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Research Paper

Growing ‘Hass’ avocado fruit under different coloured shade netting improves the marketable yield and affects fruit ripening

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ABSTRACT

Sunburn damage due to excessive solar radiation is one of the major problems affecting the avocado fruit production. Shade netting has been introduced so that growers can cover their orchards with the nets to protect their trees/fruit. However, little is known on the effect of different coloured shade netting on avocado fruit quality. Thus, the influence of blue, red and white photo selective netting on marketable yield, physicochemical characteristics and incidence of anthracnose in ‘Hass’ avocado fruit was investigated. Blue and white netting improved the marketable yield, and accelerated fruit ripening after 28 d cold storage at 5.5 °C followed by 5 d at shelf-life conditions. Ripening, as indicated by fruit softening, correlated well with the content of D-mannoheptulose. The concentration of α–tocopherol, oleic acid and phenolic acids was also affected by growing conditions, due to different coloured shade netting being used. However, incidence of anthracnose was reduced on the 5th d at shelf-life conditions due to delayed ripening, higher phenylalanine ammonia lyase activity, and epicatechin content in the pericarp. White and blue netting appear to be a suitable pre-harvest tool to improve the marketable yield.

1. Introduction

The avocado fruit (*Persea americana* Mill.) is popular among the consumers worldwide, especially due to being rich in nutrients, e.g. unsaturated fatty acids (Dreher and Davenport, 2013). However, not many people are aware of the problems during the fruit production associated with the environmental conditions, i.e. high solar radiation, wind and hail. It has been previously reported (Blakey et al., 2015) that growing avocados under the shade netting protects the fruit from excessive sun, thus reducing the incidence of sunburn. This has encouraged an increasing number of growers to cover their orchards with the nets to protect their trees/fruit. It is well known that coloured shade netting not only alters the light quality and quantity, but also affects the air movement, temperature and humidity (Stamps, 2009).

Different coloured shade netting may affect the fruit quality, as has already been reported for apples (Solomakhin and Blanke, 2010; Amarante et al., 2011), kiwi (Basile et al., 2012), mandarin (Lee et al., 2015), plums (Murray et al., 2005), and tomato (Ilic et al., 2012) fruit mainly due to the phytochromes (red/far red light receptors), cryptochromes and phototropins (blue light receptors) mediated responses that may involve the upregulation of specific genes, e.g. those responsible for the biosynthesis of phenolic compounds during the fruit growth. However, to the best of our knowledge there are no reports describing the effects of coloured shade netting on the quality of avocado fruit. Thus, taking into account the size of the avocado industry in the South Africa (according to the food trade and supply chain directory (www.foodtradesa.co.za) ~13,000,000 boxes of avocados are exported from South Africa annually), the objective of this study was to compare i) the marketable yield (pack–out rate) of ‘Hass’ avocado fruit grown under the blue, red and white netting with those grown in the open field (without netting), ii) their physicochemical characteristics (fruit firmness, biochemical composition) and iii) incidence of anthracnose and, phenylalanine ammonia lyase (PAL) and epicatechin content in the pericarp after 28 d of cold storage at 5.5 °C followed by 5 d at 20 °C.

2. Materials and methods

2.1. Trial details

Lombard Avocado farm in Agatha, Tzaneen, Limpopo Province (23.7° South latitude, 30.13° East longitude, 986 m above the sea level) was chosen for the study. The orchard has a history of being affected by strong winds and regular hailstorms, and fruit suffering from sunburn, thus it seemed ideal for the investigation of this type. A randomised complete block design was adopted, with each of the following treatments: 1. 20% Knittex Blue net (Knittex Ltd, South Africa), 2. 20% Red

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Table 1
Spectral quality of transmitted light under the different coloured shade nets.

	B/R	% difference relative to open field	R/FR	% difference relative to open field	UV	% difference relative to open field	PAR (μmol m^{-2} s^{-1})	% difference relative to open field
Open field	1.11a		0.95a		98.49a		745a	
Red net	1.35b	−21.62	0.90a	5.23	88.30b	10.34	678b	8.9%
White net	0.83c	25.23	0.80b	16.78	66.64c	32.30	558c	25.1%
Blue net	0.78c	29.72	0.81b	14.73	65.33c	33.67	552c	25.9%

Means in each column followed by the same letter are not significantly different at $P < 0.05$.

Leno net (Ginger plastics, Kibbutz, Israel), 3. 20% Knittex White net (Knittex Ltd, South Africa), 4. Control – open field (without netting) replicated five times in five blocks. Trees were spaced 7.0 m by 4.0 m using South-North orientation. The nets were erected horizontally at about 6.0-7.0 m above the ground. The experiment included 4 data trees per treatment. The distance between the rows, row length and row width were 7.0 m, 17.5 m and 21.0 m respectively. Irrigation and fertiliser application were carried out according to standard orchard management practices recommended by the South African Avocado Growers' Association. Spectral quality of transmitted light under the different coloured shade netting, plant canopy temperature and relative humidity were recorded as described by Buthelezi et al. (2016) and are given in Table 1. Two fruit from each treatment on 'data trees' were tagged and monitored for surface temperature using Tinytag temperature and relative humidity data loggers (Gemini data loggers Ltd, UK). Data loggers were placed within the tree canopy and protected from direct exposure to solar radiation.

2.2. Fruit assessment at harvest

Late season 'Hass' avocado fruit were harvested at dry matter content being in the range of 34–38%. Fruit with signs of damage either due to excessive solar radiation (sunburn) or with physical injuries (wind, diseases and pests, etc.) were considered unmarketable and were categorised as 'waste'; the number of fruit in this category was recorded. The marketable yield (%) was recorded as a% of sound fruit out of all fruit.

2.3. Storage trial

A set of 420 unblemished uniformly shaped and sized green fruit were selected for each of the treatment, i.e. from under the blue, red and white netting, and from the open field, respectively. Fruit were packed into standard commercial cartons – count 14. Subsequently, a set of 30 cartons of fruit from each replicate net (e.g. red 1, red 2, red 3) were laid out in a completely randomised design at 5.5 °C and 85% RH for 28 d (low temperature storage), followed by 5 d at 20 °C.

2.3.1. Fruit firmness

Fruit firmness was determined after 5 d at shelf-life conditions, as previously reported (Glowacz et al., 2017) by recording the firmness measured at the equatorial region of the fruit with a Chatillon Penetrometer, Model DFM50 (Ametek, Largo, Florida, USA), using a 8 mm diameter flat-head stainless-steel cylindrical probe; the results were reported in kilograms. Based on the fruit firmness readings, fruit were classified into three different groups, i.e. 'ripe and ready to eat' (firmness of less than 1.0 kg), 'firm ripe' (firmness within the range of 1.0–1.5 kg), and 'unripe' fruit (firmness above 1.5 kg). The% of fruit falling into different groups was then calculated.

2.3.2. Biochemical analyses

Fruit were assessed after 5 d at shelf-life conditions. The analyses included quantification of D-mannoheptulose, fatty acids, α-tocopherol, phenolic acids and antioxidant activity and capacity. Determination of D-mannoheptulose, fatty acids, and phenolic acid composition was performed as previously described (Glowacz et al., 2017), while α-tocopherol content was determined according to the method used by Lu et al. (2009). Briefly, 2 g of freeze-dried mesocarp was homogenised for 1.5 min at 4 °C with 4 mL of acetone and 0.05% (w/v) 2, 6-di-*tert*-butyl-4-methylphenol (BHT), 0.2 g Na_2CO_3 and 2 g of Na_2SO_4. The resulting mixture was concentrated and subjected to saponification and partition into dichloromethane (2 mL) and water and subjected to the HPLC analysis.

2.3.3. Incidence of anthracnose, phenylalanine ammonia lyase activity (PAL) and epicatechin content

Incidence of postharvest diseases were recorded after 5 d at shelf life conditions according to Bill et al. (2017). The exocarp of the fruit were frozen in liquid nitrogen and held at −80 °C until use. For the quantification of epicatechin content, samples were freeze dried as described by Bill et al. (2017). and 5 g of the freeze dried sample were extracted in 40 mL of 70% (v/v) methanol (MeOH). The epicatechin content in the exocarp was determined using the method described by Bill et al. (2017). PAL enzyme activity was conducted adopting the previously described methodology (Sellamuthu et al., 2013) by incubating enzyme extract (75 μL) with 150 μL of borate buffer (50 mM, pH 8.8) containing 20 mM l-phenylalanine for 60 min at 37 °C. Subsequently the 75 μL of 1 M HCl was added into the mixture to stop the reaction and the PAL enzyme activity was expressed as nmol cinnamic acid h^{-1} mg of protein^{-1}.

2.4. Statistical analysis

The experiment was conducted twice, i.e. in 2015 and 2016. Since there was no significant difference between the data obtained over the two years, data were pooled and subjected to analysis of variance (ANOVA). Significant differences among the treatments were determined using Fisher's protected LSD (least significant differences) test at the level of significance of 5%. Pearson's correlation coefficient was calculated to estimate the strength of the linear relationship between the fruit firmness (softening) and the concentration of D-mannoheptulose.

3. Results

3.1. Conditions under the coloured shade netting

As expected, coloured shade netting altered light quality reaching the trees. The photosynthetic radiation (PAR) was ~25% and ~26% lower under the white and blue Knittex nets respectively, whereas it was only reduced by around 9% in the case of Red Leno net (Table 1). Similar trend was observed for UV light, where both blue and white Knittex nets reduced the radiation by around 32–34%, compared to ~10% under Red Leno net. The fruit surface and canopy temperatures were reduced under the blue and white Knittex nets, while relative humidity was increased (Table 2).