Shade netting reduces sunburn damage and soil moisture depletion in 'Granny Smith' apples

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Abstract

The benefits associated with the use of protective netting for apple orchards have been assessed in several growing regions, but no studies exist for Washington State, USA. This region experiences semi-arid conditions characterized by long days, high light intensity and high temperatures which increases the risk of plant stress and fruit sunburn damage. The aim of this study was to assess the effect of anti-hail nets on orchard microclimate, soil moisture and fruit sunburn. Seven-year-old 'Granny Smith'/'M9-T337' apple trees were covered in 2014 with 20% white shade net sheltering a rectangular area. Uncovered trees served as control. Shade net reduced the maximum daily photosynthetically active radiation (PAR) by 32%, with a maximum PAR value on a sunny day of 1649 and 1222 µmol m^{-2} s^{-1} in the control and netted areas, respectively. Canopy air temperature was slightly lower during the day and higher at night under the net compared to the control. Shade nets reduced soil moisture depletion at 0-30 cm depth, resulting 20% higher than the control. No significant differences were observed deeper in the soil profile. Netting significantly decreased fruit sunburn, with 92% of harvested fruit having no sunburn damage compared to control in which 51% had no sunburn damage in 2014. Although preliminary, these results show that shade netting has the potential to reduce sunburn damage in 'Granny Simith' apples and water requirements in semi-arid environments and might represent an important tool for increasing yields of high quality fruit.

INTRODUCTION

In Washington State, east of the Cascade Mountain range where a large portion of the fresh apples are grown in the United States, environmental conditions in the summer include long hot days, minimal precipitation and high light intensities. As a result, significant tree stress and a high incidence of fruit physiological disorders such as sunburn damage can occur. Other apple growing regions such as Australia, South Africa and Chile also experience similar, high-light conditions that can cause sunburn. In Australia, McCaskill et al. (2016) reported that up to 10% of total fruit can be lost due to sunburn damage for certain apple cultivars. Under South African growing conditions, producers estimate losses due to sunburn damage at 10-20%, but in some years as high as 30-50% of the total yield (Wand et al., 2006). Racsko and Schrader (2012) estimated that sunburn damage costs Washington growers over $ 100 million per year.

Growers primarily use overhead cooling or protective sprays to reduce the fruit surface temperature during the hottest hours of the day to limit the occurrence of sunburn (Racsko and Schrader, 2012). Overhead cooling usually consists of the application of irrigation water above the orchard for short, intermittent periods and to allow the energy absorption of water evaporation to cool the fruit (Gindaba and Wand, 2005). While protective sprays such as reflectance particles or protective waxes have shown improvements in sunburn prevention, they are often inadequate in completely limiting losses from sunburn (Glenn and Puterka, 2004).

Netting has been shown to reduce sunburn in apples (Shahak et al., 2004). Unlike red and bi-color apples, the development of any over color or "blush" in green apple cultivars

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like ‘Granny Smith’: red color development can actually reduce the grade of the fruit. Netting has been shown as a viable option for reducing sunburn in ‘Granny Smith’ orchards growing in other climates (Dayioglu and Hepaksoy, 2016). Here, we sought to identify how netting modifies the orchard environment including soil conditions, as well as of its effects on sunburn incidence and blush development of ‘Granny Smith’ apple in a desert environment.

MATERIALS AND METHODS

Orchard site

Netting was installed in 2014 at Washington State University’s Sunrise research orchard (Rock Island, WA) in a block of 7-year-old ‘Granny Smith’ apple trees on M9 T337 rootstock planted at 0.9 m in-row spacing and 3.6 m between rows and trained to a tall spindle system. White netting (Extenday USA, Union Gap, WA) was installed to completely cover the top and sides (to the ground) for each pod; 4 pods in replicated fashion throughout the block. Pods covered a rectangular area of 7 tree rows with 12 trees per row (18×11×5.2 m high). Netting was deployed after petal fall. Within the same block, uncovered trees of equal plot size served as control. The netting was a non-transparent polyethylene plastic woven netting in a hexagonal weave design that reduced light by ~30%.

Environmental monitoring

Water was supplied to trees using a combination of daily micro-sprinkler and drip irrigation applications. Monitoring locations within each replicate were selected based on a priori evaluation of irrigation patterns within the orchard. Water collection trays were placed at several locations within the orchard and environmental sampling spots were chosen based on uniformity of water application within each replicate. Soil moisture monitoring tubes (Delta T-Devices Ltd., Cambridge, UK) were installed to 60-cm depths at sampling spots within each replicate. Soil moisture was measured periodically at 10, 20, 30, 40 and 60 cm depth throughout July and August, 2014 using a handheld soil capacitance probe (PR2, Delta-T Devices Ltd.).

The netting effects on canopy conditions were determined by recording air temperature 1.5 m above the ground at 10-min intervals from August 1 to 31, 2014 (Hobo Pro v2, Onset Computer Corp.) without radiation shields. Photosynthetically active radiation (PAR) was recorded hourly (6 am to 4 pm) on two sunny days (August 21 and 27, 2014) by placing a handheld PAR sensor and data logger (QSO-S, Apogee Instruments Inc.) 3 m above the ground, but still within the tree canopy. PAR light intensity was recorded (μmol m^{-2} s^{-1}) and repeated for each of the four netted and control replicates.

Sunburn evaluation

Immediately prior to harvest, sunburn damage was assessed visually on 200 fruits that were taken from sun-exposed regions of the tree at random from 40 non-border trees per replicate. Fruit was scored for sunburn severity using a six ranking sunburn scale adapted from Schrader et al. (2003) and also evaluated for the development of red blush that leads to commercial downgrading of ‘Granny Smith’ apples (Figure 1).

Figure 1. Sunburn scale for visual assessment of damage (Schrader et al., 2003). Original scale was for ‘Fuji’ apple. Scale was modified for ‘Granny Smith’ by I. Hanrahan and M. Mendoza (WA Tree Fruit Research Commission, pers. commun.). Clean fruit indicates no sunburn while Y1 to Y3 indicate increasingly severe discoloration. Tan represents epidermal damage and Black indicates cell death and necrosis.

RESULTS AND DISCUSSION

Netting reduced light intensity, in-canopy air temperature and water-use in 'Granny Smith' apple

The shade netting installed after bloom in 2014 reduced light intensity by approximately 32%, with the maximum value on a sunny day being 1649 µmol m^{-2} s^{-1} in non-covered control compared to 1222 µmol m^{-2} s^{-1} under the netting (Figure 2). The material used in this netting was non-transparent, resulting in lower scattering of light compared to other types of netting used in other studies (Shahak et al., 2004; Bastías et al., 2012). Therefore, at low sun angles, the shading effect would be stronger compared to high sun angles in the orchard. For example, the shading effect on August 21 and 27, 2014 was pronounced at 09:00 where the average light intensity of the control exceeded 800 µmol m^{-2} s^{-1} while the netted treatment averaged 100 µmol m^{-2} s^{-1}. Earlier in the season, in May, June, and July, sunrise would occur earlier and sun angles would be greater. Therefore, the impact of the sun angle on the shading effect in mid-morning would be reduced.

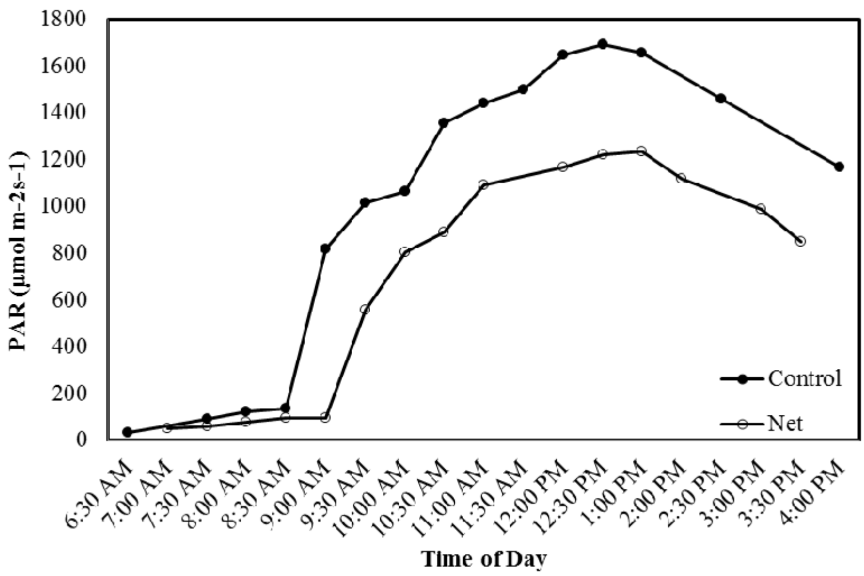

Figure 2. Photosynthetically active radiation (PAR, µmol m^{-2} s^{-1}) measured on August 21 and 27, 2014, from 06:00 to 16:00 under netting and an uncovered control.

Air temperature was significantly lower under the net compared to the uncovered portion of the orchard (30.9±3.2°C vs. 31.9±3.3°C, respectively) (Figure 3). Reported differences in air temperature between netted and non-netted orchards have been inconsistent. Middleton and McWaters (2002) and McCaskill et al. (2016) reported no differences in canopy temperature between netted and non-netted trees. However, Iglesias and Alegre (2006) reported decreased temperatures under netting compared to an uncovered control. Studies showing no changes in air temperature were associated with the use of a radiation shield covering the temperature sensor. The sensors used here did not have radiation shields and were similar to those used in Iglesias and Alegre (2006).

Soil moisture was measured at 10, 20, 30, 40, and 60 cm depth. The orchard was irrigated daily and therefore, significant daily variation in soil moisture content was not observed (Figure 4). Shade net significantly reduced soil moisture depletion at 10-30 cm depth, resulting in soil water content 20% greater than non-covered control (Figure 5). No significant differences were observed at 40 and 60 cm depth. The impact of air environment and overall water-use was less at greater soil depths. Soil moisture was less variable at greater depths compared to more shallow locations in the soil profile.

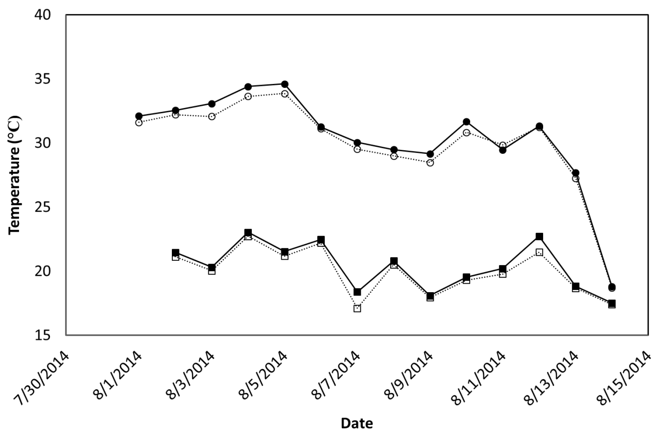

Figure 3. Maximum (circles) and minimum (squares) canopy air temperature (°C) in trees covered by netting (open symbols) compared to an uncovered control (closed symbols) from August 1-12, 2014.

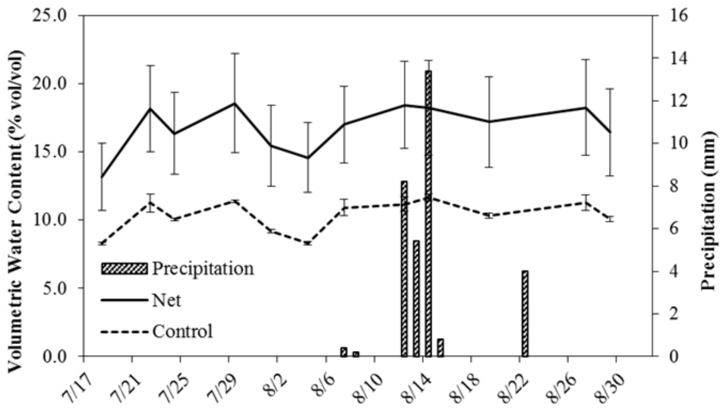

Figure 4. Soil volumetric water content (% vol/vol ±SE, *n*=4) at 20 cm depth under net and an uncovered control. July and August, 2014.

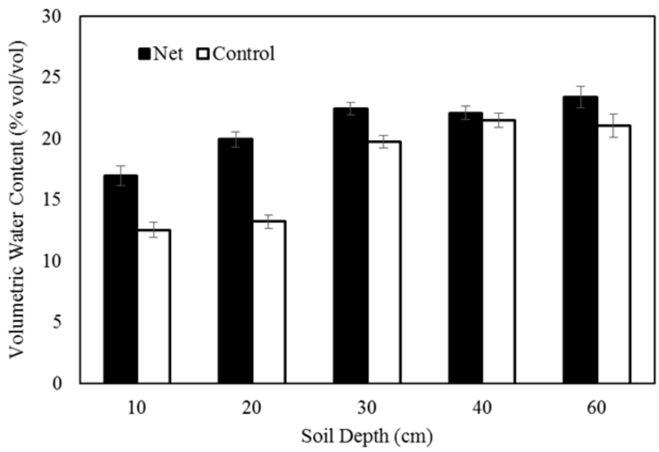

Figure 5. Mean soil volumetric water content (% vol/vol ±SE, *n*=4) under netting compared to an uncovered control at 10, 20, 30, 40 and 60 cm depth measured weekly at mid-day. July 17-September 24, 2014.

Netting significantly reduced fruit sunburn incidence and severity

The incidence of sunburn decreased from 49% for fruit harvested from the uncovered control to 8% for fruit from the netted treatments (Figure 6). The severity of sunburn was also markedly higher in fruit from the control compared to the netted trees. More than 30% of apples were classified as Yellow 2 (Figure 7) or worse in the control, which indicates a probable decrease in commercial fruit quality, in contrast to only 2% under netting. Interestingly, the west side of the tree consistently had more severe sunburn. Similarly, Racskó et al. (2005) reported higher fruit surface temperature and sunburn on the West sides of apple trees. This is in contrast to Fouché et al. (2010) where there were no differences in sunburn incidence between the west and east side of north-south rows. Air temperatures generally peaked between 2:30 and 4:00 pm. This is also the period of day with the lowest relative humidity and leaf water potential, which both may contribute to increased fruit surface temperature and sunburn. With light exposure being greater on the west side of north-south rows during this period of maximum plant stress, the incidence of sunburn should be greater on this exposure as well.

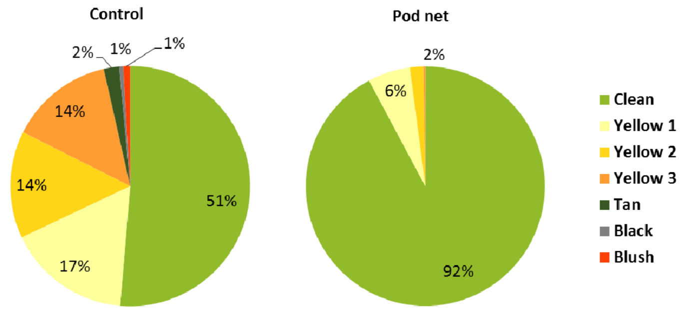

Figure 6. The percentage of fruit belonging to the six sunburn classes and with red blush for ‘Granny Smith’ apple harvested from sun-exposed regions under net compared to uncovered control.

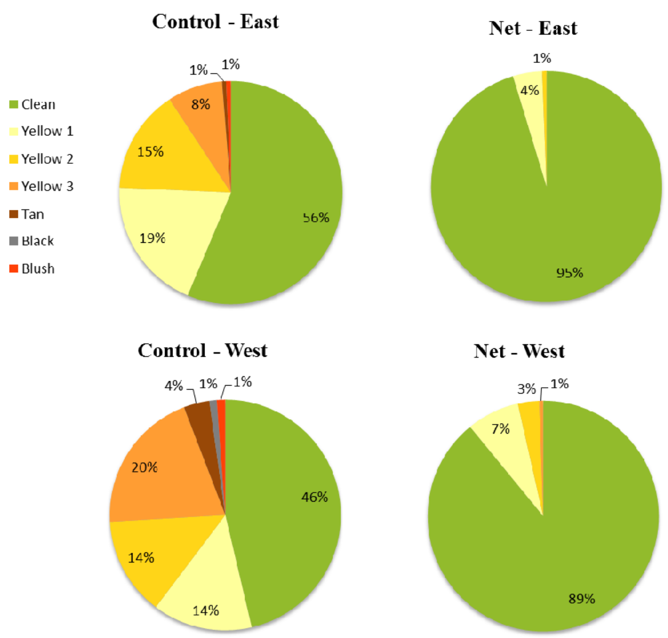

Figure 7. Percentage of fruit belonging to seven sunburn classes for ‘Granny Smith’ apple harvested from either the east or west sides of sun-exposed regions under net compared to an uncovered control.

CONCLUSION

Shade netting can alter the orchard microclimate and reduce stressful conditions caused by excessive light and heat load. Shade nets reduced sunburn damage and soil moisture depletion for 'Granny Smith' apple in the semi-arid environment of Central Washington. Overhead netting represents an important tool for decreasing stress-related losses of marketable fruit for 'Granny Smith' apple.

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