Shade Effect on Growth and Productivity of Tomato and Chili Pepper

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SUMMARY. Southern U.S. states such as Texas experience high temperatures and intense solar radiation during the summer production season. Use of shade cloth is common in Spain and other Mediterranean countries and is becoming popular with homeowners or small-acreage farmers in Texas. Little information is available on the applicability of using shade cloth on tomato (*Solanum lycopersicum*) and chili pepper (*Capsicum annuum*) in the warm climate of Texas. The effects of two shade nets differing in shading intensity on growth, chlorophyll fluorescence, and photosynthesis of 'Celebrity' tomato and 'Sweet Banana' chili pepper was investigated from May to Aug. 2014. Plants were grown in 50% shade, 70% shade, or full sun. Compared with the unshaded control, tomato grown in 50% shade had similar yield and shoot fresh and dry weight and less photochemical stress. The 50% shade reduced number and weight of unmarketable tomato fruit. Similar results were obtained with chili pepper except for lower numbers of marketable fruit. The 70% shade significantly reduced yield parameters of both tomato and chili pepper. Both 50% and 70% shade cloth reduced leaf temperatures of tomato and chili pepper with variable results in June and July. Growth index [(height + width 1 + width 2) ÷ 3] of tomato and chili pepper was the highest with 50% shade, the lowest with full sun, and intermediate with 70% shade. The maximum net photosynthetic rates (P_n) of tomato determined from a P_n to light response curve supported the results on growth and yield. However, the maximum P_n of chili pepper was higher in full sun treatment compared with 50% or 70% shade. The latter two were almost identical. This one growing season study indicated that shading at 50% benefits tomato and chili pepper production in west Texas by reducing heat stress; however, a shading percentage below 50% may be better.

High temperature and light intensity during the summer have a negative effect on plant growth and yield (Lopez-Marin et al., 2012). Excessive light and heat load on leaves is a result of high solar radiation (Lopez-Marin et al., 2011) which severely limits the productivity

of a crop. Reductions in crop yield are frequently observed under Mediterranean conditions with high levels of solar radiation and low air humidity (Katsoulas and Kittas, 2008). Shading is a popular method to improve plant microclimate in the summer by decreasing leaf temperature and leaf transpiration rate, thus alleviating heat stress (Aberkani et al., 2008). The cultivation area under shade is constantly increasing in Mediterranean countries such as Israel, Morocco, and others (Tanny et al., 2014).

In Texas, commercial tomato production in open field is limited to relatively short periods of favorable temperatures during the spring and early fall. With the advent of high temperatures, usually in June, vegetative vigor and reproductive ability of the plants start to decline with a corresponding blossom abscission and failure of fruit set. Flowering, pollination, and fruit set of tomato are often adversely affected by extreme high temperatures. The optimum temperatures for tomato fruit set are from 18.5 to 26.5 °C (LeBoeuf, 2004). Chili pepper is primarily cultivated in warm and semiarid regions where high irradiance and temperatures during summer growing seasons are common (Dorji et al., 2005). Therefore, the optimal temperatures for chili pepper may be higher than those for tomato. In other words, chili pepper may be more tolerant than tomato to full sun and high temperatures in Texas.

In southern and western Texas, high temperatures in summer months often exceed 35 °C and in some days the high temperatures can even reach to 40 °C and higher. According to our local weather station (El Paso, TX), relative humidity during the day can be in the teens and maximum solar radiation can reach 32 MJ·m⁻²·d⁻¹, equivalent to 64 mol·m⁻²·d⁻¹ in the 400 to 700 nm range of the photosynthetically active radiation (PAR). The high temperature and solar radiation lead to high plant temperatures, thus causing heat stress.

Shade screens reduce solar radiation during the day, thus reducing heat stress (Lopez-Marin et al., 2012). Previous studies indicated that shade screens, mostly light shade, led to an increase in productivity and quality of tomato, pear (*Pyrus* sp.), apple (*Malus × domestica*), strawberry (*Fragaria × ananassa*), grape (*Vitis vinifera*), and chili pepper

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
10	%	g·L ⁻¹	0.1
0.3048	ft	m	3.2808
0.0929	ft ²	m ²	10.7639
3.7854	gal	L	0.2642
2.54	inch(es)	cm	0.3937
0.4536	lb	kg	2.2046
4.8824	lb/1000 ft ²	g·m ⁻²	0.2048
1	mmho/cm	dS·m ⁻¹	1
28.3495	oz	g	0.0353
(°F - 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

(Rajapakse and Shahak, 2007; Shahak et al., 2008). With temperature reduction under the shade proportional to shade intensity (Kittas et al., 2009), a shade may be necessary to alleviate the heat stress of plants for regions with high solar radiation and temperatures. El-Gizawy et al. (1992) reported that shading (up to 51%) significantly increased the number of fruit and total yield of tomato in Egypt and the highest yield was achieved at 35% shading while heavy shading of 63% had similar yield to full sun. Nevertheless, too much shade can cause yield reduction in some crops, but no research-based information is available in Texas. The purpose of this research is to quantify the effect of relatively heavy shading intensities (50% and 70%) on the growth, yield, chlorophyll fluorescence (F_v/F_m), and P_n of tomato and chili pepper in semi-arid west Texas. We also quantified microclimate traits underneath the shade structures.

Materials and methods

SITE DESCRIPTION. A field experiment was conducted at Texas A&M AgriLife Research Center at El Paso (lat. 31°41'48''N, long. 106°16'54''W, elevation 1140 m). The dominant soil is deep sandy soil according to the soil map of El Paso (U.S. Department of Agriculture, 1971). The analytical results of chemical characteristics of the soil indicated that phosphorus, potassium, calcium, magnesium, and sulfur were above critical levels. Nine 5 × 20-ft raised beds were amended with manure at 292 kg per bed and completely tilled. Slow-release fertilizer at 0.9 lb/1000 ft² nitrogen (equivalent to 227 g per bed) [14–16 months 18N–2.6P–10K (18–6–12) Osmocote® Lo-Start®; Scotts, Marysville, OH] was applied and tilled to provide additional nitrogen to maintain vegetative growth. Beds were covered with black weed barrier fabric (DeWitt Co., Sikeston, MO) to suppress weed growth.

PLANT MATERIAL AND SHADE TREATMENT. ‘Celebrity’ tomato and ‘Sweet Banana’ chili pepper plants were purchased from Peterson Brothers (San Antonio, TX) on 26 Mar. 2014. They were transplanted to 1-gal plastic containers [14.5 cm diameter, 13.5 cm height, and 2600 cm³ volume (Poly-Tainer No-1P; Nursery Supplies, Orange, CA)] filled with commercial medium (Metro-Mix 360; Sun Gro

Horticulture, Bellevue, WA). All plants were grown in a greenhouse and watered with nutrient solution which was prepared by adding 0.72 g·L⁻¹ 15N–2.2P–12.5K (Peters 15–5–15, Scotts) to tap water. The electrical conductivity (EC) and pH of the nutrient solution were 1.4 dS·m⁻¹ and 6.4, respectively. On 24 Apr. 2014, plants were transplanted to the field raised beds in two rows with a distance of 3 ft between the two rows and 2 ft between plants of the same row. Planting density was two plants per 10 ft². Plants were watered through a drip irrigation system twice daily at 7:00 AM and 1:00 PM (with about 1 L each irrigation) except on rainy days. In addition, plants were hand watered with 2 g·L⁻¹ 15N–2.2P–12.5K (Peters 15–5–15) solution (EC around 3.0 dS·m⁻¹; pH around 6.2), 1 L per plant, once per week from 27 May to 8 July.

ENVIRONMENTAL CONDITIONS. Air and soil temperatures were measured every 30 min using type T copper-constantan thermocouples (Omega Engineering, Stamford, CT) connected to a datalogger (CR1000; Campbell Scientific, Logan, UT). For air temperatures, three thermocouples per bed were placed at 20-inches aboveground to record ambient temperature. For soil temperatures, three thermocouples per bed were placed in the root zone of three randomly selected plants at 3 inches below the soil surface and at 4 inches away from the plant. *PPF* was recorded every 30 min with a quantum sensor for each treatment (SP-110; Apogee Instruments, Logan, UT). Light sensors were placed at 2-ft aboveground and 1.5 ft below shade cloth. The daily light integral (DLI) was then calculated from the instantaneous *PPF* (Korczynski et al., 2002).

PLANT GROWTH AND FRUIT YIELD. Plant height and two perpendicular widths (width at the widest point and the other perpendicular width) were measured weekly (Hammond et al., 2007). Growth index was calculated as (height + width at the widest point + width perpendicular to the other width at the widest point) ÷ 3. These measurements were discontinued at the end of June for tomato because adjacent plants were touching each other. Marketable fruit was harvested weekly for both crops with first harvest dates of 27 May for

chili and 9 June for tomato, and the number and fresh weight of fruit was recorded. In the middle of September, all plants were harvested for analysis. The marketable and unmarketable fruit were separated, and the number and fresh weight of fruit recorded. Shoot fresh weight was also recorded immediately. Due to limited oven space, all shoots were dried in a glass greenhouse at day temperatures ranging from 23 to 35 °C for 2 weeks and dry weight was noted.

PHYSIOLOGICAL CHARACTERISTICS. Chlorophyll fluorescence and leaf temperature were taken at 10:00 AM and 2:00 PM in the middle of June, July, and August (a total of three replications). Chlorophyll fluorescence was determined with a chlorophyll fluorometer (pocket PEA; Hansatech Instruments, Norfolk, UK). Healthy and fully expanded leaves were chosen for the measurements, five plants per treatment per species. The leaves were dark acclimated for at least 30 min before F_v/F_m measurements. Minimal fluorescence values in the dark-adapted state (F_0) were obtained by application of a low-intensity red measuring light source (627 nm), whereas maximal fluorescence values (F_m) were measured after applying a saturating light pulse of 3500 μmol⁻²·s⁻¹, and maximum quantum use efficiency of photosystem II (PS II) in the dark-adapted state was calculated as $F_v/F_m = (F_m - F_0)/F_m$. Leaf temperatures were measured using an handheld infrared thermometer (OS530; Omega Engineering), five plants per treatment per species. The thermometer was pointed at a healthy and fully expanded leaf at a distance of 3 ft (using a ruler).

Photosynthetic light responses were measured for tomato and chili pepper plants by using a portable photosynthesis system with an automatic universal PLC6 broad leaf cuvette (CIRAS-2; PP Systems International, Amesbury, MA). All plants were well watered before measurements. Healthy and fully expanded leaves of three plants per bed per species were chosen for the measurements. The carbon dioxide concentration within the leaf chamber was maintained at 375 μmol·mol⁻¹ when the photosynthetic light response curve was measured. Constant temperature (25 °C) and relative humidity (50%) were maintained within the leaf cuvette during each measurement. Before each response curve was measured,

the leaf clamped inside the leaf cuvette was exposed to a dark acclimation period of 30 min. Light intensities (*PAR*) were gradually increased from 0 to 2000 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ at 200 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ intervals. The minimum holding time between each step was 45 s.

EXPERIMENTAL DESIGN AND STATISTICAL ANALYSIS. The experiment was arranged in a split-plot design with shade treatment as the main plot and plant species as subplot with three replications. Shade treatment started on 12 May 2014 by installing the 7-ft-wide black woven polypropylene cloth at 50% or 70% shade (Hummert International, Earth City, MO) over the raised beds. Metal fence posts were used to hold the shade cloth at 4 ft aboveground. Both ends were also covered with the same shade cloth. One bed was considered as one replication for each shade level and there were five plants per species per bed, a total of 15 plants per species. For each species, an analysis of variance was conducted to test the influence of shade treatment on plant growth and physiological characteristics. Means separation among shade treatments was conducted using Tukey's honest significant difference multiple comparison when the shade treatment was significant. All statistical analyses were carried out using JMP (version 12; SAS Institute, Cary, NC). Polynomial regression model in SigmaPlot (version 13; Systat Software, San Jose, CA) was used to fit the photosynthetic light response data.

Results and discussion

ENVIRONMENTAL PARAMETERS. Air temperatures were higher in full sun treatment at all measurement dates compared with 50% and 70% shade (Fig. 1). The difference in air temperatures was as high as (mean $\pm$ SD) 1.1 ± 0.3 °C for 50% shade and 0.9 ± 0.3 °C for 70% shade. Air temperatures did not differ between 50% and 70% during the duration of this study. Kittas et al. (2009) found that the reduction of solar radiation above the crop was proportional to the shading intensity of the net and the canopy temperature was significantly lower under the shading nets than in the open field. Lopez-Marín et al. (2012) noted a large difference between the unshaded control and the greenhouses shaded by screen. This difference was as high as 5.2 °C under 60% shade and 4.1 °C under 40%

shade. Similar results were obtained by Beppu and Kataoka (2000) who reported a 1.9 and 3.3 °C reduction in daily maximum air temperatures with shading levels of 53% and 78%, respectively.

We observed similar trends in soil temperature measurements with full sun treatment having the highest soil temperatures compared with 50% and 70% shade. Soil temperature in full sun treatment was about 2.4 ± 0.6 °C higher than 50% shade and 3.0 ± 0.7 °C higher than 70% shade. No apparent differences were observed for soil temperature measurements between 50% and 70% shade. Lower soil temperatures mean lower evaporation rates which lead to less moisture loss.

The average DLI, which is the total amount of light received in a single day, was between 20.4 ± 3.4 and 12.1 ± 1.2 $\text{mol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$ for the 50% and 70% shade treatments, respectively, and 52.5 ± 8.9 $\text{mol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$ for full sun. In reality, the 50% and 70% shade treatment reduced DLI 60% and 77% compared with full sun.

FRUIT YIELD AND GROWTH. In general, tomato and chili pepper yield (number and fresh weight of marketable fruit) and potential yield (number and fresh weight of unmarketable fruit) were numerically the highest for plants grown in full sun, with the exception of fresh weight of marketable tomato fruit (Table 1). The number and fresh weight of marketable tomatoes at 50% shade was not statistically different from the control, while those of unmarketable fruit were significantly lower. Tomato plants grown at 70% shade had significantly lower yield of both marketable and unmarketable fruit compared with the full sun control. Tomato plants grown at 70% shade were also significantly lower than 50% shade treatment for marketable fruit but not for unmarketable fruit.

El-Gizawy et al. (1992) reported an increase in total production with the use of shading up to 51% and the highest tomato yield obtained under 35% shading. Fresh weight of tomato shoots was not statistically different among all treatments; however, dry

Fig. 1. Air and soil temperatures measured at 50% shade cloth, 70% shade cloth, and full sun from June to Aug. 2014; $(1.8 \times ^\circ\text{C}) + 32 = ^\circ\text{F}$.

Table 1. Accumulated number and fresh weight of marketable and unmarketable fruit over the season and FW and dry weight of shoots of tomato and chili pepper plants at the end of experiment grown under 50% shade cloth, 70% shade cloth, and full sun in a field experiment with three replications and five plants per replication.

Treatment	Marketable fruit			Unmarketable fruit		Shoot fresh wt (g)	Shoot dry wt (g)
	Fruit (no.)	Fresh wt (g) ^z	Avg fresh wt (g)	Fruit (no.)	Fresh wt (g)		
Tomato							
50% shade cloth	18.7 a ^y	1,570.7 a	79.5 ab	6.5 b	410.1 b	3,475.7 a	489.4 ab
70% shade cloth	7.2 b	559.6 b	63.1 b	5.0 b	184.0 b	2,997.0 a	412.9 b
Full sun	22.6 a	1,160.5 a	89.9 a	27.0 a	1,320.9 a	3,630.0 a	600.3 a
Chili pepper							
50% shade cloth	103.4 b	1,884.5 a	16.6 ab	10.2 a	135.4 a	530.2 a	104.9 a
70% shade cloth	77.9 b	1,311.3 b	14.2 b	11.0 a	121.7 a	431.7 a	84.3 a
Full sun	167.4 a	2,195.2 a	18.1 a	14.4 a	152.1 a	485.0 a	102.2 a

^z1 g = 0.0353 oz.

^yMeans with same lowercase letters within columns are not significantly different among treatments by Tukey's honest significant difference multiple comparison at $P < 0.05$.

weight was lower at 70% shade compared with the unshaded control. Kittas et al. (2009) found that shading (34% to 50%) increased total marketable yield production, reduced the appearance of tomato cracking about 50% and, accordingly, the marketable tomato production was about 50% higher under shading conditions than under nonshading conditions. El-Aidy and El-Afry (1983) observed the highest tomato yields with 40% shading and concluded that increasing shading intensity over 40% does not increase crop production. Aberkani et al. (2008) observed that fruit yield was numerically higher in the shaded treatment, but not statistically different from the unshaded control. However, fruit number and marketable yield were statistically higher. Kittas et al. (2012) studied the effect of four shade nets with different shading intensities (34% to 49%) and reported that the total dry matter of tomato was not decreased. Ideally, a movable shade structure works the best. On raining days or in early mornings when the temperature and light intensity are not too high, shading should be removed. However, this would increase labor cost. Mobile shading improved the quality of tomato and increased marketable yield of cucumber [*Cucumis sativus* (Lorenzo et al., 2006)].

Chili pepper yield grown at 50% shade did not differ statistically from the full sun control except for number of marketable fruit (Table 1). However, 70% shade resulted in significantly lower yields of marketable fruit compared with full sun. The two shade treatments did not differ statistically for all measured growth and yield traits except for fresh weight of

Fig. 2. Growth index of tomato and chili pepper plants measured at 50% shade cloth, 70% shade cloth, and full sun from May to Aug. 2014. Means with same lowercase letters on the same date are not significantly different among treatments by Tukey's honest significant difference multiple comparison at $P < 0.05$; 1 cm = 0.3937 inch.

marketable fruit. No differences were observed for fresh and dry weight of shoots of chili pepper at all shade levels. In contrast, Lopez-Marín et al. (2012) determined that chili pepper plants grown under 40% shade yielded 1.26 kg·m⁻² more than control; however, yields of 60% shade and control

treatment were similar. Ryłski and Spigelman (1986) obtained similar results. Santana et al. (2012) evaluated the effect of red and blue screens (both at 40% shade rating) on chili pepper. The authors observed that blue and red screens reduced yield of chili pepper compared with field conditions

Table 2. Chlorophyll fluorescence (F_v/F_m) of tomato and chili pepper plants grown at 50% shade cloth, 70% shade cloth, and full sun measured at 10:00 AM (AM) and 2:00 PM (PM) between June and Aug. 2014.

Treatment	F_v/F_m					
	June		July		August	
	AM	PM	AM	PM	AM	PM
Tomato						
50% shade cloth	0.81 a ^z	0.72 a	0.81 a	0.75 a	0.81 a	0.75 a
70% shade cloth	0.82 a	0.75 a	0.81 a	0.75 a	0.81 a	0.75 a
Full sun	0.70 b	0.51 b	0.76 b	0.65 b	0.76 b	0.65 b
Chili pepper						
50% shade cloth	0.80 a	0.75 a	0.80 a	0.73 ab	0.80 a	0.73 ab
70% shade cloth	0.81 a	0.77 a	0.81 a	0.75 a	0.81 a	0.75 a
Full sun	0.71 b	0.61 b	0.76 b	0.70 b	0.76 b	0.70 b

^zMeans with same lowercase letters within columns are not significantly different among treatments by Tukey's honest significant difference multiple comparison at $P < 0.05$.

and that red screen had higher yields than blue screen. However, the authors observed that fruit weight was higher in blue screen than red and field conditions which did not differ. In our trial, black shade cloth at 50% resulted in similar yields to full sun conditions. It appears that shade cloth color plays an important role on yield, not just the shade rating.

Tomato and chili pepper plants grown in full sun generally had the lowest growth index throughout the growing season compared with the two shade treatments (Fig. 2). No difference in growth index was found for tomato plants between the two shade treatments. Similar results were observed for chili plants in growth index after 24 June. By 1 July when measurements for tomato plants were ended, plants were 95 and 92 cm in height for 50% and 70% shade treatments, respectively, compared with 73 cm for those in full sun. On the other hand, chili pepper plants grown in full sun averaged 60 cm in height by 14 Aug. compared with 73 and 70 cm for 50% and 70% shade treatments, respectively. Both tomato and chili pepper plants had the highest growth index with 50% shade, the lowest with full sun, and an intermediate growth index with 70% shade.

There were no differences in fresh weight of shoots for both tomato and chili pepper plants (Table 1). No differences in dry weight of shoots were found among treatments for chili pepper, while that of tomato plants grown under 70% shade was the lowest. No statistical difference was found in dry weight of shoots in tomato plants between 50% shade and full sun.

CHLOROPHYLL FLUORESCENCE. F_v/F_m was significantly lower for

Fig. 3. Net photosynthetic rates in response to light intensity (light response curves) of tomato and chili pepper plants grown at 50% shade cloth, 70% shade cloth, and full sun [photosynthetically active radiation (PAR)]. Polynomial regression model was used to fit the photosynthetic light response data. Error bars represent SE of nine measurements.

Table 3. Leaf temperatures measured by an infrared thermometer of tomato and chili pepper plants grown at 50% shade cloth, 70% shade cloth, and full sun measured at 10:00 AM (AM) and 2:00 PM (PM) between June and Aug. 2014.

Treatment	Leaf temp (°C) ^z					
	June		July		August	
	AM	PM	AM	PM	AM	PM
Tomato						
50% shade cloth	24.6 b ^y	26.8 a	22.9 a	33.1 a	28.5 b	31.4 b
70% shade cloth	28.3 b	31.0 a	21.7 a	30.4 a	26.4 c	29.2 c
Full sun	33.3 a	29.9 a	24.4 a	34.9 a	30.0 a	33.5 a
Chili pepper						
50% shade cloth	28.4 a	28.5 a	21.9 b	32.2 a	26.3 b	29.7 b
70% shade cloth	29.3 a	29.4 a	21.8 b	32.2 a	27.1 b	29.9 b
Full sun	32.1 a	27.8 a	23.3 a	34.3 a	28.7 a	31.1 a

^z(1.8 × °C) + 32 = °F.

^yMeans with same lowercase letters within columns are not significantly different among treatments by Tukey's honest significant difference multiple comparison at $P < 0.05$.

tomato plants grown in full sun when measured in June, July, and August (Table 2) indicating plants were more stressed. Lower F_v/F_m (<0.8) indicates higher stress to the photosynthetic process, which was observed in plants grown in full sun (Maxwell and Johnson, 2000). No significant differences in F_v/F_m were observed between 50% and 70% shade treatments. Aberkani et al. (2008) observed higher F_v/F_m values in late summer in tomato plants in a foam shaded greenhouse and concluded that unshaded plants were more stressed.

Chili pepper also had higher and statistically different F_v/F_m values for 50% and 70% shade compared with full sun. One notable exception was observed in July and August when F_v/F_m measured in the afternoon of chili pepper at 50% shade was not statistically different from full sun (Table 2).

RESPONSE OF P_n TO LIGHT INTENSITY. Light response curves indicate the potential photosynthetic ability of the plants. The maximum P_n indicates the maximum potential P_n at light saturation point. Maximum P_n of tomato plants was lowest for the plants grown under full sun with a peak at $12.4 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ and highest with 50% shade with a peak at $15.5 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ at $2000 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ (Fig. 3). Tomato plants grown in 70% shade had a photosynthetic response curve similar to that of full sun. Aberkani et al. (2008) evaluated foam shading (40% to 65% shade) and observed slightly higher light response curves of tomato compared with unshaded control early in the summer.

Chili pepper, on the other hand, had a different photosynthetic response curve whereby plants grown

in full sun had the highest P_n at light saturation point (maximum of $13.0 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$), while 50% and 70% shade had almost identical response curve with a maximum of $10 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ (Fig. 3). These results may indicate that tomato plants grown in the 50% and chili plants grown at full sun have greater photosynthetic capacity compared with other treatments, although the differences were small, especially at lower light intensities. These results may indicate that chili pepper plants could yield the highest biomass, which coincided with dry weight of shoots and fruit yield, and possibly the highest fruit yield under full sun.

Katsoulas et al. (2012) evaluated two insect-proof white nets (13% and 34% shading) and observed no reduction in photosynthesis in chili pepper despite a substantial difference in incident light regimen. Unshaded open field and 13% shade white nets had similar rates of photosynthesis and significantly higher than 34% shade. In a study on chili pepper cultivated under 40% and 60% shade, Lopez-Marin et al. (2012) observed that the maximum daily PAR decreased to 580 and $220 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, respectively, compared with the unshaded control.

LEAF TEMPERATURE. Leaf temperature generally did not differ among all treatments and crops except for early in the season (morning in June for tomato) and late in season (August for tomato and chili pepper) (Table 3). In August, leaf temperatures were the highest in plants grown in full sun and the lowest in 70% shade. Seventy percent shade was statistically different from 50% shade for tomato, but not for chili pepper. Similar results were

observed by Smith et al. (1984) in greenhouse tomato and cucumber and by Raveh et al. (2003) in Murcott tangor (*Citrus reticulata* × *Citrus sinensis*).

Based on the 1-year results of measured DLI, and growth and physiological parameters, we conclude that 70% shade was too much shade for tomato and chili pepper and that a 50% shade treatment resulted in higher growth index in both crops. Although 50% shade is suitable to alleviate heat stress and to maintain similar yield, a lower shade percentage may be more effective to maximize yield and productivity. Further study is needed to determine the best shading intensity.

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