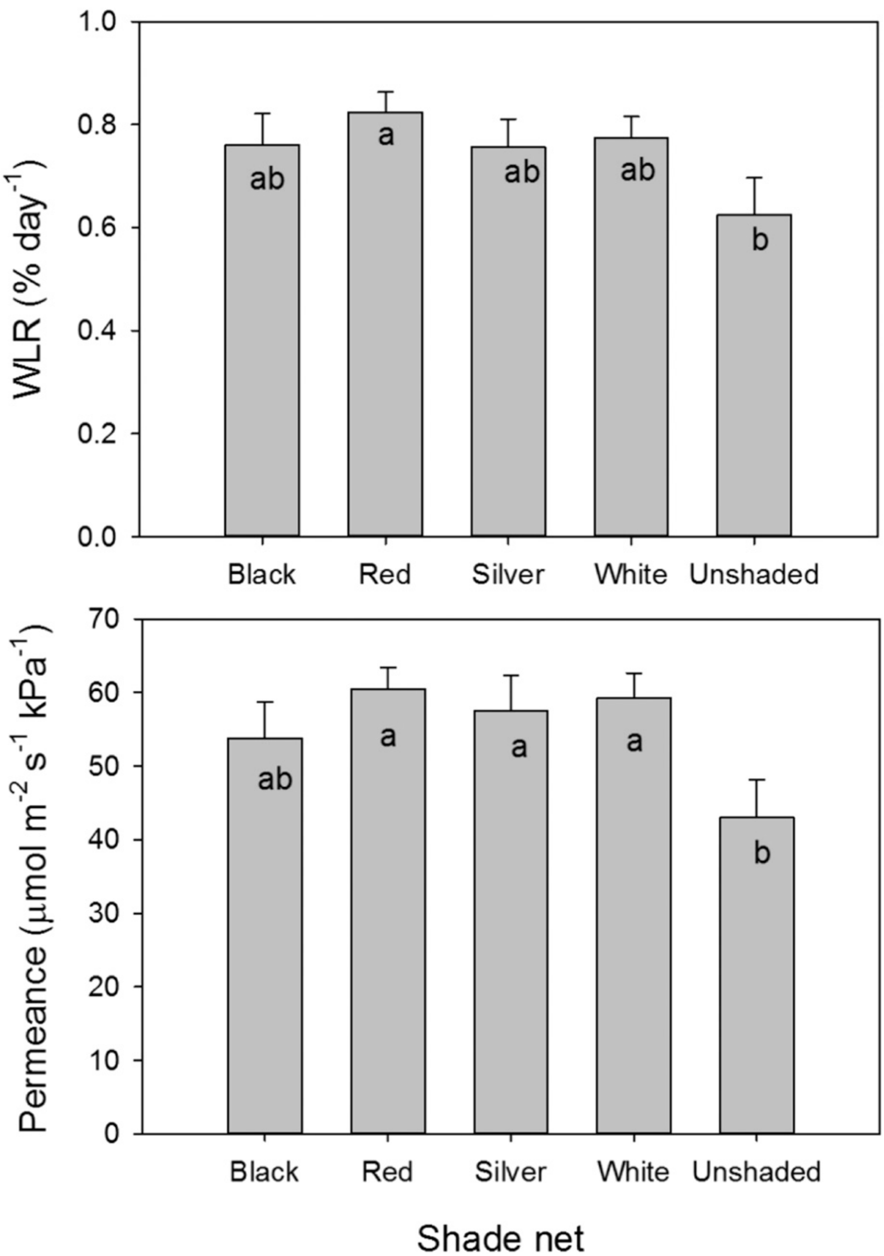

Fig. 2. Postharvest water loss and skin permeance of marketable bell pepper fruit grown under colored shade nets. Fruit kept at 20 °C (vapor pressure difference of 1.50 kPa) for 7 d, Tifton, GA.

with full covering had higher daily maximum air temperatures under red, blue, and pearl nets compared with black nets or in uncovered conditions. In the present study, colored shade nets (on structures with open sides) had little effect on air temperature, but reduced root zone temperatures compared with unshaded conditions; leaf temperatures were increased under white net and under unshaded conditions. Air temperatures were similar under the different colored shade nets probably because the sides of the structures were open, allowing for enhanced ventilation.

Fruit yield. Fruit marketable yields were reduced in the unshaded treatment and there were inconsistent differences in marketable yields among colored shade nets. Thus, light quality as modified by colored shade nets probably had a minor effect on fruit yields. In Israel, bell pepper plants under red, pearl, and yellow shade nets had increased fruit yields compared with plants under black net (Shahak et al., 2009). In other studies on colored shade nets in bell pepper, fruit yields were reduced in unshaded conditions (Ambrozy et al., 2016; Ayala-Tafoya et al., 2015). Decreased fruit yields in the unshaded treatment indicate that high temperature (and high VPD) conditions because of high irradiation were a major factor affecting the bell pepper crop.

Our finding that total and marketable fruit yields decreased with increasing leaf temperatures support the contention that high temperatures affect plant function under unshaded conditions. In fact, leaf net photosynthesis and stomatal conductance decreased with increasing midday leaf temperature above 32 °C (Díaz-Pérez and St. John, 2019). However, the mechanism through which fruit yields were reduced under unshaded conditions was probably not via a direct effect of high leaf temperature on leaf gas exchange because no relationships were observed between total fruit yield with either leaf net photosynthesis ($r^2 = 0.461$; $P < 0.05$) or stomatal conductance ($r^2 = 0.336$; $P < 0.05$). Instead, reduced plant water status resulting from increased evaporative demands under unshaded conditions may be a probable explanation for the reduced fruit yields. Reduced leaf net photosynthesis with increasing leaf temperature was probably caused by stomatal factors due to plant water stress rather than by nonstomatal factors, such as photo-inhibition; this suggestion is supported by the similar PSII efficiency values obtained in unshaded conditions and those under shade nets (Díaz-Pérez and St. John, 2019).

In addition, leaf temperature was not related with *PAR* under the shade nets, suggesting that the differences in leaf temperature were not primarily due to differences in *PAR*. Instead, differences in the amount of IR light traversing the shade nets probably resulted in the observed differences in leaf temperature. In 2015, leaf temperature ranged from 31.8 °C under black net and 34.2 °C under

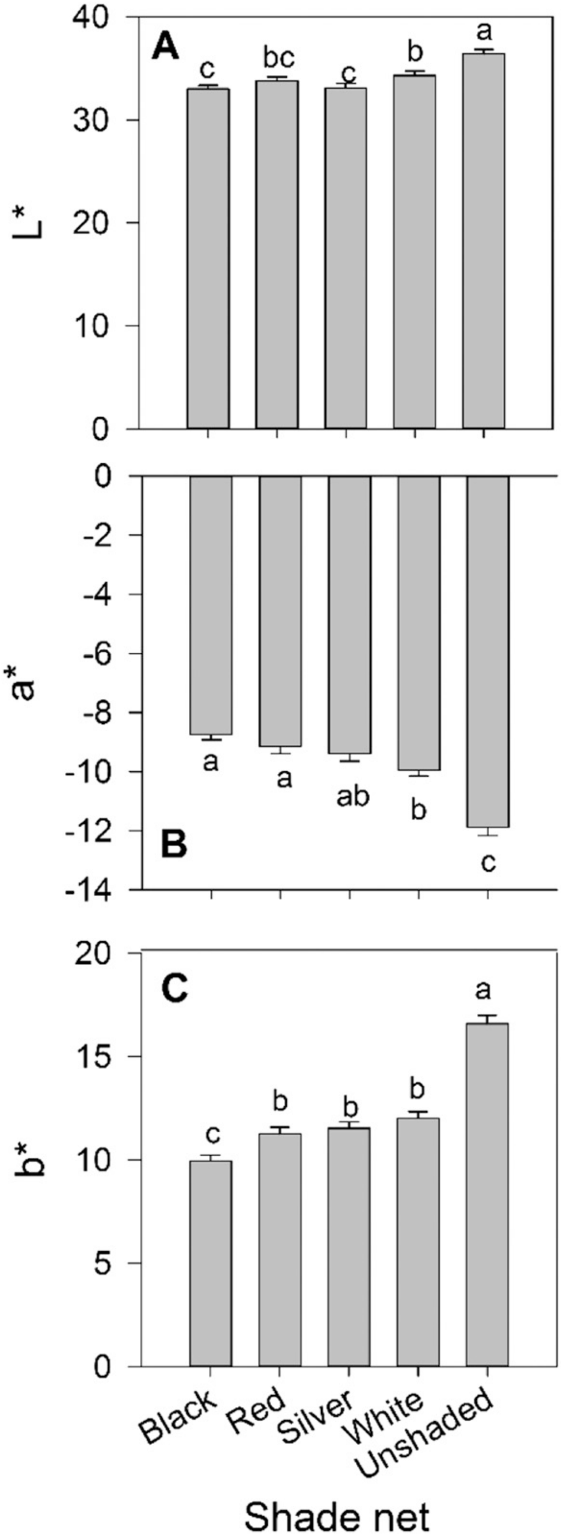

Fig. 3. Skin color of marketable bell pepper fruit grown under different colored shade nets, Tifton, GA. Color L* value goes from 0 (white) to 100 (black); a* value from –a (green) to +a (red); b* value from –b (blue) to +b (yellow).

unshaded conditions, with their respective marketable yields being 61 and 13 $t\cdot ha^{-1}$. Increased leaf temperature may result in decreased rates of leaf net photosynthesis and consequently decreased fruit yields under warm conditions. Thus, shade nets played an important role in ameliorating heat stress and water stress by reducing solar radiation, and as a result reducing leaf temperature and leaf transpiration through a decrease in evaporative demand between leaves and the surrounding air.

Postharvest fruit transpiration. Bell pepper fruit grown under unshaded conditions (i.e., full solar radiation) had reduced fruit water loss rates and reduced skin permeance compared with fruit produced under colored shade nets. Interestingly, shade net color did not affect either the rate of fruit water loss or fruit skin permeance. The rate of postharvest fruit water loss or transpiration strongly affects fruit quality and shelf life (Ben-Yehoshua and Weichmann, 1987; Díaz-Pérez, 2019). In bell pepper, fruit transpiration is restricted due to lack of stomata and a relatively thick cuticle (Parsons et al., 2013). Approximately 26% of fruit water loss in bell pepper occurs via the calyx (Díaz-Pérez et al., 2007).

The effects of shade nets on the rate of fruit water loss in bell pepper may be variable. In Georgia, the rate of fruit water loss in bell pepper was unaffected by shade level in black nets, although there were differences between cultivars (Díaz-Pérez, 2014). In Israel, bell pepper fruit under pearl shade net had a reduced water loss rate and increased firmness compared with fruit under a black net (Kong et al., 2013). In the present study, the fact that fruit skin permeance was unaffected by colored net color indicates that the transpirational properties of the fruit epidermis were not influenced by the colored nets. These results suggest that light quantity rather than light quality (as modified by colored shade nets) influenced the rate of fruit water loss in bell pepper. Fruit response to light may be similar to that shown by leaves in which sun leaves have reduced cuticular transpiration compared with shade leaves (Larcher, 1995). Thus, increased bell pepper fruit transpiration under colored shade nets was probably due to differences in cuticle amount, composition, or morphology resulting from light and temperature effects (Hull et al., 1975; Kerstiens, 1996). Cuticle thickness or composition, however, were not measured in the present study. In a cross between *Capsicum annuum* and *Capsicum chinense*, fruit water loss was more related with cuticle composition than with cuticle thickness (Parsons et al., 2012).

In 'Keystone', 'NuMex R Naky', and 'Santa Fe Grande' peppers differing in physical characteristics, rate of fruit water loss was positively correlated with initial water content, surface area-to-volume ratio, and cuticle thickness (Lownds et al., 1993). In bell pepper, the rate of fruit water loss was found to decrease as fruit water content declines under storage conditions (Díaz-Pérez et al., 2007). In the present study, fruit water content was probably reduced in unshaded conditions because of the high evaporative demand conditions. This reduced fruit water content may explain at least partially the diminished rate of transpiration of such fruit.

Fruit skin color and composition. Shade net treatments showed different fruit skin color values; the unshaded treatment had the smallest (more negative) a* value and the highest b* value. Environmental conditions as modified by shade nets may affect fruit phytochemical content (Ilic and Fallik,

Table 5. Effect of colored shade nets on chemical composition of marketable bell pepper fruit, Tifton, GA, Spring 2015.

Shade net	SSC[z] (%)	Total phenols [gallic acid equivalent ($mg \cdot L^{-1}$)]	Flavonoids [quercetin equivalent ($mg \cdot mL^{-1}$)]	CUPRAC[y] (μM)	TEAC[x] (μM)
Black	3.3 c[w]	477 d	38.0 bc	1806 c	3116 c
Red	4.1 a	557 b	34.0 c	2178 b	4056 b
Silver	3.6 bc	526 c	35.5 c	2062 b	3731 b
White	3.9 ab	582 ab	42.9 ab	2507 a	4571 a
Unshaded	4.0 ab	603 a	47.0 a	2706 a	4756 a
P	0.004	<0.0001	0.001	<0.0001	<0.0001

[z]SSC = soluble solids content.
[y]CUPRAC = Cupric Reducing Antioxidant Capacity.
[x]TEAC = Trolox Equivalent Antioxidant Capacity.
[w]Means within the same column followed by the same letter are not statistically different according to Fisher's protected least significant difference test ($P \leq 0.05$).

Table 6. Effect of colored shade nets on chemical composition of marketable bell pepper fruit, Tifton, GA, Spring 2016.

Shade net	SSC[z] (%)	Total phenols [gallic acid equivalent ($mg \cdot L^{-1}$)]	Flavonoids [quercetin equivalent ($mg \cdot mL^{-1}$)]	CUPRAC[y] (μM)	TEAC[x] (μM)
Black	1.7	301 b[w]	67 b	1718 a	1882 b
Red	3.0	249 b	62 b	555 c	1059 c
Silver	2.2	240 b	51 b	578 c	1001 c
White	4.6	277 b	54 b	1200 b	951 c
Unshaded	2.9	423 a	123 a	934 bc	3386 a
P	0.157	<0.0001	<0.0001	<0.0001	<0.0001

[z]SSC = soluble solids content.
[y]CUPRAC = Cupric Reducing Antioxidant Capacity.
[x]TEAC = Trolox Equivalent Antioxidant Capacity.
[w]Means within the same column followed by the same letter are not statistically different according to Fisher's protected least significant difference test ($P \leq 0.05$).

2017). Fruit color values may be predictors of fruit pigment concentrations. In pumpkin and squash, the color a* value was found to be positively correlated with total carotenoids (Itle and Kabelka, 2009). In tomato, the color a* value and the ratio $(a^*/b^*)^2$ were positively correlated with lycopene concentration (Dsouza et al., 1992). In our study, the reduced a* value in bell pepper fruit under unshaded conditions probably indicates a diminished fruit carotenoid concentration. In Serbia, bell pepper fruit was found to have decreased carotenoid concentration when grown in unshaded conditions compared with fruit under red, black, pearl, and blue nets (Ilic et al., 2017). Tomato fruit in unshaded conditions and under white shade net showed reduced lycopene content compared with fruit under black, blue, or red shade nets; reduced lycopene concentration was attributed to high air temperatures under the nets (Helyes et al., 2007; Ilic et al., 2015).

Bell pepper fruit SSC responded inconsistently to shade treatments in the two seasons and fruit under black shade net had reduced SSC in 1 of the 2 years. Low fruit SSC values under black shade may be attributed to either reduced leaf net photosynthesis or increased fruit respiration due to high temperatures, resulting in reduced sugar accumulation in the fruit. Fruit SSC, however, was not related with leaf temperature ($r = 0.087$; $P > 0.05$). In Georgia, SSC in bell pepper fruit under black shade net decreased with increasing shade level (Díaz-Pérez, 2014). In Serbia, bell pepper under red, black, pearl, or blue nets produced fruit with reduced SSC compared with fruit in open field (Ilic et al., 2017).

Fruit total phenols, flavonoids, and antioxidant capacity (TEAC) were among the highest in unshaded conditions, although there were inconsistent responses among colored shade nets in the 2 years. In baby spinach, flavonoids were more abundant under intense solar radiation and decreased under colored shade nets (Bergquist et al., 2007). Bell pepper fruit under pearl shade net had reduced ascorbic acid content and antioxidant activity compared with fruit under black shade net (Kong et al., 2013). The effect of colored shade nets on compounds of secondary metabolism, such as phenols and flavonoids and antioxidant capacity requires further studies due to the importance of these compounds on human diet and health.

In conclusion, the present study is consistent with previous reports indicating that shade nets increase fruit yield and quality in bell pepper compared with unshaded conditions. Colored shade nets have been reported to modify the light microenvironment of the crop, influencing the action of plant photoreceptors and as a consequence altering plant morphology and physiology (Stamps, 2009). The present study, however, showed no consistent significant differences in fruit total and marketable yields, postharvest fruit transpiration, and fruit chemical composition under colored shade nets. Reduced leaf temperatures under the shade nets, regardless of net color, played a major role in improving bell pepper fruit yield and quality by presumably reducing plant water stress due to decreased evaporative demand compared with unshaded conditions.

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