The Effects of Temperature and Light in High Tunnel Primocane Red Raspberry Production- Year 1

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Introduction

A number of studies have shown how to optimize red raspberry production in high-tunnels, including providing adequate nutrient and water uptake, high soil organic matter, fulfilled chilling requirement, low winter injury, improved cane height and growth rate (Demchack, 2009; Oliveira et al., 1998). Due to their low chilling requirement, double-cropping potential, high fruit quality, and ease of manipulation, primocane (fall) fruiting red raspberries are best grown under high-tunnel production (Pritts, 2008).

Primocane red raspberries have shown various benefits from warmer air temperatures provided by high-tunnels. Compared to field grown primocane red raspberries which are typically available in the Midwest from mid-August to early-October, production of high-tunnel grown primocane red raspberries begins in mid-July and extends through November, lengthening the harvest season an additional 3 to 4 weeks in the early and late season (Demchak, 2009; Domoto et al., 2009; Heidenreich et al., 2007).

While past research has mainly focused on variation among primocane bearing types and cultivars and the benefits of increased temperature on growth and development under protected environments (Pritts, 2008; Privé et al., 1993; Stafne, 2001; Carew et al., 2003; Remberg et al., 2010), researchers have recently discovered that high air and soil temperatures can be detrimental to raspberry production (Bushway, 2008) resulting in a state of bud dormancy, delayed time to ripening, decreased water uptake, and reduced fruit quality and overall yield (Hoover et al, 1989; Privé et al., 1993; Oliveira et a., 2004; Remberg et al., 2010).

Similar to temperature, increased light intensity levels also adversely affect overall primocane yield (Oliveira et al., 2004). In general, primocane-fruiting red raspberries favor the warmer months of the Midwest to initiate flowers (Carew, 2003). However, during this time, the warmer temperatures and light intensity levels often exceed optimal conditions for proper growth and development. As light intensity levels increase beyond an optimum range of $600 \mu mol \cdot m^{-2} s^{-1}$ and soil and air temperatures exceed 16˚C and 24˚C, primocanes enter a state of bud dormancy, delaying ripening time and reducing fruit quality and fruit weight (Oliveira et al., 2004; Remberg et al., 2010).

Despite widespread findings of the effects of increased temperature and light intensity, no recognized assessment has been made linking these two critical factors with the development of red raspberry primocane height and growth rate, flower bud initiation, fruit set, and overall crop productivity. The proposed study is intended to (1) assess the relationship between temperature and light intensity and their effect on primocane growth and development, (2) evaluate how effective shade cloths and soil mulch are in reducing temperature and light intensity levels of high tunnel red raspberry production, and (3) provide relatively inexpensive solutions to minimize temperature and light intensity damage in protected red raspberry production during the warm summer months.

Materials and Methods

This study was located at the Horticulture Research Station, rural Ames, Iowa, under 3 identical tunnels that served as replications, obtained from FarmTek, Dyersville, IA, each 11.0 m (36 ft) long and 4.3 m (14 ft) wide, with 6 ml polyethylene plastic covering. Representative soil samples were collected from each tunnel and showed slight inconsistency with fertility; therefore, to ensure uniformity, additional fertilizer applications were applied.

Dormant, 1-year old canes of the primocane red raspberry cultivar Autumn Britten, obtained from Nourse Farms, South Deerfield, Massachusetts, were planted in raised beds 9.1 m (30 ft) long and 61 cm (2 ft) wide, with 46 cm (1.5 ft) spacing within row and 1.2 m (4 ft) spacing between rows in a split-plot, randomized complete block design on April 18. Raspberry canes were trained on a temporary T-trellis, with twine located at heights of 90 cm (3 ft) and 1.8 m (6 ft). Plants were watered and fertilized via trickle irrigation at recommended rates (Bushway et al., 2008).

Prior to treatment application, light transmission under the plastic covering was measured, using a LI-COR (LI-1400) data logger and LI-COR sensors (Quantum Sensor LI-190 and Line Quantum Sensor LI-191), and exhibited 17% light intensity reduction. Two general strategies were used to provide temperature and light intensity reduction in the controlled tunnel environment: the main plot treatment of 50% reduction of light with the combination of shade cloth containing a 33% shade factor in addition to the 17% light reduction of the polyethylene plastic covering, as suggested from Willits (2003), and the sub-plot treatment of switchgrass mulch, *Panicum virgatum* L., obtained from Armstrong Research Farm, rural Lewis, IA, applied within rows to a 15.2 cm (6 in) depth at planting. Twelve treatment combinations over the 3 replications will be used (2 shade treatments x 2 mulch treatments x 3 replications = 12 combinations).

To determine the optimum growing temperatures of both air and soil temperatures inside a tunnel, WatchDog™ B-Series Button Temperature Loggers were placed at a 10.2 cm (4 inch) soil depth and at primocane growing point. Temperatures were measured continuously, at 30 min intervals. Light intensity levels were measured at three different plant canopy heights; 30 cm, 90 cm, and 1.8 m (1, 3, and 6 ft respectively); in addition to three randomly selected locations under main plot treatments. Light intensity was measured when skies were mostly sunny, with efforts to record on a weekly basis depending upon favorable weather conditions. Beginning on June 15, shade cloth (33%) was placed over the designated plot treatments, completely covering the plant canopy and removed on September 22.

Vegetative growth was determined by measuring end-of-season cane height and counting total number of lateral branches and leaves per cane from 5 randomly selected primocanes in each plot. An additional analysis of leaf area per cane was measured, using a Li-Cor LI-3100 Area

Meter, from the 5 selected canes from each plot. To determine if fruit yield is significantly affected by temperature, berries were picked every 2 to 4 days, and a total weight and fruit number per treatment was recorded. Average fresh berry mass was calculated by dividing the total weight by the fruit number.

Data was analyzed and compared statistically using SAS, version 9.3. Within each treatment, total number of berries, average berry weight, total yield, cane height, total number of lateral branches per cane, total leaves per cane, leaf area, and light levels was analyzed by ANOVA. Means were separated by using Tukey's multiple comparison test, at a significance of P≤.05.

1st Year, Preliminary Data (from the planting being established)

The 2012 growing season was considerably warmer than typical Midwest seasons and it was the warmest year on record in Iowa. Maximum field air temperatures ranged from 26.66˚ to 37.77˚C for three straight weeks in July, with lows remaining in the mid-teens to mid-20s˚C, during this same period (data not shown). The air temperature in the protected-tunnel environments received no reduction of temperature under the main plot treatments of shade cloth (Fig. 1). Tunnels had to be vented and thus shade cloth did not change the ambient temperature. In addition, due to the high minimum night temperatures, little reduction of temperature occurred after sun-down, even with all possible ventilation in place. As a result, cane growing point temperature remained well above the optimum temperature range, reported by Remberg et al. (2010) and Carew et al. (2003), for much of the season.

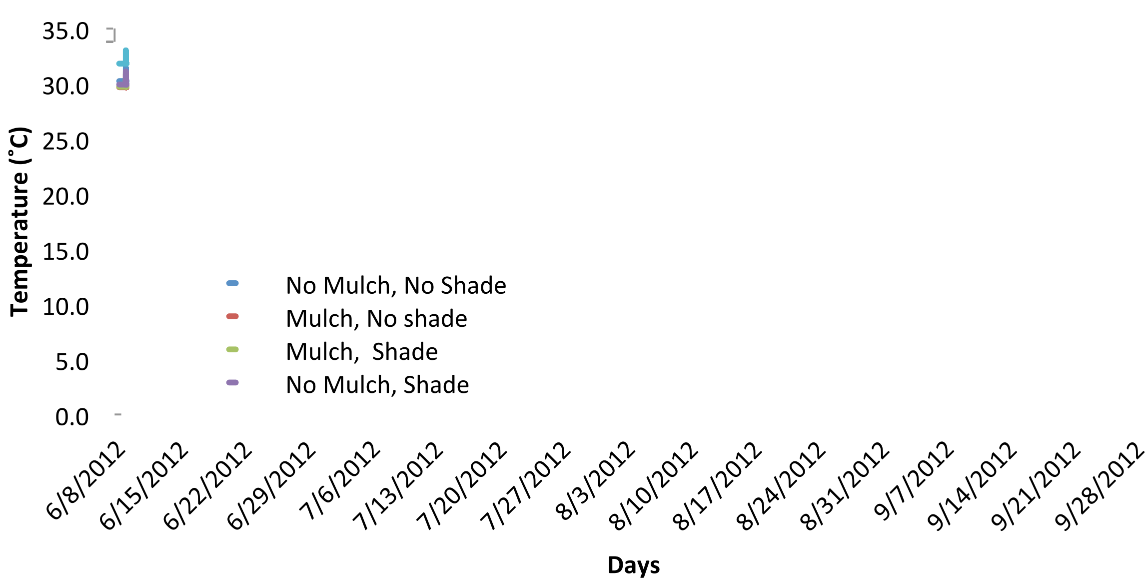

Figure 1: Daily temperature averages at cane growing point height, among two main plot treatments of 33% shade cloth and plastic covering, and two sub-plot treatments of switchgrass mulch or no mulch. Field daily temperature averages from Gilbert, IA weather station, ISU AgClimate, were also recorded.

The abnormally warm season also increased the soil temperature well beyond optimum conditions for successful cane growth and development. While 16˚C soil temperatures were attained at the beginning of June in 2011, 16˚C field soil temperatures were already reached on May 5th, in 2012 (data not shown). The effects of high air temperature on the relative soil depth readings in relation to main and sub plot treatments are shown in Fig. 2. As assumed, higher soil temperatures were recorded in the control treatment plots. Adding shade to the treatment area reduced the soil temperature considerably up until the second week of July, correlating with the three week period of air temperatures above 26.6˚C. Using switchgrass mulch alone did seem to have positive effects in reducing the soil temperatures of the designated replications. In addition, increased berry weight was observed in the mulch treatments (Table 1). The treatment of shade cloth and switchgrass mulch showed greatest potential in reducing the soil temperature at a 4" depth.

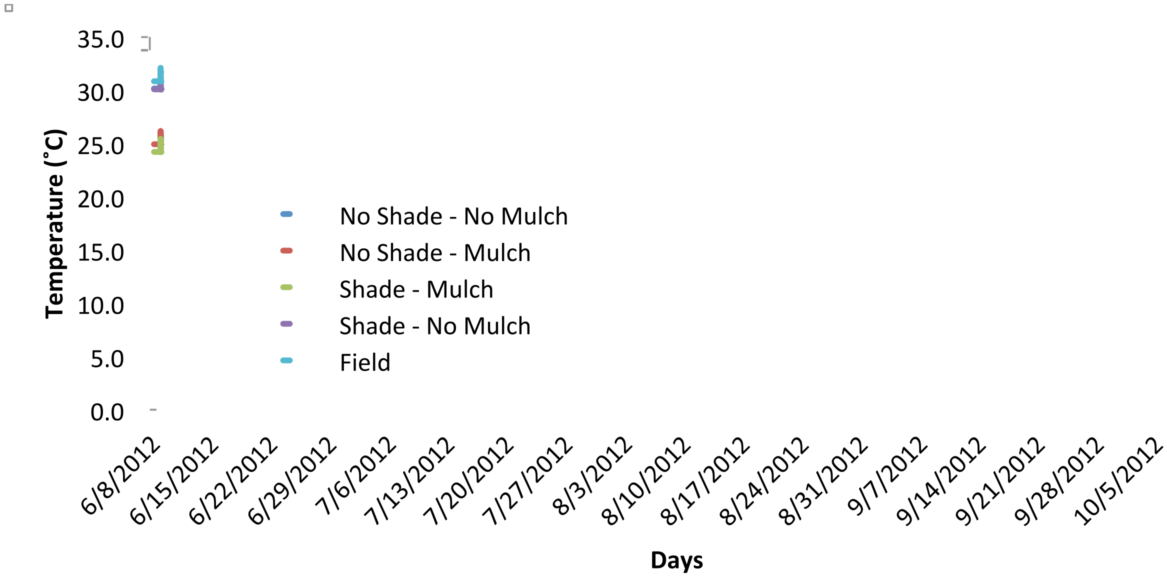

Figure 2: Weekly temperature data with WatchDog™ data sensors placed at a 4" soil depth under main and sub-plot treatments. Temperatures were logged at 30 minute intervals and daily averages were mapped.

This is the first year, out of two, that this research is being conducted. Due to the immaturity of the canes and the extreme warm climatic conditions of the environment, little significant difference was shown between main and sub-plot treatments in relation to the growth and development of the raspberry canes from treatment effects (shade cloth and mulching). Increased average cane height of ~30 cm was observed with the application of mulch compared to bare soil, but an additional growing season is needed to determine if this observation will continue. In addition, the covering of shade with soil mulch provided ~28 additional centimeters of cane height, though, the differences were not statistically significant (Table 1).

Table 1: Effect of shade cloth on light intensity and shade cloth and switchgrass mulch on fruiting and growth characteristics.

		Growth and Development Characteristics[1]				Yield[1]			Light Intensity
Treatments		Cane height (cm)	No. of leaves	Leaf area	No. of laterals	No. of berries	Ave. weight (gms.)	Total yield (gms)	$\mu mol \cdot m^{-2}s^{-1}$
Shade									1302.88a
	No Mulch	106.13	109.13	2877.80	31.53	433.33	2.69a	1164.17	
	Mulch	158.23	198.20	4979.70	94.47	370.00	2.27b	945.61	
No Shade									655.14b
	No Mulch	111.07	151.53	3262.23	67.13	503.33	2.71a	1348.86	
	Mulch	129.70	192.33	3905.53	47.80	577.00	2.55a	1481.66	
		Ns	Ns	Ns	Ns	Ns		Ns	

[1]Means separation, Tukey adjustment P≤.05

[Ns] Nonsignificant

Poor canopy development, including the number of laterals produced, number of leaves, and leaf area, was observed more visually noticeable in the non-mulch treatments, although no significant difference was observed. This is likely due to high light intensity and air and soil temperatures that occurred 2-3 weeks after planting, resulting in leaf scorch and decreased growth rate. In contrast, while increased development was observed in the mulch treatments, the 33% shade cloth significantly reduced average berry weight under soil mulch.

The time of the year and climatic conditions of the environment also had an impact on the level of light transferred through the plastic covering. As shown in Fig. 3 and Table 1, 33% shade cloth significantly reduced the light intensity level of the tunnel environments, with maximum readings recorded on summer solstice, June 21. While the light intensity readings were well above the optimum levels of $600 \mu mol \cdot m^{-2}s^{-1}$ throughout the growing season, the 33% shade cloth was able to achieve an optimum level as early as August 22; reducing potential light intensity levels by nearly 50%. Furthermore, while cane growth and developmental characteristics were not significantly different between treatments, an increase rate of growth and decreased leaf scorch was observed after August 22, on canes under shade cloth.

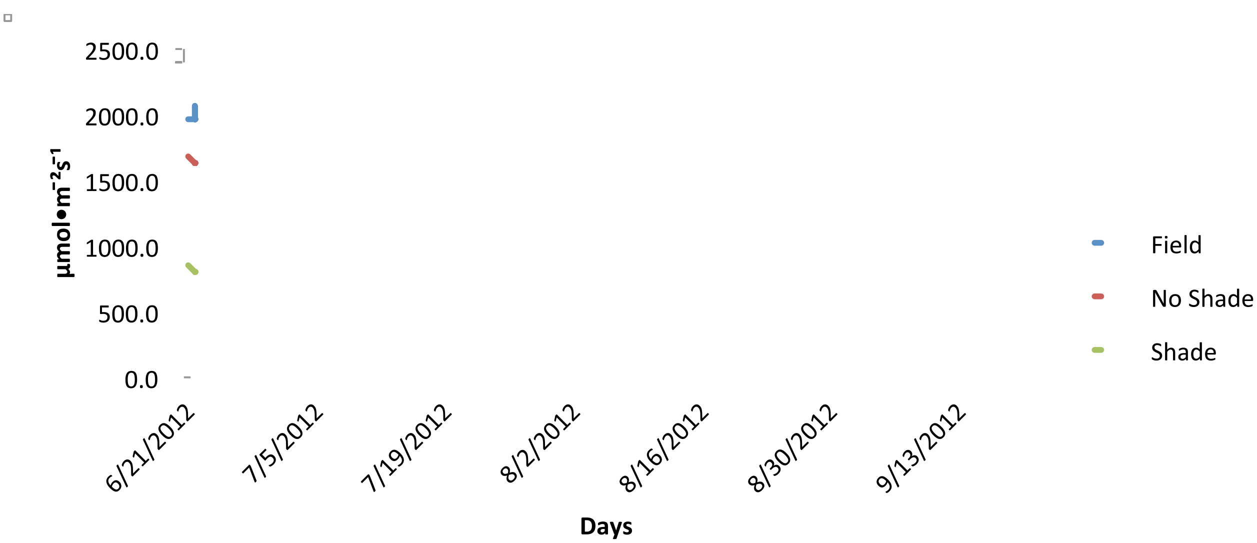

Figure 3: Weekly light intensity readings under field light conditions and tunnel main-plot treatment of 33% shade and no shade.

Discussion

Our first-year results show that 33% shade cloth adequately reduced light intensity of the tunnel environment to achieve a 50% level reduction. However, because of the climatic extremes of the 2012 growing season, reduced light intensity showed no effect on reducing tunnel air and soil temperature. Furthermore, because air and soil temperatures exceeded 24°C and 16°C, respectively, for extended periods of the summer, no potential increase of primocane growth and development was shown due to the shade and mulch treatments.

The only significant difference found among treatments was that of reduced average berry weight under the full main and sub-plot treatments of shade and soil mulch. An assumption here is that due to lower soil temperatures and higher moisture concentration the soil remained saturated for extended periods of time, restricting air availability to the roots and potentially declining the health of the plants. However, these data are from newly planted dormant crowns and not fully developed plant canopies.

As previously stated, this is the first year that this research is being conducted. Perennial, primocane red raspberry plants require more than one year for establishment; therefore, treatment effects on growth and development were not expected. In addition, while 50% light reduction was achieved under the shade cloth treatments, we were unable to assess the relationship reduced light intensity has on temperature and the potential effects projected on cane growth and development. Data from 2013 will provide a more accurate projection of cane growth and development due to an increase in plant crown maturity as well as provide additional information under a different climatic growing season.

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Appendix Figure 1.
One of three replicated tunnels showing shade cloth and switchgrass soil mulch treatments; Iowa State University

Appendix Figure 2.
Leah Riesselman measuring light intensity at noon in full sun in the raspberry plant canopy; Iowa State University Horticulture Station.