Influence of photo-selective shade netting to improve fruit quality at harvest and during postharvest storage

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ABSTRACT

Avocado fruit quality for marketing can be affected by physical damage due to higher summer temperatures, as well as wind and hail during production. Increase in fruit surface temperature and higher solar radiation can result in sunburn damage and affect the pack-out rate and marketability of the fruits. Exposure of fruits to higher temperatures during growth was reported to show variability in ripening patterns and fruit firmness and can affect the present 'ready to eat' programme.

Commercially used nets help to provide shading and protection against pests; these nets do not alter the light spectral composition. During the 2015 growing season a study was undertaken to investigate the effect of photo-selective coloured shade nets (red leno and pearl leno) (20% shading) on fruit size (diameter), marketable yield, sunburn and wind damage, incidence of diseases and pests on cv. Hass. Open field and widely used common white Knittex nets (20% shading) were utilised for comparison. A Randomised Complete Block Design with five treatments (nets) with six data trees per treatment was included in this study. The irrigation and fertiliser application was carried out according to standard orchard management practices.

The results from the first year data (2015) indicated that the shade nets remarkably reduced the sun damage. The total yield was higher under the blue nets. The white and blue nets (Knittex nets) significantly helped to reduce the defects and improved the pack-out rate. During harvest, white nets had more preferred fruit count (16, 18, 20, 22) for the commercial market. Fruit surface temperatures and the percentage of sun burned fruits were significantly higher in the open field. Fruits from the open field ripened faster. Variation in ripening pattern was noted under the different shade nets. Different coloured shade nets influenced the fruit quality, mainly due to microclimate spectral quality modification.

INTRODUCTION

Higher solar radiation, canopy temperature, wind, hail and limited water resources are major environmental factors affecting avocado production in South Africa. The implementation of net protection to safeguard orchards against excessive solar radiation damage, hailstorms and flying pests (Blanke, 2007) is gaining popularity in modern fruit plantations around the world. Exposure to higher temperatures can cause morphological, anatomical, physiological and biochemical changes in plant tissues. As a consequence, the growth and development of different plant organs can be impacted, with concomitant effects on the yield. Nets are commonly used to protect agricultural crops from either excessive solar radiation, environmental hazards or pests. The pack-out rates for exports are affected due to sunburn, wind and hail at the farm gate, as well as the production of smaller fruits, especially for cv. Hass (Blakey *et al*., 2015).

Producing fruits that meet export standards is beneficial, increasing the export of avocados and providing growers with a good return on investment. However, growing different kinds of fruits such as pome fruit or stone fruits under nets has shown different results with regards to fruit size, yield, pest incidence, plant architecture, fruit ripening and firmness. Shade nets were shown to reduce the fruit growth in 'Royal Gala' and 'Cripp's Pink' apples (Gindaba & Wand, 2005), whereas increased fruit growth was found under shade netting in 'Fuji' apples (Smit, 2007). Shahak *et al*. (2004) reported that a red/white shade net reduced PAR by 18% and increased the fruit set in apple 'Smoothee' 'Golden Delicious', compared with the no-net control. Preliminary studies on pears indicated that shade nets can influence pear fruit size and russeting (Shahak *et al*., 2008). Pearl netting (30%) increased large fruit yield and 26% red netting reduced fruit russeting.

The effects of light conditions on fruit growth have been documented. Brief reduction of light intensity by heavy shading during early stages of fruit growth slowed apple fruit growth rate and induced fruit drop (McArtney *et al*., 2004). Radiation quality can affect both plants and the micro-organisms associated with them. It is reported that exposure of fruits to high temperatures (30-35°C) affected fruit ripening, fruit firmness (by affecting the cell wall composition), cell number and cell turgor properties (Woolf *et al*., 2000). Although not much information is available in South Africa in terms of growing avocados under the different coloured shade nets, Blakey *et al*. (2015) reported that producing avocados ('Carmen Hass' ®) at Mooketsi under the shade nets was beneficial. In regions where the fruits were exposed to higher sun or wind damage, the nets also reduced the wind speed and the rate of evapotranspiration.

Therefore, the objectives of this investigation are to evaluate the effect of different spectral shade nets on micro climate, fruit surface temperature, percentage transmittance of radiation, light quantity, total yield, marketable yield and fruit quality according to different export grades at harvest, as well as the ripening pattern during post-harvest storage.

MATERIALS AND METHODS

Trial site

Lombard Avocado Farm in Tzaneen, Limpopo Province (23.7° South latitude, 30.13° East longitude and 986 m elevation above sea level) was chosen for the study. The farm is situated in New Agatha, Tzaneen. The orchard is affected by sunburn of fruits, by winds and by regular hailstorms.

Trial details of different coloured shade nets and experimental design

The trial was based on cultivar Hass. Randomised Complete Block Design (RCBD) was adopted, each treatment (20% red leno net, 20% pearl leno net [Ginger plastics, Kibbutz, Israel], 20% Knittex white net, 20% Knittex blue net [Knittex Ltd South Africa], no net [open field]) replicated five times in five blocks (Fig. 1). Trees were spaced 7 m by 4 m, south-north (S-N) orientation. The nets were erected horizontally at about 6-7 m above ground. The whole trial occupied about 1.15 ha. Within each net section, only the central six trees in each treatment were evaluated.

Data gathering

Light quantity and microclimate

Light spectra and photosynthetically active radiation (PAR) were measured at noontime (12:00) on clear days with a Black-Comet spectrophotometer (StellarNet Inc., Florida, USA) and Ceptometer AccuPAR model LP-80 (Decagon Devices Ltd, USA) respectively. Plant canopy temperature and relative humidity were also monitored and data was collected by Tinytag T/RH data loggers (Gemini data loggers Ltd, UK). These data loggers were placed within the tree canopy and protected from direct solar radiation. Two fruits from each treatment on data trees were tagged and monitored for surface temperature using Tinytag data loggers (Gemini data loggers Ltd, UK).

Fruit assessment at harvest

Fruits damaged by sun and wind, diseases and pests were recorded from all the treatments at harvest. Total yield (fruit), fruit marketable yield and pack-out rate according to different grades and fruit sizes (in terms of counts) were also recorded after the harvest.

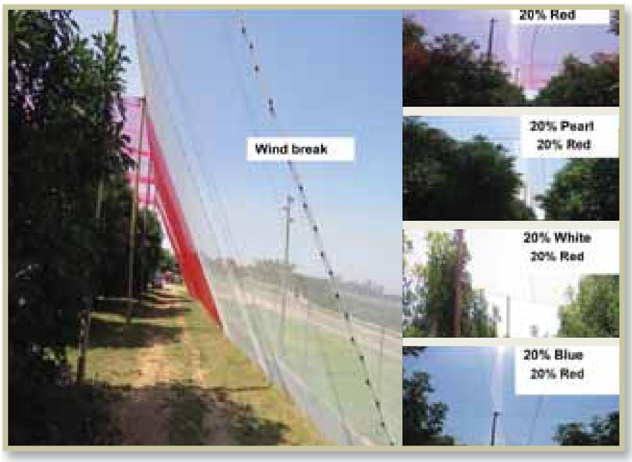

Figure 1. Different coloured spectral nets with 20% shading at Lombard Farm in Tzaneen.

Postharvest trial

Disease-free uniformly shaped or sized fruits without any injuries or defects were selected and a set of 300 fruits per specified colour shade net (red or pearl or white or blue net) and open field were packed for postharvest storage trials. The fruits were laid out in a completely randomised design. Subsequently a set of 14 fruits were packed in commercial cartons and then stored at 5.5°C and 85% RH for 28 days, and thereafter at 25°C to simulate market shelf conditions (postharvest storage). During postharvest storage, the fruits were evaluated for a number of days to ripen and fruit firmness was recorded after storage and at ripe stage. Ripe fruit quality was assessed daily by gentle hand-squeezing. Fruit firmness was measured in two points of the equatorial region of the fruit by using a Chatillon Penetrometer, Model DFM50, with an 8 mm diameter flat-head stainless-steel cylindrical probe (puncture method) and the results were reported in kilograms. Fruit firmness of 1 kg represented soft, ripe fruit (Standard ISO 7619, International Organisation for Standardisation).

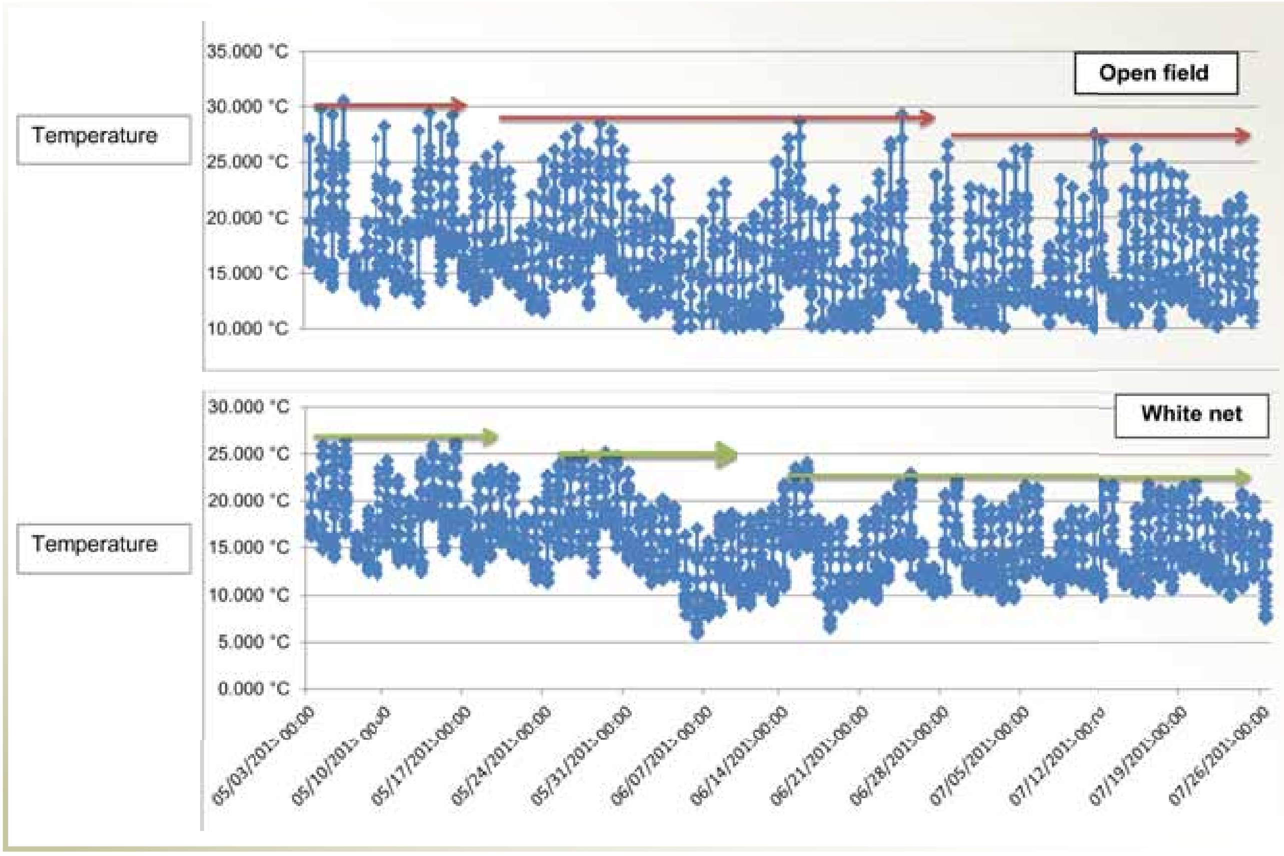

Figure 2. Canopy temperatures in open field and under the white net.

RESULTS AND DISCUSSION

Canopy temperature and light quantity

The canopy temperature was much higher in the open field (30-26ºC) and lower under the red (26-22ºC) and white nets (27-23ºC) during March to July in the 2015 growing season (Fig. 2). Photosynthetically active radiation (400 to 700 nm) is the amount of light available for photosynthesis. The light quantity (PAR) was higher in the open field and less or more or less similar under the 20% shade nets (Fig. 3).

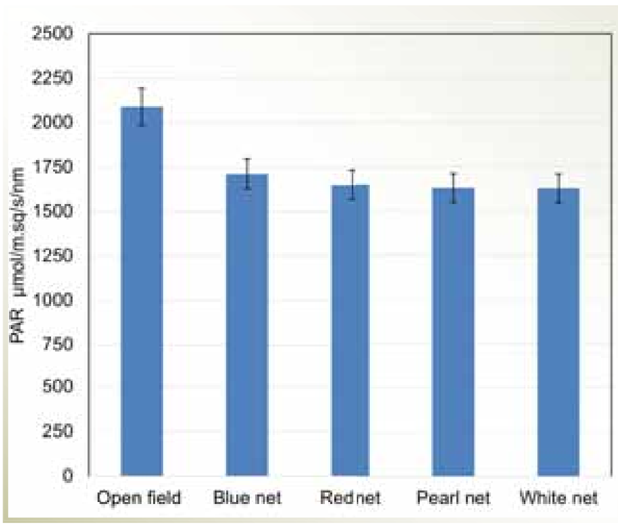

Figure 3. Photosynthetically active radiation under the different coloured shade nets.

Fruit surface temperature, plant canopy temperature and RH

Higher fruit surface temperatures were recorded in the open field compared to the fruit surface temperatures from the net types from March to July in 2015. Overall, the fruit surface temperature showed the following decreasing trend under the nets from March to July 2015: white net< red net< pearl net< blue net< open field. Fruit surface temperatures of open field and under the white nets are given in Figs. 4A and B.

The % transmittance of UV radiation (290-400 nm) was higher in the open field (Fig. 5) and was remarkably reduced under the white nets. It is evident from this study that the fruits from the open field were repeatedly exposed to higher UV radiation during the fruit growth period, which showed an increase in the fruit temperatures from March till the harvest in July.

Fruits matured rapidly in the open field and under the white nets; this was associated with oil content of the fruit (Fig. 6). At harvest, fruits from the shade net had the highest moisture content compared to fruits harvested in the open field (Fig. 3). Oil content of the fruits at harvest was high in the fruits harvested in the open field compared to fruits harvested in the nets (Fig. 6). This could be because the fruits were more mature at harvest than the fruits in the nets. Oil content is known to increase and water content to decrease with increasing maturity. At the same time the moisture content (MC) of fruits produced under the open field was 61% and under the

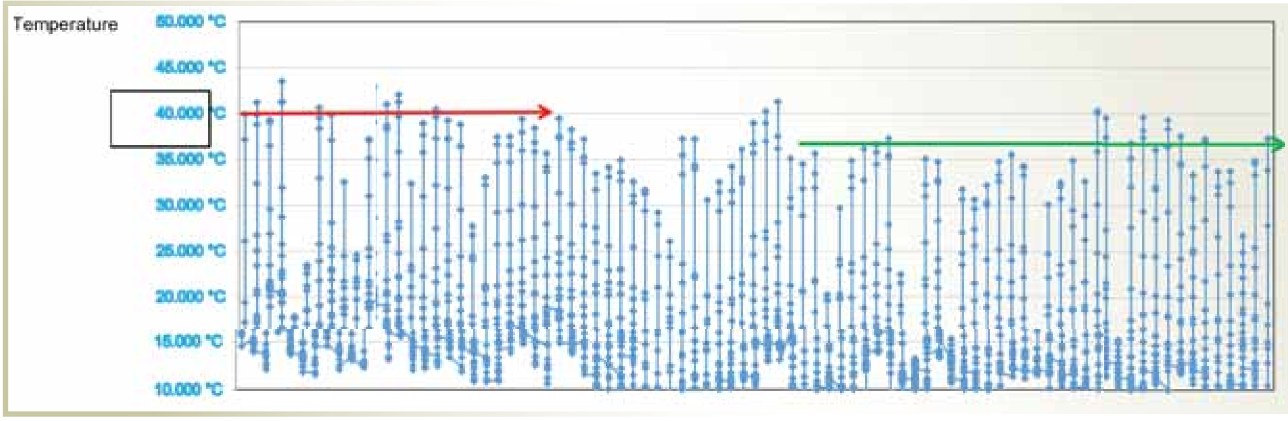

Figure 4a. Fruit surface temperatures in open field.

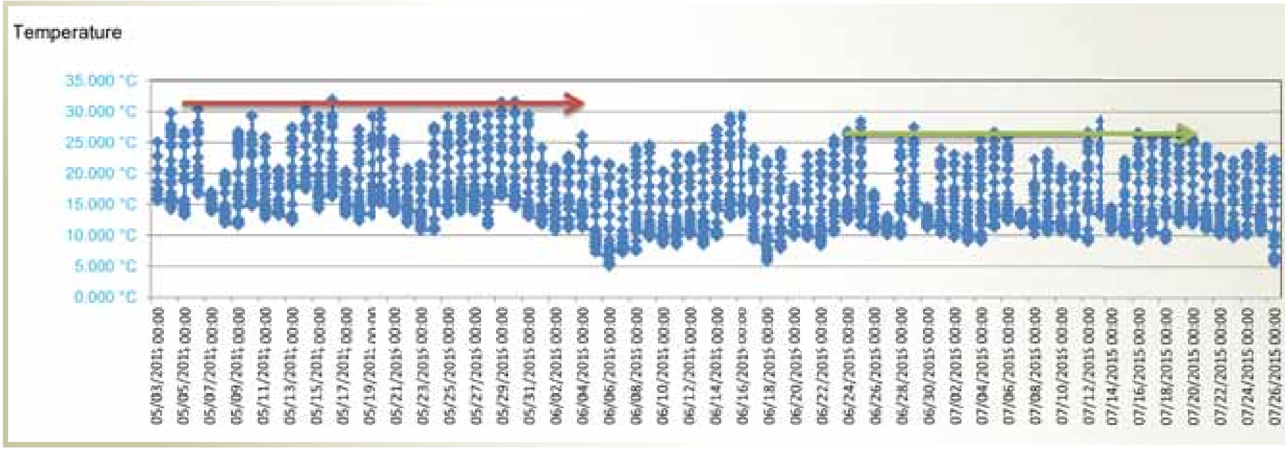

Figure 4b. Fruit surface temperatures under the white net.

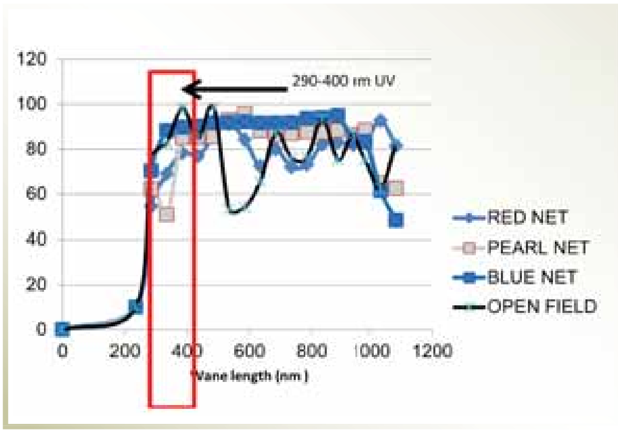

Figure 5. Percentage transmittance of spectral light in open field and under the shade nets.

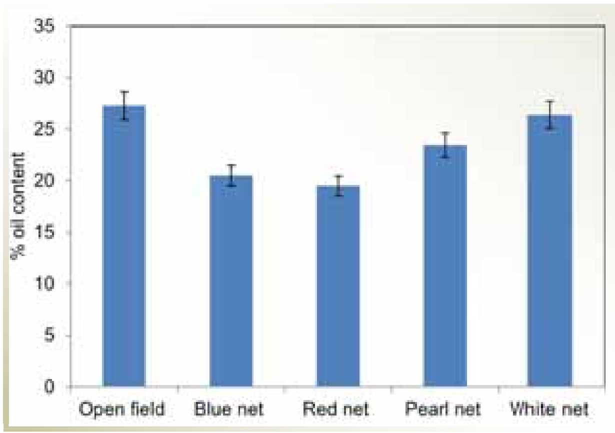

Figure 6. Influence of different coloured shade nets on oil content in fruit.

white shade nets it was 62% MC for the late season cv. Hass; the difference was 1% (Fig. 7). The MC in fruits from the other coloured shade nets (red, pearl and blue) was more or less 65.8% and the difference in MC compared to the open field was 4.8%.

Long term exposure to higher temperatures and an increase in fruit temperatures could have resulted in more fruit maturation and accumulation of oil content in fruits produced in the open field. A similar observation was reported by Woolf *et al.* (1999) in avocados exposed to direct sunlight.

Total yield, pack-out and fruit size distribution

Total yield during the 2015 growing season showed the following trend: blue> white> red net> open field> pearl net. Total yield was around 800 kg/ha under the blue nets, 721 kg/ha under the white nets and 578 kg/ha in the open field (Fig. 8). The pack-out rate was higher under the blue and white nets and 72% of the yields (fruits) under the blue nets were categorised as class 1, whereas under the white nets 81% of the yields (fruits) were categorised as class 1. A high waste (industry grade fruits) was observed

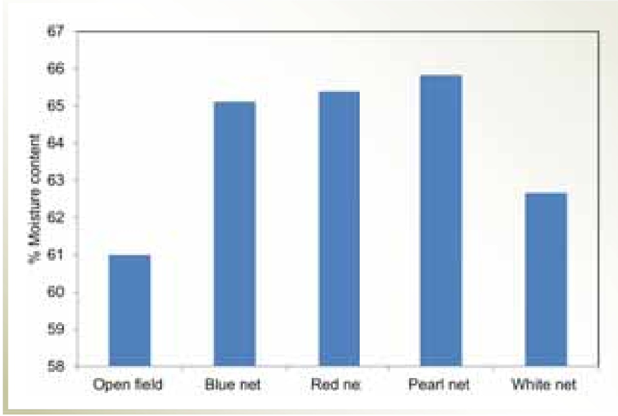

Figure 7. Influence of different coloured shade nets on moisture content in fruit.

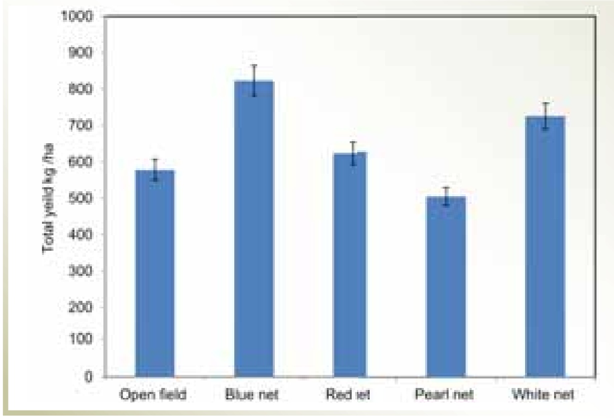

Figure 8. Influence of different coloured shade nets on total fruit yield.

in the open field compared to the nets (Fig. 9). This was mainly due to sunburn damage.

Larger fruits (count 8 or 10) were not observed in the open field or under the different coloured shade nets (Fig. 9). The fruit size distribution of the open field fruits showed 25% count 22 and 15% count 20. Fruit size distribution under the blue nets showed 27% count 18, 17% count 16 and 13% count 20. The fruit size distribution under the pearl net showed 29% count 16, 18% count 18 and 16% count 22. The red nets showed 16% of fruits belonging to count 18, 20 and 22. However, under the red nets counts 28 and 30 (more shifted towards smaller fruit) were around 8%. Under the white nets fruit size distribution was 20% for count 18, 17% for count 22, 15% for count 16 and 17% for count 22. Therefore, under the white nets the shift in fruit size distribution is towards average size (medium) fruits preferred for the commercial market (Fig. 10).

The differences in fruit size distribution could be due to the differences in the distribution of vascular tissue in avocados which could have affected the accumulation of sugars and minerals (Moore-Godon *et al*., 1998).

Postharvest fruit quality

Fruit ripening pattern after harvest and fruit firmness

Fruits from the open field ripened faster than the fruits produced under the shade nets (Fig. 11), while the fruits obtained from the trees grown under the white shade nets ripened faster than the fruits from the other types of shade nets.

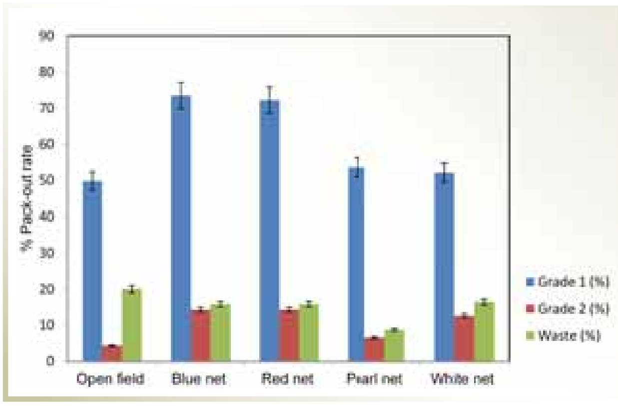

Figure 9. Influence of different coloured shade nets on pack-out rate.

However, when fruit firmness was determined, the fruits from the open field and the pearl nets were firmer. Fruits produced under the white nets showed more or less 1 kg firmness after ripening. Fruit firmness of 1 kg represents soft ripe fruit for the ready to eat programme. The differences in fruit firmness during ripening are shown in Fig. 12.

The results of this study showed significant differences between the fruits from the open field that were exposed to the sun and those under the shade nets with respect to parameters such as ripening pattern and fruit firmness determined in the study. Exposure of fruits to higher temperatures in the open field could have resulted in biochemical changes and affected the rate of fruit respiration and emission of ethylene, the natural ripening hormone.

Higher dry matter and oil content observed in fruits produced in the open field indicate that the fruits can be harvested earlier and they most likely will have the desired flavour. On the other hand: if the fruits are exposed to higher temperatures during ripening, they can become intensely coloured or unevenly coloured to meet the marketing standards. Moreover, fruits from the white nets ripened faster; this means they would be suitable for the ready to eat ripening programme.

In conclusion: pack-out rate is severely affected due to sun damage. Growing cv. Hass avocados under the white (Knittex) nets could provide a solution, reducing the sun burn damage and improving the pack-out rate. However, as mentioned by Blakey *et al*. (2015), measures should be in place to improve the pollination in order to meet the projected total yields at harvest.

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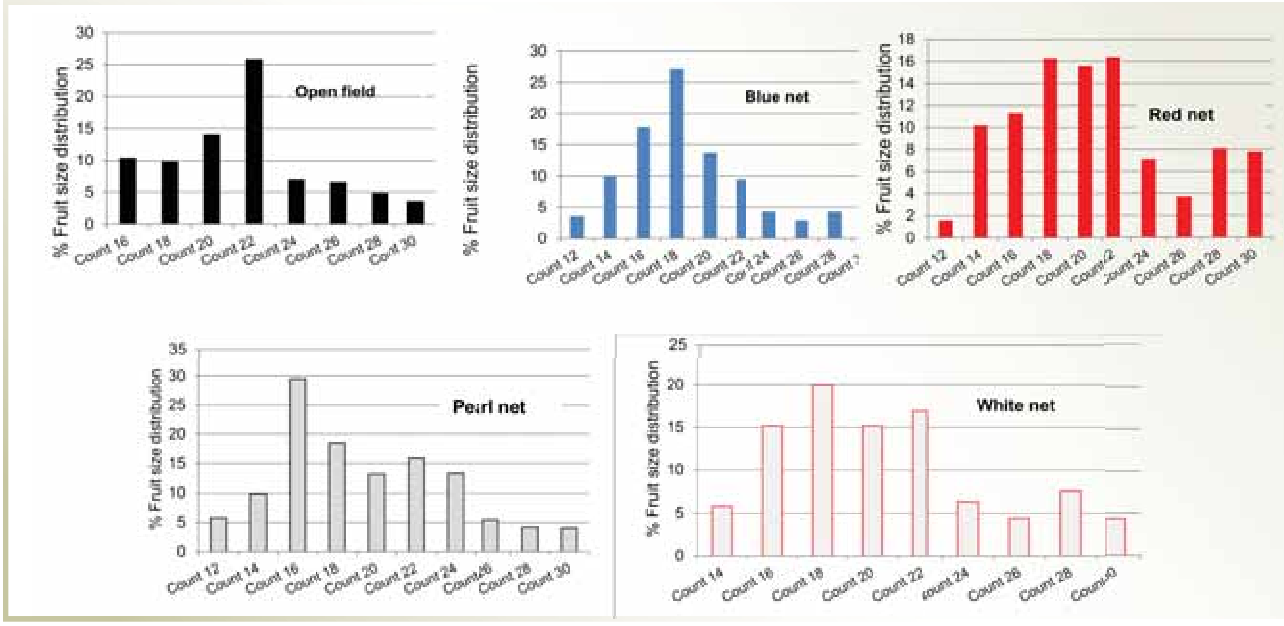

Figure 10. Fruit size distribution for March to July cv. Hass from Lombard farm. Smaller fruit has larger number (counts).

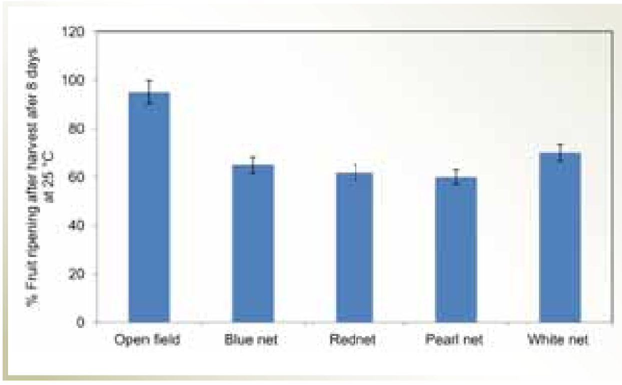

Figure 11. Effect of different coloured shade nets on percentage of fruit ripening at harvest at 20°C.

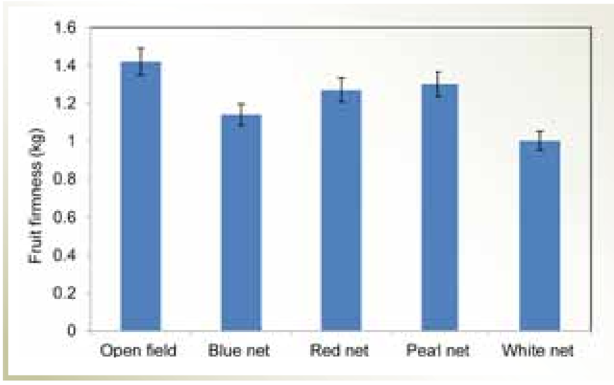

Figure 12. Effect of different coloured shade nets during ripening on fruit firmness at harvest at 20°C.

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