The Effects of Temperature and Light in High Tunnel Primocane Red Raspberry Production–Year 2

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Introduction

Climatic factors found in tunnels of the Midwest may show negative effects to primocane growth and development of raspberry. Researchers have found that as air- and root-zone temperature exceed 24°C (75.2°F) and 16°C (60.8°F), respectively, the following plant development occurs: decrease in water uptake by primocanes, premature dormancy of lateral and axillary buds, delayed time to fruit ripening, and reduced fruit quality and weight. In addition to temperature, high light (irradiance) causes a decline of fruit yield and quality. Premature dormancy and delayed time-to-flowering occur when irradiance exceed 600 $\mu mol \cdot m^{-2} s^{-1}$. The proposed study was intended to (1) assess the relationship between temperature and light intensity and their effect on primocane growth and development, (2) evaluate how effective shade cloth 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 conducted at the Horticulture Research Station, Ames, Iowa, under three identical 11.0 m (36 ft)-long by 4.3 m (14 ft)-wide tunnels in a randomized complete block with a split-plot arrangement of treatments. Dormant, one-year-old canes of primocane red raspberry Autumn Britten were planted on April 18, 2012 in raised beds. Canes were spaced 46 cm apart within rows and 120 cm between rows. Raspberry canes were trained on a temporary T-trellis, with twine located at heights of 90 and 180 cm. Plants were watered and fertilized by trickle irrigation at recommended rates.

Before treatment application, tunnel polyethylene-plastic covering exhibited a 17 percent irradiance reduction as measured with a quantum sensor (LI-190) data logger (LI-1400). White shade cloth that provided 33 percent shade factor was installed on June 3, 2013 as the main-plot treatment, resulting in the 50 percent target reduction of irradiance from plain tunnel-plastic covering (50% shade). Sub-plot treatment of switchgrass mulch (plus mulch) was applied to a depth of 15.2 cm under main-plot treatment on the soil surface. Irradiance was measured weekly, at noon, at plant canopy heights of 30 and 90 cm using an LI-191 line quantum sensor. Irradiance also was measured at three randomly selected locations under the shade cloth treatments using an LI-190 quantum sensor, and LI-1400 data logger. Shade cloth was removed on September 30, when irradiance decreased below 600 $\mu mol \cdot m^{-2} \cdot s^{-1}$.

Air- and root-zone temperatures were recorded under main and sub-plot treatments at the primocane shoot apex and a root-zone depth of 10.2 cm with WatchDog™ B-Series Temperature Loggers. Temperature was recorded at 60-min intervals and was averaged over every 24-hr period. Data on total cane height, leaf number, and number of vegetative laterals were collected at the end of the harvest period from six randomly selected canes from each treatment. Fruiting laterals per cane, length of flowering laterals, and fruit number per cane also were recorded. Berries were harvested every 2 to 4 days, and total weight, fruit yield, and average fresh and dry weight of berries were recorded. Mean fresh and dry berry weight was calculated from the average of 10 fresh and dried berries from each treatment over the harvest period. Leaf area per cane was quantified with a Li-Cor LI-3100C Area Meter. Flower bud development data were taken throughout the 2013 growing season on three randomly selected canes in each treatment. Julian dates of bud primordia initiation, bud break, petal fall, and first harvest were recorded. Data were subjected to analysis of variance and least square means were separated at $P \leq 0.05$.

Results and Discussion

Open-field irradiance ranged from 1340 $\mu mol \cdot m^{-2} \cdot s^{-1}$ on September 24, 2013, to 1990 $\mu mol \cdot m^{-2} \cdot s^{-1}$ on June 3; whereas in tunnels with 6-ml woven polyethylene-plastic, tunnel irradiance was 1285 $\mu mol \cdot m^{-2} \cdot s^{-1}$ on September 4 to 1574 $\mu mol \cdot m^{-2} \cdot s^{-1}$ on July 3. Seasonal reduction of irradiance averaged 58.6 percent under the combination of 33 percent shade cloth and plastic covering of the tunnel (17%) during 2012 and 2013.

Maximum root-zone temperature occurred on August 28, 2013 under all treatments (Figure 1). Compared with tunnel plastic alone, maximum root-zone temperature was reduced by 3.7 and 4.9°C in the presence of tunnel plus soil mulch and 33 percent shade cloth plus mulch. Mean reduction of root-zone temperature of 3.5°C was found in presence of soil mulch. Optimum mean root-zone temperature was best achieved with 33 percent shade cloth plus soil mulch, showing a 1.3°C decrease compared with soil mulch alone. Root-zone temperatures were higher in the tunnels than the open-field nearby when mulch was not used. Shade cloth plus mulch showed the greatest potential in reducing temperature at root-zone depth.

Preliminary analysis showed no effect on timing of bud development with main and sub-plot treatments of 50 percent shade and soil mulch. The use of 50 percent shade was associated with increased average fresh and dry berry weight (Table 1). The increase of average flower lateral length per cane (data not shown) also was associated with the presence of shade. Contrary to year one's findings, berry quality and fruiting lateral growth were influenced more by irradiance reduction than by reduced air or root-zone temperature. In addition, 50 percent shade showed the highest increase in plant canopy cover early in the season (data not shown) and provided a more constant rate of plant seasonal growth. Preliminary results indicated that although no effect was shown with the number of fruiting laterals produced per cane, an increase in blind-buds may be associated with increased flower lateral length and decreased irradiance.

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Table 1. Fruiting characteristics of primocane red raspberry Autumn Britten produced in high tunnels. Means represent pooled data from three high tunnels (replications) across main and sub-plot treatments of 50 percent shade, 50 percent shade plus mulch, tunnel plastic, and tunnel plastic plus mulch.

Treatment	Berry yield (g)[z]	Berry number[z]	Fresh berry weight (g)[y]	Dry berry weight (g)[y]
Tunnel alone (17% shade)				
No mulch	22901.9 ab	8673 a	2.7 b	.37 a
Plus mulch	25657.1 a	9836 a	2.6 b	.36 a
Tunnel (17% + 33% shade)				
No mulch	22185.9 ab	8148 a	2.9 a	.39 a
Plus mulch	19458.2 b	6800 a	2.8 b	.38 a

[z]Means followed by the same letter within rows are not different from one another ($P \leq 0.05$).
[y]Fresh and dry weights are averaged from the weight of ten berries.

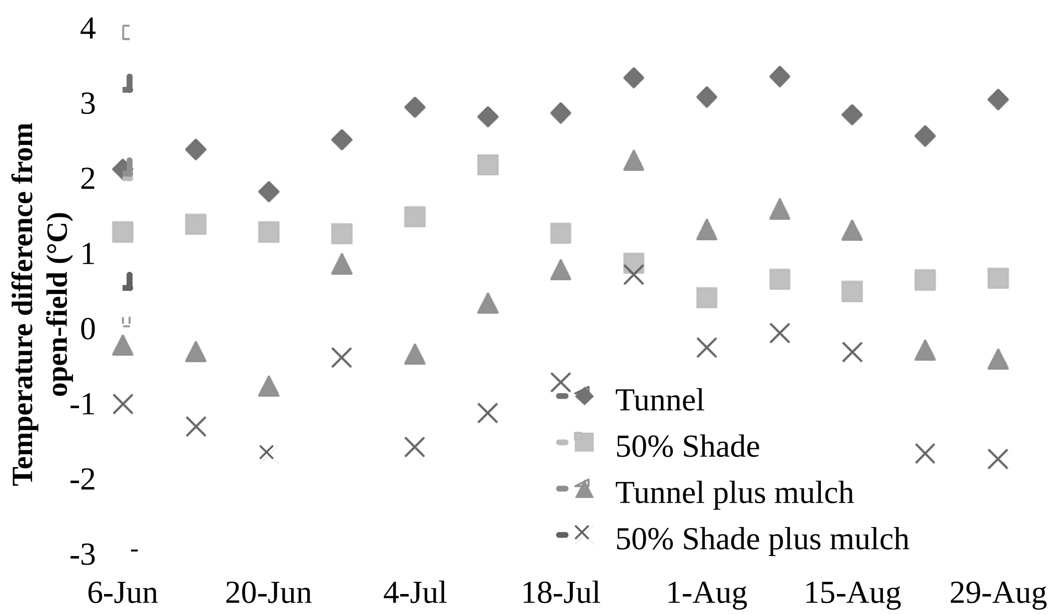

Figure 1. Main and sub-plot treatment effects from 50 percent shade and switchgrass soil mulch (plus mulch) on mean root-zone temperature differences from open-field, at a depth of 10.2 cm. Daily temperature means represent pooled data from three high tunnel replications compared with open-field production. Temperature was recorded at 60-minute intervals and averaged over a 24-hr period.

Key: Tunnel=17 percent shade from tunnel covering and no soil mulch; 50 percent shade=33 percent shade cloth + 17 percent shade from tunnel covering and no soil mulch; tunnel plus mulch=17 percent shade from tunnel covering and soil mulch; 50 percent shade plus mulch=33 percent shade cloth + 17 percent shade from tunnel covering and soil mulch.