Photosynthetically Active Radiation and Root-zone Temperature Effects on High Tunnel Primocane Red Raspberry Development

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Introduction

Climatic conditions found in high tunnels of the Upper Midwest have shown adverse effects to primocane red raspberry growth and development. Photosynthetically active radiation (PAR) greater than 600 $\mu mol \cdot m^{-2}s^{-1}$ has been found to decrease shoot growth, fruit quality and yield, and contribute to the onset of premature bud dormancy. Researchers also found as air- and root-zone temperatures exceed 75°F and 60°F, respectively, reduced yield, berry weight, and berry quality may result. The proposed study was intended to conclude results taken from 2012 and 2013, with an additional year of data taken on fully established canes in 2014. Our objectives were to 1) assess the relationship between PAR and temperature and their effect on primocane development, and 2) evaluate the efficacy of shade cloth and soil mulch in reducing PAR and root-zone temperature during high tunnel primocane red raspberry production.

Materials and Methods

We conducted our study at the Horticulture Research Station, Ames, Iowa. Dormant, one-year old canes of Autumn Britten were planted in raised beds on April 18, 2012 under three identical 36 × 14 ft tunnel structures. Canes were spaced 18 in. apart within rows and 48 in. between rows. Raspberry canes were trained on a temporary T-trellis, with twine located at heights of 35 and 70 in. Throughout the growing season, plants were watered and fertilized by trickle irrigation at recommended rates.

Prior to treatment application, the 6-ml tunnel polyethylene-plastic covering exhibited a 17 percent PAR reduction as measured with a quantum sensor (LI-90) data logger (LI-1400). A split-plot, randomized complete block design was used. Whole plot treatment of 33 percent shade cloth was assigned randomly to the three replicated tunnels, creating a block effect of either tunnel plastic covering alone (17% shade) or 33% shade cloth with plastic covering (17% +33% shade cloth). A sub-plot treatment of *Panicum virgatum* L. (switchgrass) mulch was applied to the soil surface at a 6-in. depth.

White shade cloth that provided 33 percent shade factor (Hummert International, Springfield, MO) was installed June 2 and removed September 30, when PAR exceeded and decreased below 600 $\mu mol \cdot m^{-2}s^{-1}$, respectively. Temperature at a root-zone depth of 4 in. was recorded at 60-minute intervals and averaged over every 24-hr period with Watchdog™ B-Series Temperature Loggers (Spectrum Technologies, Plainfield, IL).

Cane growth development including total cane height, leaf number, vegetative and flowering lateral count, flowering lateral length, and fruit number per cane were recorded, but were not subject to analysis for this report. Berries were harvested every two to four days, and total weight, fruit yield, and average fresh and dry berry weights were recorded in a 20 ft long row. Mean fresh and dry berry weight were calculated from the average of 10 fresh and dried berries of each treatment over the harvest period. Data were subjected to

analysis of variance, and means were separated at $P \leq 0.05$ using Fisher's protected least significance difference test. A Type III test of fixed effects was performed using Satterthwaite approximation of standard errors.

Results and Discussion

The 2014 growing season was another year of climate extremes for high tunnel production in Iowa. April was the 14th wettest on record in the state. Increased precipitation caused submergence of canes during a three-week period until a tile system was installed. Delayed cane growth and bud initiation resulted. Average temperatures from April to June and August fell within normal climatological rankings of the state, with the exception of July ranking as the third coolest. In addition, as average monthly air temperatures ranked the 18th coolest from September through November, root-zone temperatures also were reduced across treatments, with increased reduction from soil mulch (data not shown). Premature bud dormancy and early termination of berry harvest resulted. Although the target 50 percent PAR reduction decreased root-zone temperature with shade cloth alone, the use of soil mulch was more beneficial in reducing root-zone temperature extremes of the high tunnel environment. Root-zone temperatures from shade cloth alone (tunnel and 33% shade cloth no mulch) and tunnel (17%) plus soil mulch were most similar to the field (data not shown).

Consistent with 2012 and 2013 findings, mulching increased berry yield and number when shade cloth was not used (Table 1). In the presence of shade cloth, treatments with soil mulch had greater berry yield and number, contradicting results found in 2012 and 2013. Although berry yield and number favored root-zone temperatures most similar to field conditions in the first two years of the experiment, increased root-zone temperatures from the absence of shade cloth increased yield and berry number in the first full production year (year 3). Reduced root-zone temperatures from soil mulch decreased berry yield and number due to seasonal climatic years at the beginning and end of the 2014 season. Overall yield, berry number, and fresh berry weight of high tunnel primocane red raspberry Autumn Britten has shown numerous benefits to decreased PAR from the field, but all parameters were decreased due to reduced PAR from shade cloth in a tunnel environment.

No differences of dry berry weight were found between tunnel treatments in all three years of the experiment. This study concludes that natural PAR and increased root-zone temperature conditions are favorable to the overall production potential of primocane red raspberry cultivars bred for the field and grown in high tunnel environments.

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Table 1. Average yield and berry number from 22 canes or 15-ft length row, and average fresh and dry berry weights of high tunnel primocane red raspberry Autumn Britten, produced in 2014. Data represents means of three pooled high tunnels across whole plot treatments of tunnel and shade cloth and split-plot treatments of with and without soil mulch.

Treatment	Yield (lb)	Berry number	Fresh weight (g)[z]	Dry weight (g)[z]
Tunnel (17%)[y]				
No mulch	7,255.3[x] b	2,679 b	31.0 a	4.14 a
Plus mulch	9,280.6 a	3,230 a	30.7 b	4.07 a
Tunnel (+33% shade cloth)				
No mulch	4,903.0 d	1,853 d	27.1 c	4.13 a
Plus mulch	6,242.0 c	2,227 c	30.6 b	4.17 a

[z]Fresh and dry berry weight taken from an average of 10 berries.
[y]Tunnel alone provided 17 percent PAR reduction, and tunnel and shade cloth provided 50 percent (17% from tunnel and 33% from shade cloth) PAR reduction.
[x]Analysis of variance using PROC MIXED multi-treatment comparisons with Fisher's protected least significance difference. Means followed by the same letter within columns are not different from one another ($P \leq 0.05$).