HortScience 22(3):396–397. 1987.

Solar Injury of Raspberry Fruit

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Additional index words. sunscald, fruit temperature, *Rubus idaeus*

Abstract. **Red raspberry (*Rubus idaeus* L.) is prone to a "white drupelet" disorder on the sun-exposed side of the fruit, largely during those harvest periods when daytime temperatures exceed about 33°C. In mid-August, more than 40% of the fruit were affected. Three types of shade covers (30% and 60% black shade fabric and 25% shade white polyester), placed over raspberry plots for 1 to 3 weeks prior to fruit harvest, reduced the amount of solar-injured fruit from 41% in unshaded plots to between 8% and 16%. Fruit surface temperature was reduced about 4° by both black shade fabrics, but only 1° by the polyester cover. Fans cooled fruit by about 2°, but the reduction in solar injury was less than with shade covers.**

Red raspberries grown in western Colorado at elevations of ≈1400 m with little or no cloud cover and daytime temperatures often above 33°C during ripening are prone to apparent solar injury or sunscald. Symptoms usually involve one to 12 drupelets on the sun-exposed side of the fruit. These drupelets enlarge but fail to develop red pigment and remain white. Fruit so affected is not acceptable for fresh market and, at times cullage may be more than 30%. Similar problems have been noted in other regions, including California and New Mexico (J. Scurich and D. Solomon, personal communications). The disorder also has been reported in southeastern Australia (H.A. Daubeny, personal communication). Insects or pathogens have not been found to be associated with the condition.

Solar injury could be due to elevated temperature on the exposed side of the fruit (2) or to ultraviolet (UV) radiation as noted in other crops (1, 3, 4). Mitigation of injury by UV-B attenuation with filters (3, 4), shading through plant canopy manipulation (2), or promoting air movement with cultural practices (2) have been effective in various crops.

Because of the increasing importance and high value of fresh-market raspberries, this disorder has a large economic impact in affected production areas. Thus, the present study was designed to characterize the disorder and to investigate the effectiveness of shade and forced air in reducing it.

The test plots were assigned within a nontrellised 1-year-old planting of 'Heritage' red raspberry. This cultivar is typical in the extent of this disorder. Standard cultural practices were used. Drip irrigation was applied three times per week, at a rate equal to Class A Pan evaporation. The season total of irrigation plus rainfall equalled 154 cm.

In Expt. 1, the six shade treatments listed in Table 1 were replicated four times in a randomized complete block design. Since the time of solar injury was unknown, the Sarlon shade covers were applied during early fruit development (3 weeks prior to ripening, labeled Early), or only during the final few days (labeled Late). Each plot was covered by a 1.8-m-wide shade fabric suspended on a wire over the top and sides of a section of row. Within each plot, 10 canes with developing fruit at the top of the canopy but within the area shaded by each cover were labeled. Individual canes and berries unavoidably differed somewhat in exposure to the sun, so some variability was inherent in the design. Fruit were harvested three times per week from the flagged canes in each plot. The berries were counted and the data converted to percentage of berries with solar injury. All shade covers were removed on 23 Aug. and solar injury was measured on 26 Aug.

In Expt. 2, the two treatments, Fan and No Fan, were replicated four times in a randomized complete block design. A 55-cm box fan with 48-cm 5-blade propeller (0.10 HP) was used to move air past each Fan plot. The small area influenced limited the plot size to two labeled canes. Solar injury data were expressed as in the first experiment. The fans were 125 to 135 cm from the ripening berries and the fan-induced windspeed near the fruit was 2.1 ± 0.35 $\mathrm{m \cdot s^{-1}}$ under calm conditions. Windspeed was measured with a hand-held generator anemometer connected to a voltmeter. The fans were operated from 1200 to 1800 HR on 26 Aug. and then daily through 1 Sept. from 0900 to 1800 HR. During these 6.5 days, about 1.5 days were cloudy and 21 daytime hours were breezy (average windspeed = 2.3 $\mathrm{m \cdot s^{-1}}$). The remaining 39 hr had an average windspeed of 1.2 $\mathrm{m \cdot s^{-1}}$ and included many calm hours. Fruit were harvested three times, 30 Aug. and 2 and 4 Sept. The weather was cloudy, rainy, and much cooler for 3 days prior to the final harvest.

Fruit temperatures were measured with 30-gauge copper–constantan thermocouples, using an Omnidata Polycorder datalogger. In Expt. 1, thermojunctions were placed in the upper surface of two exposed berries under each cover type: Reemay 25% (R), Sarlon 30% (S-30), Sarlon 60% (S-60), and nonshaded (N). A sheltered sensor also recorded ambient air temperature (A) within the canopy. Sensors were located on fruit from 90 to 120 cm aboveground, and fruit temperature was recorded every 2 min during selected times. A separate test confirmed that the temperature in the mesocarp just under the epidermis (used in this study) was slightly but not significantly lower than that on the surface measured with an appressed thermojunction. In Expt. 2, sensors recorded temperatures of fruit and of air near fruit within the zone influenced by a fan, as well as berries in an adjacent row without a fan. On 23 Aug., the fan was operated on cycles of 6 min on and 6 off to compare temperatures of a given fruit. Only the last 4 min of each half-cycle were used to calculate averages.

Expt. 1 characterized the effect of shade covers on solar injury. Due to the inherent variability in orientation and position of berries within the canopy, data were averaged (Table 1). Each value is the mean of four replicate plots on a given date, with the overall mean based on three replicates in time

Table 1. Percentage of raspberry fruit with solar injury in response to shading treatments and timing. Among Sarlon treatments, late shading refers to the period just prior to fruit ripening, while early shading includes the period in which the bulk of fruit enlargement occurs.

Treatment	Date applied	Percent fruit with solar injury			
		19 Aug.	21 Aug.	23 Aug.	Overall Mean
Nonshaded check	- - -	42^{y}	45	35	41 a^{x}
Sarlon					
30% shade (early)	1 Aug.^{z}	13	10	13	12 b
60% shade (early)	25 July	9	11	9	10 b
30% shade (late)	14 Aug.	16	17	13	15 b
60% shade (late)	14 Aug.	4	17	4	8 b
DuPont Reemay					
25% shade (late)	14 Aug.	17	22	8	16 b

^{z}The 30% shade fabric was applied later than the 60% cover due to a shipping delay.

^{y}Each value is the mean of four replicate plots. The overall means are derived by using the values from the three dates as replicates in time.

^{x}Means separated by Duncan's multiple range test, $P = 1\%$.

Received for publication 22 Sept. 1986. Funding was provided by Colorado Agricultural Experiment Station (Projects 6041 and 138). Technical assistance from Nancy Dutcher is gratefully acknowledged. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

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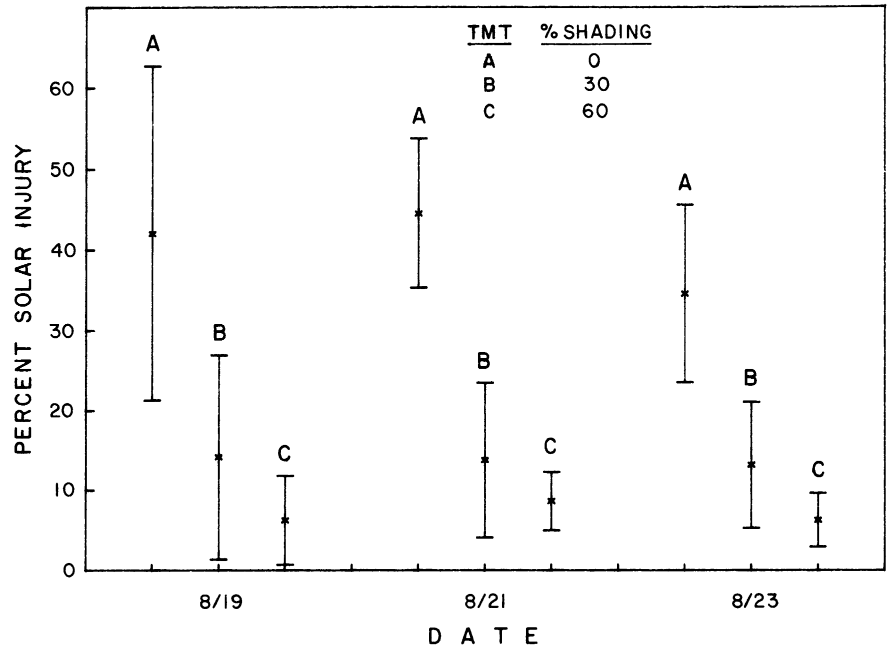

Fig. 1. Effect of Sarlon shade covers on raspberry solar injury (% fruit affected). The bars are 95% confidence intervals from an x-y plot. Each bar is labeled by treatment (i.e., 0%, 30%, or 60% shade).

Table 2. Raspberry fruit surface heating relative to air temperature ranging from 31.8° to 37.4°C during the 3.5-hr measurement period.

Treatment	Average temp difference^z (fruit surface minus air, °C)
Nonshaded	7.3
Reemay 25%	6.1
Sarlon 30%	3.2
Sarlon 60%	3.0

^{z}Average of 103 two-minute intervals starting at 1306 HR MST on 22 Aug. 1985.

during the week of 19–23 Aug. 1985. All five shade treatments had significantly fewer solar-injured fruit than the nonshaded checks (Table 1). The early shaded treatments were no better than the late shaded, indicating that the injury occurs during the final few days prior to harvest ripeness. This conclusion was strengthened by solar injury data on 26 Aug., 3 days after shade covers were removed. All previously shaded plots had rapidly developed solar injury of fruit and were not significantly different than the nonshaded treatment (44%).

To quantify the effect of shading on reducing solar injury, the data from the two S-30 treatments were pooled, as were those from the two S-60 treatments, and compared to the N treatment. An X-Y plot with 95% confidence intervals (Fig. 1) shows the consistent tendency for reduced solar injury on each of three dates with 60% shade compared to 30% shade and nonshaded. The bulk of the difference occurred between nonshaded and 30% shade. The Reemay white polyester covers (25% shade) were also reasonably effective at reducing solar injury and were much lower in cost than the Sarlon shade fabric. However, Reemay tended to be torn by raspberry thorns.

Table 3. Influence of air movement on percent raspberry fruit with solar injury.

	Percent solar injury			
Treatment	30 Aug.	2 Sept.	4 Sept.	Mean
Fan^z	26^y	38	5	23 a^x
No fan	48	53	26	42 b

^{z}Fan running during daytime from 26 Aug. to 1 Sept.

^{y}Each value is the mean of four replicate plots on that date.

^{x}Mean separation at the 5% level by paried *t* test.

Fruit surface temperature reduction is one mode by which shade covers may reduce solar injury. Upper fruit surface temperature was recorded on a clear, calm day (22 Aug.). Table 2 shows that surface temperature of unshaded berries averaged 7.3°C above air temperature. Similar large temperature gradients have been noted with apples (5). Sarlon shade fabric reduced this heating effect by over 4° with either 30% or 60% shade. Dupont Reemay lowered temperature by only about 1°, although solar injury of fruit was significantly reduced.

The use of fans in Expt. 2 presumably could reduce only the temperature component of solar injury. Due to small plot size plus those causes of variability already cited in the shade cover experiment, a summary approach was also taken with these data. Fans reduced solar injury to fruit, even though the magnitude of the response was not large (Table 3). The cool, wet weather prior to the 4 Sept. harvest was the likely cause of reduced injury in both treatments on that date. The relatively greater decline with fans could have been due to evaporative cooling of the wet fruit.

Table 4. The extent of fruit surface heating relative to air temperature during seven on/off fan cycles, each a total of 12-min long.

	Fruit temp minus air temp (°C)	
Cycle	Fan off	Fan on
1	2.3^z	1.6
2	2.7	1.4
3	2.5	1.0
4	3.1	0.3
5	2.4	1.5
6	2.4	0.8
7	2.1	1.1
Mean	2.5	1.1

^{z}Each value is the mean of the last 4 one-minute temperature differences per half-cycle.

A fan reduced fruit temperature on 23 Aug. 1985, during Expt. 1 (Table 4). A berry in an adjacent row with no fan was warmer than ambient by an average of 3.2°C during this same time period. The cooling effect of the fans during calm afternoons may have been greater than that of the Reemay shade cover at such times, but probably less than with Sarlon shade cloth. However, protection agaisnt solar injury with fans was less than with either shade cover.

There is strong evidence that the white drupelet disorder is caused by solar injury. It can affect more than 40% of the fruit in the early part of the harvest period. A summer crop of 'Heritage' would be even more prone to injury. High fruit temperature on the exposed surface is a probable factor, but is not the sole cause of injury. Work with UV irradiation of detached berries suggests that UV is not the sole cause either, but injury does occur with a combination of high temperature and UV light (unpublished data). Air movement to lower fruit temperature does reduce injury, but not as much as shade covers. A large reduction in solar injury can be achieved with 25–30% shade. The cost of shading would need to be justified by savings from the labor required to sort fruit plus the large difference in value between fresh-market raspberries and those used for processing, a use for which solar-injured fruit has proven to be acceptable.

Literature Cited

1. Beckwar, M.R., F.D. Moore, III, and M.J. Burke. 1982. Effects of deletion and enhancement of ultraviolet-B (280-315 nm) radiation on plants grown at 3000 m elevation. J. Amer. Soc. Hort. Sci. 107:771–774.
2. Bergh, O., J. Franken, E.J. Vanzyl, F. Kloppers, and A. Dempers. 1980. Sunburn on apples. Decid. Fruit Grower 30:8–22.
3. Kossuth, S.V. and R.H. Biggs. 1978. Sunburned blueberries. Proc. Fla. State Hort. Soc. 9:173–175.
4. Lipton, W.J. 1977. Ultraviolet radiation as a factor in solar injury and vein tract browning of cantaloupes. J. Amer. Soc. Hort. Sci. 102:32–36.
5. Rogoyski, M.K. 1985. Physical and horticultural aspects of heat transfer characteristics in apple fruit. HortScience 20:583. (Abstr.)