Effects of Sunburn Treatments on Honeycrisp in the Hudson Valley in 2015

Gemma Reig[1], Peter Jentsch[2], David Rosenberger[3]
[1]Horticulture Section, School of Integrative Plant Science, Hudson Valley Research Laboratory, Cornell University, Highland, NY
[2]Department of Entomology, Hudson Valley Research Laboratory, Cornell University, Highland, NY
[3]Plant Pathology and Plant-Microbe Biology Section, School of Integrative Plant Science, Hudson Valley Research Laboratory, Cornell University, Highland, NY

This research was partially supported by the New York Apple Research and Development Program

Appearance is a major factor in determining apple marketability. Anything that adversely affects fruit appearance, including sunburn (apple fruit discoloration caused by heat-related stress), reduces economic viability of the crop (Felicetti and Schrader 2009). Sunburned areas cause fruit to be either culled or downgraded on the packing line. With some high-value cultivars like Honeycrisp, which sell for $50 to $100 per packed box, any fruit that are damaged and unmarketable represent significant losses to the grower.

> "Over the past five years, sunburn has been an issue in the production of Honeycrisp high-density orchards in New York, particularly in the Hudson Valley. Considering that the climate is warming and that high-density plantings are allowing more exposure of fruit to sunlight, sunburn could be an increasing concern."

Sunburn is a physiological disorder of apples and other fruits caused by excessive solar radiation and high air temperature during the ripening period. Other factors that play a role in the formation of sunburn include cool or mild weather abruptly followed by heat and direct sun, trees suffering from water stress, cultivar susceptibility, developmental stage of the fruit due to effects on flesh elasticity and its capacity to adapt, cultivar growing habits, and rootstock. Position of fruit on tree, number of fruit per cluster, competition for assimilates, row orientation in the orchard, and sudden exposure of fruit from a low-light environment to high irradiance and low humidity can also contribute to its development (Racksó and Schrader 2012).

Three types of sunburn in apples have been identified and characterized (Racskó and Schrader 2012): sunburn necrosis (Figure 1), sunburn browning (Figure 2) and photooxidative sunburn (Figure 3). Sunburn necrosis occurs when the apple fruit surface temperature (FST) approaches 126°F for approximately 10 minutes. A dark brown or black necrotic spot appears on the exposed surface within 1–4 days after exposure to such temperatures and cells in the necrotic spot often collapse (Racskó and Schrader 2012). Sunburn browning, the second type of sunburn injury, occurs on attached sun-exposed apples when high solar radiation raises the apples' FST above a certain threshold temperature, which varies within cultivar. For Cameo and Honeycrisp the threshold FST is near 115°F; for Pink Lady it is close to 129°F under Washington State conditions. When sunlight is excluded from attached apples that were heated to the threshold FST, sunburn browning does not occur (Schrader 2011). In other parts of the world where ultraviolet radiation is different, it is conceivable that the minimum FST for induction of sunburn may be different than in Washington State. The last sunburn type, photooxidative sunburn, can develop at FST below 88°F (air temperature below 65°F) and can be detected within 24 hours of irradiation. The first symptom is a white spot that appears on previously shade-grown (non-acclimated) apples that are abruptly exposed to full sunlight. With continued exposure

Figure 1. Sunburn necrosis.

Figure 2. Sunburn browning.

Figure 3. Photooxidative sunburn.

to full sunlight, the center of the photobleached area often turns brown and cells become necrotic (Racskó and Schrader 2012).

Over the past five years, sunburn has been an issue in the production of Honeycrisp high-density orchards in New York, particularly in the Hudson Valley. In 2015, the incidence of sunburn in Honeycrisp in commercial orchards was 10 to 25 %, depending on the area, the number of sunburn prevention sprays that were applied, and the cultivar. Considering that the climate is warming and that high-density plantings are allowing more exposure of fruit to sunlight (Racskó and Schrader 2012), sunburn could be an increasing concern.

Different strategies are currently used around the world to avoid sunburn in apples. One strategy involves the application of sprayed sunburn suppressants. There are at least two classes of suppressants: White particle films composed of either kaolin clay, calcium carbonate, or talc; all provide a white, highly reflective cover on the fruit surface that increases reflection of solar radiation, a key aspect of reducing sunburn incidence in apples (Glenn et al. 2002). These include Surround® WP, ScreenDuo®, and others. The second class of sunburn suppressants contain organic-chemical absorbing agents in addition to physical inorganic constituents that augment the natural waxes in the cuticle and pigments in the upper epidermis of the apple. These suppressants attenuate some of the damaging ultraviolet rays and heat-producing infrared radiation and enhance the optical properties of the natural wax layer. Raynox®, among others, belongs to this group.

Two other strategies for avoiding sunburn involve changing the micro-environment of the orchard. Overhead application of water to the trees reduces heat stress when air or fruit temperature exceeds a given threshold (Iglesias et al. 2005). The ameliorative effect of this strategy manifests primarily in the reduction of FST through the evaporation of water from the fruit surface. Another strategy is the use of shade nets over the tree canopy to reduce incident sunlight on the fruit surface, thereby reducing FST (Racskó and Schrader 2012). All of these strategies have their pros and cons, but there is still no strategy or combination of strategies that will completely eliminate the incidence of sunburn on apple fruit.

There are few published reports about these techniques, especially as they apply in New York State and, especially, to the Hudson Valley, where sunburn is starting to be a problem (Schupp et al. 2002). For this reason, two trials were set up in 2015 to study the incidence and control of sunburn in Honeycrisp. The objective of the first trial was to compare Raynox®, ScreenDuo®, Decco 405, and Raynox®+Decco 405 applied late in the season for their impact on sunburn evident at harvest. Decco 405, a concentrated 33% liquid calcium chloride applied for bitter pit control, was included to determine if application of calcium ahead of heat events would result in more sunburn. The objective of the second trial was to determine how different spray timings of Raynox® late in the season would affect the incidence of sunburn at harvest.

Material and Methods

Trial 1

Treatments were evaluated in an experimental orchard planted in 2001 at the Hudson Valley Research Laboratory (Highland, New York). This orchard contained 56 plots, wherein each plot contained one Cameo tree on Bud.9 rootstock and one tree each of Royal Court and Honeycrisp on EMLA.111 rootstocks with M.9 interstems. Trees were trained to a slender spindle, spaced at 10 ft. between trees within the row and 25 ft. between rows, and grown in silt loam soil.

Fifty plots were used in this study. Half of them (25 plots) were irrigated according to the NEWA irrigation model (http://www.

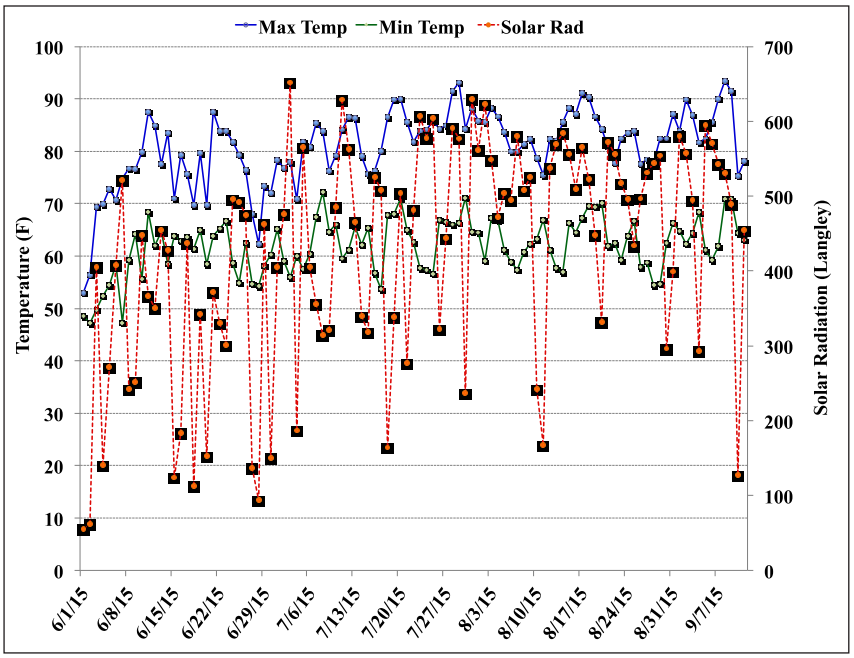

Figure 4. Daily minimum and maximum temperatures and solar radiation. Black arrows indicate the dates of treatments applications.

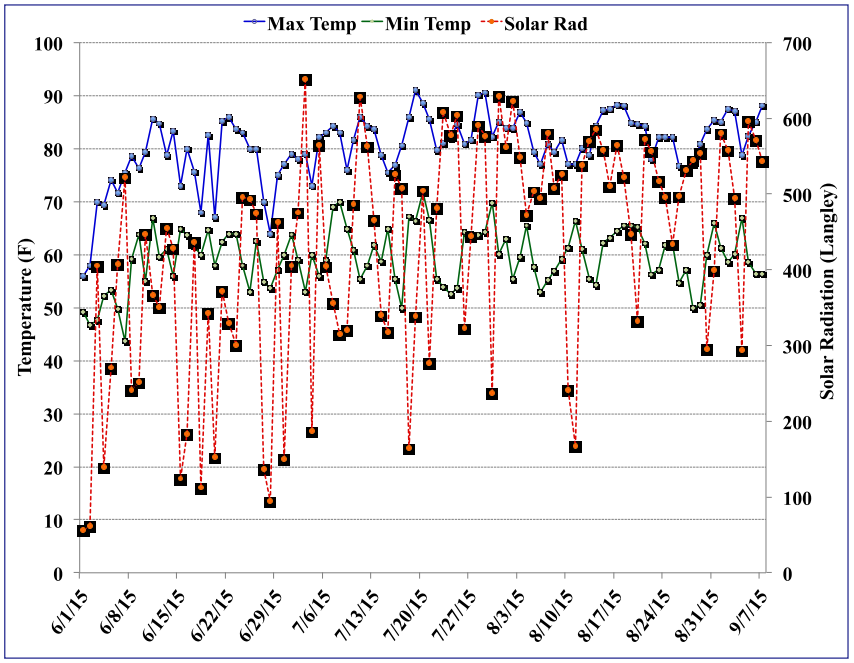

Figure 5. Daily minimum and maximum temperatures and solar radiation. Black arrows indicate the dates of treatments applications. This data is from the NEWA weather station in Modena, New York, which is the weather station closest to the farm.

newa.cornell.edu) from the end of July until the end of September, while the other half (25 plots) was not irrigated. From each block (irrigated and non-irrigated), five plots were used for each treatment (i.e. Raynox®, ScreenDuo®, Decco 405, Raynox®+Decco 405, and Control). Treatments were applied using an airblast sprayer calibrated to apply 91.2 gal. per acre on two dates (July 28 and August 14). The rates for Raynox®, ScreenDuo® and Decco 405 were 2.5 gal. in 100 gal. of water, 20 lbs in 100 gal. of water and 1 gal. in 100 gal. of water, respectively

All fruit were harvested from each tree as they matured. At each harvest, the presence or absence of sunburn was recorded for each fruit. Sunburned fruit were classified according to the three sunburn types described earlier. Total fruit sunburn was expressed as the percentage of sunburned fruit (three types included) on each tree relative to the total number of fruits on the tree. In the case of sunburn browning, its severity was also evaluated according to the following categories: Category 1, 0–10% of non-green surface area with sunburn browning; Category 2, 10.1–30% of non-green surface area with sunburn browning; and Category 3, greater than 30% of non-green surface area with sunburn browning.

After sunburn evaluations at harvest were completed, a random sample of five non-sunburned fruit and five fruit with sunburn browning from each tree and harvest date were evaluated for flesh firmness, soluble solids content, and titratable acidity.

The maximum and minimum temperatures and solar radiation from one month after first bloom to first harvest are shown in Figure 4. The cumulative rainfall from the first bloom to first harvest was 14.52 inches. Most of the rain (10 inches) occurred between 16 May and 1 July, whereas total rainfall for July and August totaled only 1.23 and 3.34 inches, respectively.

Trial 2

Raynox® treatment was evaluated in a commercial orchard planted in 2007 at Coy Farm (Clintondale, New York) by Crist Brothers Orchard, Inc. Trees were on G.11 rootstock, trained to a tall spindle, spaced at 4 ft. between trees within the row and 14 ft. between rows, and grown in silt loam soil. One block of three rows was used for Raynox® treatments. Raynox® was applied using an airblast sprayer calibrated to apply 72 gal. per acre one time (July 28) on row one, two times (July 28 and August 12) on row two and three times (July 28, August 12, and August 28) on row three. From each row, five trees with similar crop load were selected and harvested.

At each harvest, the presence or absence of sunburn was recorded for each fruit. The severity of sunburn browning was also assessed, using the three categories described earlier.

After sunburn evaluation, harvest assessments were performed as in Trial 1 from both sides of the fruit (sun side and shade side) of five non-sunburned fruits and five fruits with sunburn browning from each tree and harvest date.

The maximum and minimum temperatures and solar radiation from 1 month after first bloom to first harvest are shown in Figure 5. The accumulative rainfall from the same period of time was 16.65 inches. Most of the rain (10.2 inches) occurred between May 16 and July 1, whereas total rainfall for July and August totaled only 1.61 and 4.69 inches, respectively.

Table 1. Yield, average fruit weight, crop load and yield efficiency (YE). The data show mean values and standard error.

Block	Treatment	Yield (lb)	Average fruit weight (g)	Crop Load (# fruit cm^{-2})	YE (lb cm^{-2})
Irrigation	Decco 405	82.4 ± 25.1	219.1 ± 28.7	3.6 ± 1.1	0.5 ± 0.1
	Control	77.1 ± 28.5	159.4 ± 22.5	4.5 ± 0.8	0.4 ± 0.1
	Raynox®	90.8 ± 34.1	206.2 ± 33.8	4.1 ± 1.3	0.5 ± 0.2
	Raynox® + Decco 405	70.8 ± 48.7	197.7 ± 23.7	3.6 ± 1.1	0.5 ± 0.1
	ScreenDuo®	74.9 ± 47.8	177.6 ± 39.5	3.8 ± 0.8	0.4 ± 0.2
	Pr≤ 0.05	**NS**	**NS**	**NS**	**NS**
No irrigation	Decco 405	73.2 ± 30.4	186.0 ± 11.7	3.4 ± 0.8	0.4 ± 0.1
	Control	100.2 ± 38.5	209.1 ± 21.3	3.6 ± 0.7	0.5 ± 0.1
	Raynox®	90.1 ± 19.6	216.7 ± 21.8	4.3 ± 1.4	0.5 ± 0.1
	Raynox® + Decco 405	78.9 ± 34.4	213.5 ± 19.1	3.6 ± 0.3	0.5 ± 0.1
	ScreenDuo®	106.5 ± 37.4	195.9 ± 18.5	4.4 ± 0.8	0.5 ± 0.1
	Pr≤ 0.05	**NS**	**NS**	**NS**	**NS**

NS, not significant.

Results and Discussion

Trial 1

Yield, average fruit weight, crop load and yield efficiency were not influenced by treatments and blocks in this study (Table 1). In addition, perhaps because the trial was set up at the end of July, no differences were found between the irrigated and non-irrigated blocks in terms of fruit size and yield (data not shown). Schupp et al. (2002) reported that weekly applications from the beginning of July to mid-August of another spray film, Surround®, had an effect on fruit weight of Honeycrisp. ScreenDuo®, which belongs the same class as Surround®, did not show this trend.

Applying ScreenDuo® and Raynox® to reduce sunburn incidence according to their labels is expensive for the growers. For this reason, we decided to make only two applications during the month and a half before harvest, the period of time when fruit have become large enough to have more heat-absorbing surface area perpendicular to the sun at any given time. The first application (July 28) was on the same day as the first heat event (T > 90°F), and the second application (August 24) was three days before the next heat event and two days after a heavy rain (1.33 inches).

Preliminary results comparing the two blocks (irrigated vs. non-irrigated) showed no significant differences in the percentage of fruit with sunburn (Figure 6), although the irrigated block had

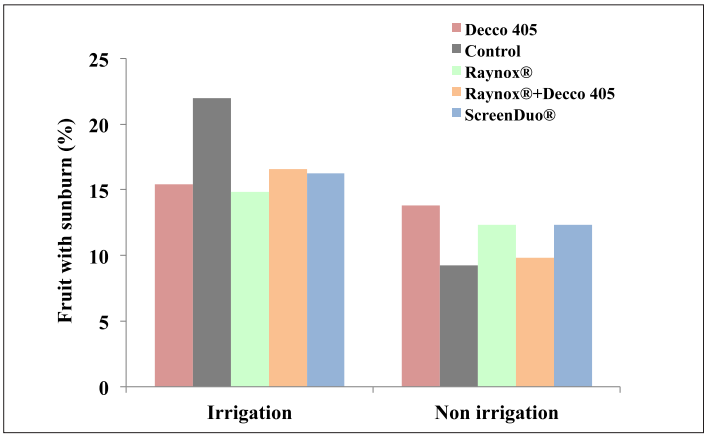

Figure 6. Total percentage of sunburn (all types) in Honeycrisp.

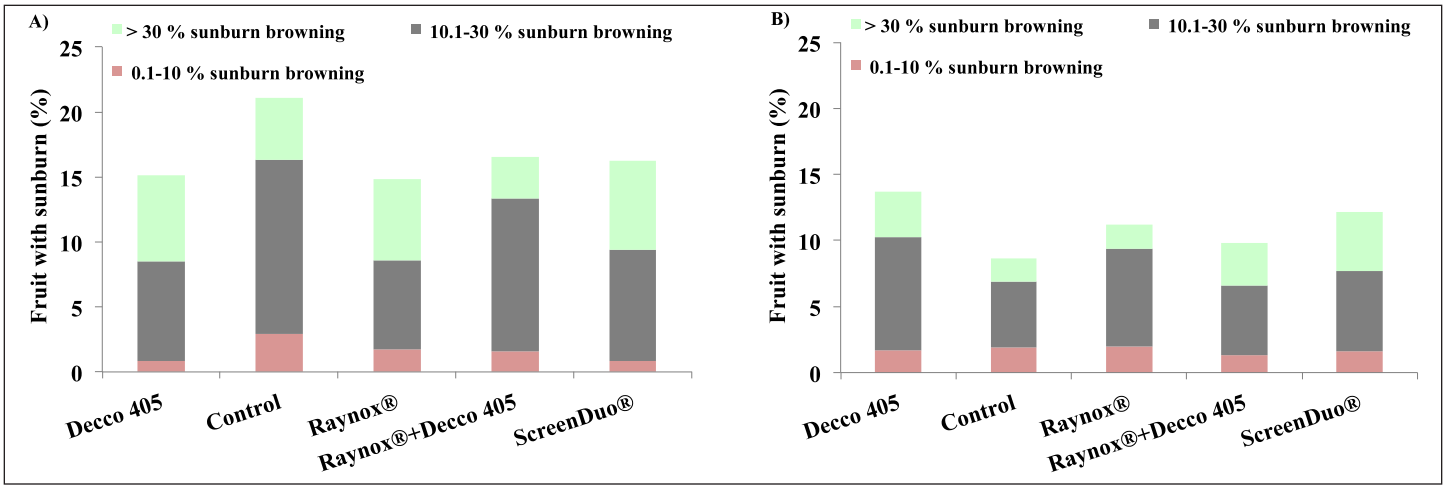

Figure 7. Percentage of sunburn browning by severity category in the two different blocks: irrigated (A) and non-irrigated (B).

a numerically greater incidence of sunburn compared with the non-irrigated block. These results were completely unexpected. July was a dry month in the Hudson Valley. The decision to add irrigation late in the season (end of July) in this Honeycrisp block may have allowed rapid growth of previously stressed fruit, thereby leaving them more susceptible to sunburn than non-irrigated fruit that remained under water stress until harvest. Some researchers have suspected that trees suffering from water stress are more prone to have more sunburn, but that was not supported by the results from this trial. However, we did not evaluate water potential of the trees in this trial and are therefore lacking the data that might have helped us to better explain these results. On the other hand, within each of the two main blocks (irrigated and non-irrigated), we also found no statistical differences among treatments (Figure 6), nor were any of the spray-applied treatments significantly affected by the irrigation treatment when irrigated versus non-irrigated plots for each treatment were compared.

Sunburn browning is the most prevalent and costly sunburn type. In this study, approximtely 98% of the sunburn observed was sunburn browning. At least half of the apples with sunburn browning had between 10.1% and 30% of the skin surface affected (Figure 7). Among treatments, no statistical differences were observed within each block (irrigated, non-irrigated) and category, and no statistical differences were observed for either treatment or irrigation effects when data from both irrigated and non-irrigated blocks were combined.

Schrader et al. (2003) classified the degree of apple sunburn in Fuji apples into six classes based on appearance. In this system, a rating of 0 denotes no sunburn, a rating of 5 signifies sunburn necrosis, and ratings of 1 to 4 refer to different degree of sunburn browning (Figure 8). In red cultivars, degrees of sunburn browning (1–4) were based on reduced red color and increasing yellow and brown colors. However, because this is the first study done under Hudson Valley conditions, where the severity of sunburn was evaluated in Honeycrisp, we decided to evaluate sunburn browning based on the percentage of the non-green surface area affected instead of the classes mention above. In addition, it is worth mentioning that few apples in this study would classify as SB-3 (Figure 8) in this study. Most of them belonged to SB-2, as in Figure 9.

In terms of internal fruit quality, flesh firmness (FF) was generally higher, sugars (soluble solids content, SSC) were lower and titratable acidity (TA) was higher in the irrigated block compared with the non-irrigated block (data not shown). The treatment of Raynox®+Decco 405 tended to show higher SSC and TA compared with the other treatments in both blocks, and high firmness in the non-irrigated block (Table 2). However, when non-sunburned and sunburned fruit were analyzed separately, this trend changed. In general, the sunburned fruit for all treatments and blocks showed higher FF and SSC, and lower TA (Table 3), in agreement with previous studies in which higher fruit firmness and soluble solids content (SSC) in the sunburned areas have been reported (Racskó et al. 2005; Schrader et al. 2009a,b; Tartachnyk et al. 2012). The higher firmness occurs because, as the sunburned plant cells die, the tissue loses water and gets harder.

Trial 2

At the Coy farm, the percentage of Honeycrisp with sunburn was not affected significantly by the different number of Raynox® applications (Table 4). The purpose of this trial was to determine if increasing the number of Raynox® applications late in the season would reduce the incidence of sunburn, but no benefit was demonstrated. Glenn et al. (2002) applied Surround® at different timings from petal

Figure 8. Degrees of sunburn browning of Fuji apples as modified from Schrader et al. (2003). NB, no sunburn; SB-1, sunburn severity 1; SB-2, sunburn severity 2; SB-3, sunburn severity 3; SB-4, sunburn severity 4.

Figure 9. Sunburn browning in Honeycrisp.

Table 2. Flesh firmness (FF), soluble solids content (SSC) and titratable acidity (TA) mean values of each block and treatment.

Block	Treatment	FF (lb)	SSC (°Brix)	TA (g malic acid L^{-1})
Irrigation	Decco 405	12.7 a	12.9 b	3.1 ab
	Control	13.7 a	12.8 bc	2.9 b
	Raynox	12.4 a	12.7 bc	3.1 ab
	Raynox®+Decco 405	13.7 a	13.3 a	3.2 a
	ScreenDuo®	12.9 a	12.8 c	2.9 b
No Irrigation	Decco 405	12.7 ab	13.2 b	2.7 c
	Control	12.5 ab	12.8 cd	2.9 b
	Raynox	12.3 b	12.9 c	3.1 ab
	Raynox®+Decco 405	12.8 ab	13.5 a	3.3 a
	ScreenDuo®	13.1 a	12.7 d	2.9 bc

For each treatment, means followed by the same letter in each column are not significantly different at P ≤ 0.05.

Table 3. Flesh firmness (FF), soluble solids content (SSC) and titratable acidity (TA) mean values of each fruit type.

Type	FF (lb)	SSC (°Brix)	TA (g malic acid L^{-1})
Healthy	12.5 b	12.9 b	3.2 a
Sunburn	13.8 a	13.1 a	2.6 b

For each treatment, means followed by the same letter in each column are not significantly different at P ≤ 0.05.

Table 4. Percentage of sunburn in Honeycrisp after different numbers of applications.

Treatment[a]	% Sunburn	0.1–10 % sunburn browning	10.1–30% sunburn browning	> 30% sunburn browning	FF (lb)	SSC (°Brix)	TA (g malic acid/L)
1x	17.4 a	1.0 a	11.9 a	3.8 a	13.3 a	13.3 a	4.1 a
2x	22.9 a	0.3 a	13.0 a	9.2 a	13.3 a	12.9 c	3.7 b
3x	12.6 a	0.1 a	4.7 b	7.2 a	13.5 a	13.0 b	3.8 b

Treatment means followed by the same letter in each column are not significantly different at P ≤ 0.05.

[a]1x applied on 07/28/2015; 2x applied on 07/28/2015 and 08/12/2015; 3x applied on 07/28/2015, 08/12/2015 and 08/28/2015.

fall to harvest and at different concentrations in various apple cultivars, concluding that the timing of applications was not clearly defined for optimum suppression of sunburn. Further studies are needed to better understand the interactions between number of applications and the weather variables as they relate to spray timings, although it is clear that Raynox® can reduce sunburn incidence in apple.

In contrast, the number of applications significantly affected fruit quality, mainly SSC and TA. In general, fruit that received one application of Raynox® tended to show higher SSC and TA compared with the other treatments (Table 4). As mentioned above, sunburned fruit tended to have higher FF and SCC, and lower TA compared with the healthy fruit in all the treatments (data not shown). In addition, comparing the fruit quality on the two sides of fruit (sun side and shade side) and among sunburned and non-sunburned fruit, higher FF and SSC and lower TA were observed on the sun-exposed side of the sunburned fruit compared with the rest of the combinations, in agreement with those results reported by Schrader et al. (2009b).

The results obtained in 2015 from both trials do not mean that these products have no value for preventing sunburn in Honeycrisp. The results indicated that the timing used in this trial did not help to reduce sunburn in Honeycrisp. Rather, further studies on timing applications are needed to help growers avoid useless applications of any given product and to know the right time to apply these products under Hudson Valley conditions. It would be interesting also to know the roles of solar radiation and fruit surface temperatures in sunburn incidence under our climatic conditions. Schrader et al. (2003) emphasize the importance of fruit surface temperature in causing sunburn. They found a high correlation between fruit surface temperature and maximum daily air temperature (r = 0.9), the mean of hourly air temperatures (between 11:00 and 17:00 hours), and solar radiation (r = 0.65), and an inverse correlation between maximum fruit surface temperature (between 11:00 and 17:00 hours) and mean wind velocity (r = -0.24) and mean relative humidity (r = -0.66).

Although sunburned fruit are not visually acceptable for the consumer, we do not know if flavor changes that might be occurring in fruit with slight sunburn would be detected by consumers to affect purchasing decisions of blushed and red apple cultivars. It is very easy at the packing line to miss low levels of sunburned fruit in blushed and red apple cultivars (mostly those with a very small area of sunburn browning or those where red color masks the sunburned area). These sunburned fruits have higher flesh firmness and sugars, but less acidity. According to Schrader et al. (2009b) apples with even slight sunburn browning have a higher starch index as compared with non-sunburned apples and are, therefore, more mature. While these sunburned fruits are ripening in cold storage together with non-sunburned fruit, the acidity taste of sunburned apples will be lower than TA in non-sunburned fruit, and the sugar-to-acid ratios of those sunburned fruit will be higher.

Literature Cited

Felicetti, D.A. and Schrader, L.E. 2009. Changes in pigment concentrations associated with sunburn browning of five apple cultivars. II. Phenolics. Plant Sci. 176: 84–89.

Glenn, D.M., Prado, E., Erez, A., McFerson, J. and Puterka, G.J. 2002. A reflective processed-kaolin particle film affects fruit temperature, radiation reflection and sunburn in apple. J. Am. Soc. Hort. Sci. 127: 188–193.
Iglesias, I., Salvia, J., Torguet, L. and Montserrat, R. 2005. The evaporative cooling effects of overtree microsprinkler irrigation on 'Mondial Gala' apples. Sci. Hort. 103: 267-287.
Racskó, J., Szabó, Z. and Nyéki, J. 2005. Importance of the supra-optimal radiance supply and sunburn effects on apple fruit quality. Acta Biol. Szegediensis 49(1-2): 111–114.
Racskó, J. and Schrader, L.E., 2012. Sunburn of apple fruit: Historical background, recent advances and future perspectives. Crit. Rev. Plant Sci. 31:455–504.
Schrader, L.E., Zhang, J. and Sun, J. 2003. Environmental stresses that cause sunburn of apple. Acta Hort. 618: 397-405.
Schrader, L.E., Zhang, J., Sun, J., Xu, J., Elfving, D.C. and Kahn, C. 2009a. Postharvest changes in internal fruit quality in apples with sunburn browning. J. Am. Soc. Hort. Sci. 143: 148–155.
Schrader, L.E., Kahn, C. and Elfving, D.C. 2009b. Sunburn browning decreases at harvest internal fruit quality of apple (*Malus domestica* Borkh.). Int. J. Fruit Sci. 9:425–437.
Schrader, L. E. 2011. Scientific basis of a unique formulation for reducing sunburn of fruits. HortScience 46: 6–11.
Schupp, J., Fallani, E. and Chun, Ik-Jo. 2002. Effect of Surround® particle film on fruit sunburn, maturity and quality of 'Fuji' and 'Honeycrisp' apples. HorTechnology 12 (1): 87–90.
Tartachnyk, I., Kuckenberg, J., Yuri, J.A. and Noga, G. 2012. Identifying fruit characteristics for non-invasive detection of sunburn in apple. Sci. Hortic. 134: 108–113.

Acknowledgements

This research was supported by New York Apple Research and Development Program and Jentsch Lab Program Funds. We thank Crist Brothers Orchard Inc.

Gemma Reig is a Postdoctoral Research Associate at Cornell Univeristy's Hudson Valley Research Laboratory in Highland, NY. **Peter Jentsch** is a Senior Extension Associate in the Department of Entomology at Cornell Univeristy's Hudson Valley Research Laboratory in Highland, NY. **David Rosenberger** is a Professor Emeritus of Plant Pathology at Cornell Univeristy, stationed at the Hudson Valley Research Laboratory in Highland, NY.

SAVE THE DATE: January 17-19, 2017

The Empire State Producers Expo at the Oncenter Convention Center in Syracure, NY.