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# Evaluation of a Spray-on Product for Improving Red Color and Decreasing Sunburn Damage of 'Red Chief Delicious' Apples

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## Abstract

Sunburn is a severe type of solar radiation damage that causes meaningful economic losses in several vegetables and fruits, including apples. In this study, we examined the efficacy of a new product, Parasol, for protecting apples (cv. 'Red Chief Delicious') against sunburn. Specifically, we examined the effect of Parasol spraying on fruit quality attributes, including fruit color, flesh firmness, soluble solids and acidity at harvest and after a 5-month period of storage. Spraying apple trees with Parasol resulted in better red fruit coloration and reduced sunburn symptoms. Parasol (2.5 and 5 L/t) treatments resulted in an increase of fruit flesh firmness compared to the control, for both years. Fruit weight, soluble solids concentration and acidity did not differ significantly between treatments. Hue values showed that apples from the control treatment had significantly less red color than the Parasol treatments. The intensity of the red color decreased in the following order: Parasol (5 L/t)> Parasol (2.5 L/t)> Control. From our results it is concluded that Parasol protects apples from sunburn injury, increases red coloration and fruit firmness and therefore their commercial value.


## Introduction

Apple (*Malus* × *domestica* Borkh.) is one of the most important fruit crops cultivated in temperate zones of the world. Among fruit quality attributes, apple skin color is a crucial component that determines apple marketability and any factors that adversely influence the appearance decreases the value of the fruits. Accordingly, apple sunburn, a fruit discoloration caused by excessive solar radiation and heat, is a common defect decreasing the value of affected fruits in hot dry weather conditions and reduces post-harvest life (Felicetti and Schrader, 2009; Schrader *et al*. 2003). Losses in apple production caused by sunburn in Washington State (U.S.A.) average about 10% if no preserving measures are taken (Schmidt, 2018). In Australia, losses may range from 40 to 50%, particularly for delicate apple cultivars (Lolicato, 2011) and in Chile 13%. 'Granny Smith' and 'Gala are considered to be most susceptible to sun damage. Other susceptible apple cultivars are 'Jonagold', 'Braeburn', 'Golden Supreme', 'Ginger Gold' and 'Fuji' (Evans, 2004). According to Schrader *et al*. (2003) 'Pink Lady' is more tolerant than 'Cameo' and 'Honeycrisp'. However, the severity of the symptoms differs from year to year depending on climatic conditions.

Apple cultivars grown mainly in lowland areas are particularly vulnerable to sunburn. The apple cultivar 'Red Chief Delicious', when cultivated in low-lying regions in Greece, is sensitive to sunburn. The injury on the fruit skin becomes visible either as a stain, or in more intense cases as a brown

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necrotic blotch, leading ultimately to entire loss of the commercial value of the fruit.

The categories of sunburn are classified as: i) Sunburn necrosis appears as a depressed dark brown or necrotic blotch on the part of fruit exposed to the sun. It is generally caused by heat induced in fruit by direct sunlight, when the fruit skin temperature of an apple reaches 52º±1ºC for ≥ 10 minutes, ii) Sunburn browning appears as a yellow or brown blotch on the side of the fruit exposed to the sun. Cells do not die and damage first appears externally, although deeper layers may show further damage after cool storage. Sunburn browning in apples usually starts to appear when fruit skin temperatures rises up to 46º to 49ºC for one hour, depending on various cultivars, iii) Photo-oxidative sunburn. Initially it appears as white, faded skin in a patch on the side of fruits exposed to the sun, that eventually becomes brown and occasionally also necrotic. It can take place at more or less low air temperature and already at a skin temperature of less than 45ºC (Fellicetti and Schrader, 2008; Racsko and Schrader, 2012).

Delayed sunburn symptoms are similar to sunburn browning and can broaden or worsen within the first four months of fruits in cold storage. Fruit that had pre-harvest sunburn that later covered over during red color development are not suitable for long-term storage (Racsko and Schrader, 2012). Beyond sunburn symptoms previously mentioned, heat and light stress can cause other fruit imperfections and disorders. External disorders can be detected such as cracking, crinkle, ‘Fuji’ stain, hot summer stress disorder, lenticel marking, russeting and splitting. Furthermore, internal disorders occur such as water core, bitter bit and heat stress internal browning.

There are several actions that can be taken to protect apples against sunburn. These may involve the use of climate ameliorating techniques such as the use of cultivars that are more tolerant to sunburn, the scheduling of irrigations to avoid tree water stress, the training of trees to develop an appropriate canopy, the avoidance of excessive summer pruning, the use of cover cropping and the improvement of air movement through the fruit block. Other measures involve the use of shade nettings, over-tree sprinkler cooling systems and spray-on products such as kaolin, calcium carbonate, wax and talc-based products. Ascorbic acid, absisic acid and anti-transpirant compounds were tested as well (Amarante *et al*., 2011; Evans and van der Gulik, 2011; Glenn 2009; Iamsub *et al*., 2009; Lal and Sahu, 2017, Lolicato, 2011, Reig *et al*., 2016; Schupp *et al*., 2002). The objective of this research was to examine the efficacy of two rates of the spray-on product Parasol in protecting apple fruit from sunburn. In addition, we tested whether Parasol affects the quality attributes of the fruit. The apple cultivar ‘Red Chief Delicious’ was chosen for this research, since it is commonly accepted among consumers in Greece.

**Materials and Methods**

Trees of the apple cv. ‘Red Chief Delicious’ grafted onto M.26 rootstock were selected for this research. The trees were 13 years old, planted in a randomized complete block design with 3.5 × 2.5 m spacing and trained to a palmette system. Twenty-five trees were used for each treatment (five replications x five-tree units). The trees received standard horticultural practices regarding pruning, irrigation and fertilization.

Apple trees were sprayed by an airblast sprayer with 2.5L and 5L Parasol (Nature S.A. Nea Efessos, Pieria, Greece) per 1000L of water for two consecutive years (2017 and 2018) in an apple orchard located in Naoussa (northern Greece, long. $22^0 12' 0''$ E; lat. $40^0$ 29’04” N; elevation 350 m) on the following dates: 15 July, 28 July, and 19 Aug. (one month prior to harvest). Control trees were not sprayed. Parasol is a dense, liquid calcium carbonate dispersion product, based on natural, ultrafine particles of 1.4 μm. When Parasol is applied to plants, a very thin, but sufficiently opacifying white film is formed, for reflecting excessive ultraviolet and infrared solar radiation.

One hundred apples were collected from the five trees of each replication, therefore 20 fruit per tree. Fruits were sampled at commercial maturity. Fruit from all treatments were harvested at the same time, based on total soluble solids concentration and color. Fruit were sampled from the same canopy position e.g. at shoulder height from the periphery of the south side of the canopy where greatest sunburn would be expected. Fruit were transported immediately to the laboratory for analyses. The protective film which was formed on the fruit surface was removed on a packing line equipment with a water tank and a brush section. A fresh water rinse (pH of 5.5 or below) is recommended. Ten fruit per tree were weighted and evaluated individually for soluble solids (%) after extracting the juice of all fruit. Soluble solids were measured with an Atago PR-1 electronic refractometer (Atago Co. Ltd.,Tokyo, Japan), acidity after titration with 0.1N NaOH (Amerine and Ough, 1980), flesh firmness measured with an Effegi penetrometer with a 11-mm tip (Effegi Model FT 327, Alfonsine, Italy), and color with the Minolta CR-400 chroma meter device (Minolta Co., Ltd., Tokyo, Japan) on the two cheek areas of each fruit. The values of L, a, and b were measured and used to calculate Chroma and Hue angles (McGuire, 1992). Apples were divided into three categories based on color and sunburn injury: Class I (absence of any sunburn symptoms), Class II (light discoloration) and Class III (visual sunburn spots). Lastly, the remaining 10 fruit per tree were placed into a cooling chamber (+0.5 $^0$C) for five months. For these fruits, the same quality attributes were determined.

Fruit quality attributes were compared separately for each year and data were subjected to two-way ANOVA. Means were compared with Tukey's test ($P \leq 0.05$) using the SPSS 17.0 statistical package (SPSS, Chicago, IL).

## Results and Discussion

With regard to the two-year meteorological data of 2017 and 2018, the average and maximum temperatures from June to Sept. fluctuated around the same levels (Table 1). The average and maximum solar radiation values from June to Sept. 2017 were higher than in 2018. Regarding maximum solar radiation values (above 1000 W m$^{-2}$), in 2017, they were recorded on the following dates: 13 June (1025), 15 June (1039), 19 June (1121), 20 June (1135) and 27 July (1035). In 2018, maximum radiation values (above 1000 W m$^{-2}$) were recorded on the following

**Table 1.** Meteorological data during apple fruit development and maturation for the growing seasons 2017 and 2018.

| | Mean Temperature (°C) | | Max. Temperature (°C) | | Mean Radiation (W·m$^{-2}$) | | Max. Radiation (W·m$^{-2}$) | | Rainfall (mm) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 |
| June | 26.8 | 25.1 | 32.1 | 29.7 | 290.19 | 247.99 | 962.49 | 872.71 | 37.5 | 122.0 |
| July | 28.3 | 28.0 | 33.0 | 32.8 | 299.99 | 276.76 | 900.46 | 878.53 | 97.0 | 54.0 |
| August | 27.5 | 27.2 | 33.7 | 33.1 | 279.20 | 234.86 | 886.68 | 790.91 | 23.5 | 104.0 |
| September | 22.1 | 23.4 | 28.6 | 29.8 | 201.24 | 179.36 | 792.27 | 651.40 | 25.5 | 12.0 |
| Mean | 26.18 | 25.93 | 31.85 | 31.35 | 267.66 | 234.74 | 885.48 | 798.39 | - | - |
| Total | - | - | - | - | - | - | - | - | 183.5 | 292.0 |

**Table 2.** The influence of two rates of Parasol on mean fruit weight, soluble solids concentration, acidity, and firmness of 'Red Chief Delicious' fruit at harvest in 2017 and 2018.

| Year | Treatment | Fruit weight (g) | Soluble solids (%) | Acidity (% malic acid) | Fruit Firmness (N) |
|---|---|---|---|---|---|
| 2017 | Control | 284.9 ± 35.9 a[z] | 13.88 ± 3.2 a | 0.23 ± 0.01 a | 64.14 ± 14.71 b |
| | Parasol (2.5l/t) | 283.7 ± 31.7 a | 13.18 ± 2.8 a | 0.25 ± 0.02 a | 67.86 ± 17.65 a |
| | Parasol (5l/t) | 289.4 ± 32.4 a | 13.70 ± 2.6 a | 0.24 ± 0.02 a | 69.14 ± 13.73 a |
| 2018 | Control | 265.3 ± 24.9 a | 12.70 ± 2.3 a | 0.18 ± 0.02 a | 61.98 ± 18.63 b |
| | Parasol (2.5l/t) | 267.3 ± 30.4 a | 12.30 ± 2.9 a | 0.20 ± 0.03 a | 69.04 ± 14.70 a |
| | Parasol (5l/t) | 264.9 ± 31.5 a | 11.20 ± 2.0 b | 0.21 ± 0.04 a | 69.73 ± 8.82 a |

[z] Means (± SD) within columns and years followed by common letters are not significantly different (Tukey's test, $P \leq 0.05$)

dates: 10 June (1000), 14 June (1000), 16 June (1024), 24 June (1042) and 19 July (1022). Maximum temperatures in 2017, were recorded on the following dates: 27 June (38$^0$C), 1 July (38$^0$C), 2 July (39$^0$C), 12 July (38$^0$C), 3 Aug. (38$^0$C), 6 Aug. (38$^0$C). In 2018, maximum temperatures were recorded on the following dates: 5 June (33$^0$C), 13 July (35$^0$C), 21 July (35.5$^0$C), 30 July (35$^0$C), 7 Aug. (35.5$^0$C), 8 Aug. (35.5$^0$C) and 19 Aug. (36$^0$C). Lastly, the 2018 rainfall was higher than in 2017.

In 2017, Parasol at (2.5 and 5 L/t) increased fruit flesh firmness compared to the control (Table 2). Soluble solids concentration, mean fruit weight, and acidity did not differ significantly among treatments. However, in 2018, soluble solids concentration was lower for fruit from the Parasol (5 L/t) treatment compared to the control. To examine whether application of Parasol on apple trees affects fruit coloration in comparison to the control, the color of apples was measured. Lightness (L) and chroma (C) did not differ significantly between treatments (Table 3). However, Hue values showed that control fruit had significantly less red color than the Parasol treatments. The intensity of the red color decreased in the following order: Parasol (5 L/t)> Parasol (2.5 L/t)> Control (Table 3). The red color development of apples increased for trees treated with Parasol due

**Table 3.** The influence of two rates of Parasol on color parameters L, a, b, Chroma (C) and Hue angle of 'Red Chief Delicious' fruit at harvest in 2017 and 2018.

| Year | Treatment | L | a | b | C | Hue |
|---|---|---|---|---|---|---|
| 2017 | Control | 41.22 ± 3.2 az | 25.01 ± 2.6 c | 21.54 ± 2.5 a | 33.01 ± 4.1 a | 40.69 ± 4.8 a |
| | Parasol (2.5l/t) | 43.72 ± 3.3 a | 27.80 ± 3.2 b | 18.82 ± 2.1 b | 33.57 ± 4.5 a | 34.21 ± 4.0 b |
| | Parasol (5l/t) | 43.95 ± 4.0 a | 30.40 ± 3.6 a | 16.09 ± 1.9 c | 34.39 ± 4.0 a | 27.92 ± 3.6 c |
| 2018 | Control | 40.25 ± 2.8 a | 28.93 ± 2.8 b | 26.36 ± 2.6 a | 39.14 ± 5.2 a | 42.30 ± 5.1 a |
| | Parasol (2.5l/t) | 39.57 ± 2.3 a | 34.21 ± 4.1 a | 19.44 ± 2.4 b | 39.35 ± 4.6 a | 29.68 ± 3.6 b |
| | Parasol (5l/t) | 42.49 ± 3.0 a | 35.32 ± 2.9 a | 17.75 ± 2.0 c | 39.53 ± 4.4 a | 26.56 ± 3.9 c |

[z] Means (± SD) within columns and years followed by common letters are not significantly different (Tukey's test, $P \leq 0.05$).

**Table 4.** The influence of two rates of Parasol on soluble solids concentration, acidity, and firmness of 'Red Chief Delicious' apple fruit after a five-months of cold storage in two years.

| Year | Treatment | Soluble solids (%) | Acidity (% malic acid) | Fruit firmness (N) |
|---|---|---|---|---|
| 2017 | Control | 14.81 ± 2.1 a[z] | 0.20 ± 0.03 a | 50.41 ± 7.85 b |
| | Parasol (2.5l/t) | 14.38 ± 1.8 a | 0.22 ± 0.02 a | 57.47 ± 9.81 a |
| | Parasol (5l/t) | 14.59 ± 1.6 a | 0.20 ± 0.03 a | 58.74 ± 8.83 a |
| 2018 | Control | 13.77 ± 1.6 a | 0.15 ± 0.02 a | 51.39 ± 5.88 b |
| | Parasol (2.5l/t) | 13.49 ± 2.1 a | 0.17 ± 0.03 a | 60.70 ± 4.90 a |
| | Parasol (5l/t) | 12.27 ± 1.4 b | 0.16 ± 0.02 a | 60.21 ± 5.88 a |

[z] Means (± SD) within columns and years followed by common letters are not significantly different (Tukey's test, $P \leq 0.05$).

to the lower discoloration percentage as was shown in Table 5 and protection of high solar radiation on the fruit's skin.

We further examined fruit quality attributes of apples stored for 5 months in cooling chambers. The fruit soluble solids concentration increased with respect to the harvest stage (Table 4). Treatments with Parasol (2.5 and 5 L/t) had increased fruit firmness in comparison to the control.

During the 2nd year, the fruit soluble solids concentration increased slightly during storage (Table 4), and treatment differences with regard to the fruit firmness, and soluble solids concentration and acids at harvest were maintained during cold storage for 5 months. At harvest in both years, more from the control treatment had sunburns and light discoloration compared to both Parasol treatments (Table 5). Parasol treatment (5 L/t) had the most fruit in Class I (Fig. 1). Alvarez *et al*. (2015) reported that calcium carbonate has a thermoprotector effect on apples and that the degree of protection depends on the reflectance and the amount of residue settled on the surface. Glenn *et al*. (2002) also reported that 'Crimson seedless' grapevines treated with $CaCO_3$ were less prone to sunburn damage than untreated grapes due to reduced fruit temperature and exposure to UV radiation because $CaCO_3$ reflected UV radiation. Furthermore, Ahmed *et al*. (2011) reported that grapevines treated with $CaCO_3$ were less prone to sunburn damage than

**Table 5.** The influence of two rates of Parasol on the percentage of 'Red Chief Delicious' apples assigned to three classifications based on the color and sunburn injury at harvest in two years.

| Year | Treatment | Class I* | Class II | Class III |
|---|---|---|---|---|
| 2017 | Control | 68 c[z] | 19 a | 13 a |
| | Parasol (2.5l/t) | 86 b | 10 b | 4 b |
| | Parasol (5l/t) | 92 a | 6 c | 2 c |
| 2018 | Control | 72 c | 16 a | 12 a |
| | Parasol (2.5l/t) | 87 b | 8 b | 5 b |
| | Parasol (5l/t) | 93 a | 4 c | 3 c |

[z] Means (± SD) within columns and years followed by common letters are not significantly different (Tukey's test, $P \leq 0.05$).
[*] Class I (extra quality-absence of any sunburn symptoms), Class II (light discoloration) and Class III (visual sunburn spots).


**Figure 1.** 'Red Chief Delicious' fruit coloration at harvest as affected by two rates of Parasol applied foliarly three times from 8 to 4 weeks before harvest.

untreated grapes. Previous researchers found that $CaCO_3$ stimulated plant metabolism by enhancing photosynthesis and formation of plant pigments in 'Crimson seedless' grapevines and Morsy *et al*. (2008) also reported the same in pomegranates.

There are several calcium carbonate-based particle film products available for sunburn control in apples: Eclipse™ (Novazone Inc., Livermore, CA), Purshade® (Purfresh, Inc., Fremont, CA), Diffusion™ (Wilbur-Ellis Co., San Francisco, CA), Bud Mate (Agrichem Liquid Fertilizer Pty Ltd, Loganholme, QLD, Australia). In a comparative trial of Cocoon, Eclipse, Fruit Shield, Invelop, Raynox, Raynox Plus, Sun Guard, and Surround WP it was found that all materials increased the percentage of sunburn-free fruit, enabling packers to move more fruit into the highest grade and increasing the returns for individual growers (Hanrahan *et al*., 2009). Furthermore, Purshade® significantly reduced sunburn when applied on three dates to 'Granny Smith' apples (https://www.novasource.com/en/products/purshade). These results are consistent with the results of the present study.

## Conclusions

In conclusion, under our experimental conditions, spraying trees with Parasol had a positive effect on the coloring of apples and also increased their firmness and the percentage of marketable fruit. The effectiveness of Parasol is likely related to several factors including a) the characteristics (origin, shape and size of particles) of the calcium carbonate, which optimizes the protective film due to its high opacifying; b) the ionic surfactant which ensures good coverage and creates a uniform film with remarkable stability; and c) the easy postharvest removal of the formed film.

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