Growing avocados under shadenetting
– Year 3

RJ Blakey[1], Z van Rooyen[1], JS Köhne[1], KC Malapana[2], E Mazhawu[2], SZ Tesfay[2] and MJ Savage[2]

[1]Westfalia Technological Services, Tzaneen, SOUTH AFRICA
[2]School of Agricultural, Earth and Environmental Science,
University of KwaZulu-Natal, Pietermaritzburg, SOUTH AFRICA
Private Bag X01, Scottsville 3209, SOUTH AFRICA

ABSTRACT
There is a global trend in high intensity horticulture, including high density planting, use of superior cultivars, greater plant manipulation and protected cultivation. Avocado growers have only recently started using protected cultivation and still need to determine the technical details of this type of cultivation.

Following on from previous reports, at Mooketsi, there was little difference in the air and canopy temperature in summer, but the winter maxima were 0.8°C and 3.3°C lower under the shade net. At Karkloof, the air temperature was between 0.5°C and 0.9°C higher under the shade net, but with a higher relative humidity. The shade net reduced wind speed to negligible levels and also reduced the rate of evapotranspiration.

The shade net resulted in improved fruit quality due to reduced wind damage and sunburn, particularly of the 'Mendez #1' ('Carmen®-Hass') at Mooketsi. Concerns remain about bee activity and pollination but this is being addressed to be able to provide a holistic commercial recommendation. The design and strength of the structures have yet to be tested by a hail storm.

INTRODUCTION
This report follows after year two's report (Blakey *et al*., 2015) and details the findings from this project between February 2015 and February 2016.

Shade netting over an orchard modulates the micro-climate in the orchard, making the environment more conducive for fruit production and reducing fruit quality defects (Smit, 2007). South Africa is a water-scarce country, with high variability in annual rainfall (Blignaut & Van Heerden, 2009). A shade-netting structure has potential to address these limiting factors.

The South African avocado industry is export-orientated, with approximately 40% of the total production volume being exported (Blakey & Wolstenholme, 2014). Export offers a significantly higher return for the grower. Therefore, it would be commercially advantageous for a grower to improve the class 1 percentage above the current average of about 60%. Sunburn, wind damage and small fruit size (particularly in 'Hass') are the major cull factors limiting the production of export grade avocados in South Africa.

Shade netting is widely used on deciduous fruit crops and citrus, but avocados have crop-specific challenges that need to be addressed before shade netting can even be considered for use on a commercial scale. The challenges include: tall trees with large inter-row spacing, the synchronous dichogamy flowering pattern, a protracted flowering period, vigorous vegetative growth and relatively low yields per ha.

As part of a multi-site long-term study, the following questions will need to be answered before the large scale use of shade nets over avocados is considered:

- How is cultural management affected?
- How are flower development, pollinators and pollination affected by the nets?
- How are yield, fruit quality and fruit maturity affected?
- What is the best structure design and how long does it last?
- What is the expected return on investment?

MATERIALS AND METHODS

Trial sites
Two Westfalia Fruit farms were used for the trial: Mooketsi, Limpopo Province (23°40'54.59"S, 30°01'50.67"E) and Karkloof, KwaZulu-Natal Province (29°26'36.88"S, 30°16'21.33"E). Further details about the sites are provided in Table 1.

Table 1. Trial details for shade net trials at Mooketsi and Karkloof.

Location	Cultivars	Covered area	Spacing	Shade net	Height
Mooketsi	Mendez #1 ('Carmen®-Hass')	1 ha	3 m x 3 m[1] 6 m x 3 m[2]	Roof: 20% white Sides: 40% green	6 m
Karkloof	3-29-5 ('Gem®')	1.5 ha	7 m x 4 m	30% crystal	6 m

[1]Trees were thinned to 6 m x 3 m in March 2015.
[2]Trees were thinned to 6 m x 3 m in May 2013.

Measurements

Automated weather stations were installed at Mooketsi and Karkloof according to Savage (2012) to measure and record the following:

- Air temperature (U23 logger, Onset Computer Corporation, MA, USA).
- Relative humidity (U23 logger, Onset Computer Corporation, MA, USA).
- Canopy temperature (SI-121 infrared radiometer, Apogee Instruments Inc., UT, USA).
- Wind speed (03101-L Anemometer, Campbell Scientific Inc., UT, USA).
- Solar irradiance (CMP3 pyranometer, Campbell Scientific Inc., UT, USA).
- Leaf wetness (LWS leaf wetness sensor, Decagon Devices Inc., WA, USA).
- Rainfall (Rain-O-Matic tipping bucket rain gauge, Pronamic ApS, Denmark).

Measurements were taken every 30 seconds and the average and record every 20 minutes.

Soil matrix water potential is recorded three times per week using tensiometers at depths of 30 cm and 60 cm. Tree phenology was monitored according to the following measurements:

- Timing and length of vegetative shoot growth;
- leaf area was measured on 50 leaves per treatment fortnightly. ImageJ (National Institute of Mental Health, MD, USA) was used to quantify leaf area after leaves were scanned on a flat-bed scanner;
- flowering intensity, timing and pattern, as well as bee activity; and,
- fruit moisture content was measured gravimetrically on 10 fruit weekly or fortnightly.

RESULTS AND DISCUSSION

Microclimate

A summary of the effect of shade net on microclimate is provided in Table 2 and Table 3.

At Mooketsi, the air temperature and relative humidity have been modified slightly under shade net, with the most pronounced differences in winter (air temperature 0.8°C lower and canopy temperature 3.3°C lower under shade net). This could be beneficial for pollination because 'Carmen®-Hass' flowers in mid-winter, when conditions are not favourable for pollination. At Karkloof, the summer maximum is 0.9°C higher and the winter maximum 0.5°C higher under the shade net, but with a higher relative humidity indicating a lower vapour pressure deficit (VPD) which should reduce evapotranspiration under the shade net. The winter maximum canopy temperature was 0.6°C lower under the shade net, and there was no difference in the winter minimum canopy temperatures. Unfortunately, the infrared radiometer failed in January 2015.

The average wind speed at both sites is low but constant. Under the shade net the wind speed has been reduced to negligible levels. At Mooketsi especially, this has resulted in reduced damage to leaves (Fig. 1) and fruit (Fig. 3). Due to cultivar differences between 'Carmen®-Hass' and 3-29-5 ('Gem®'), where 'Gem®' bears fruit inside the canopy and 'Carmen®-Hass' on the outside, the wind damage to 'Gem®' fruit outside the net is lower, and so the shade net has less of an effect.

The solar irradiance at both sites has been reduced by a similar percentage, even though the shading percentage of the net at Karkloof is 10% higher.

The leaf wetness duration (LWD) was 12% longer at Mooketsi. At Karkloof, the LWD was 7% longer in the open. The deviation occurred between midnight and 08:00.

A significant finding for Mooketsi, where cultivation is restricted by water availability, is that the evapotranspiration (ET) was reduced by 14% in 2015 and 29% less water was applied to maintain the soil matric water potential at acceptable levels. It must be noted that a compost mulch (60 L/tree) was applied in the third quarter of 2014 and eucalyptus wood chips (100 L/tree) were applied in mid-2015 to reduce soil water loss, because the tree condition outside the net declined (in part) due to transient day-time water stress. The evapotranspiration at

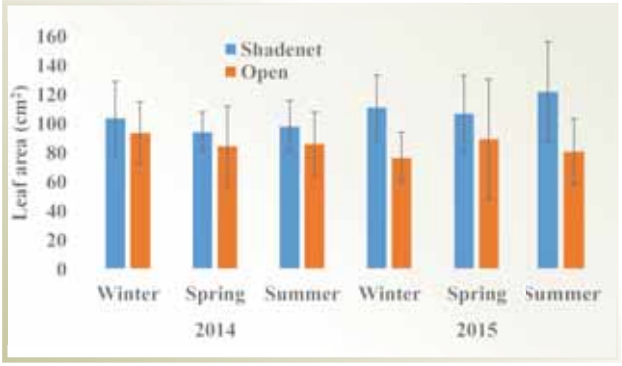

Figure 1. Leaf area from three flushes in 2014 and 2015 for 'Carmen®-Hass' trees grown under shade net and the open trees at Mooketsi.

Table 2. Minimum and maximum air temperatures (T_{air}), canopy temperatures (T_{canopy}), and relative humidity (RH) in summer and winter for the two trial sites at Mooketsi and Karkloof, South Africa.

		Mooketsi				Karkloof			
		Summer[1]		Winter		Summer		Winter	
Parameter	Treatment	Min	Max	Min	Max	Min	Max	Min	Max
T_{air} (°C)	Open	19.5	30.0	9.3	24.8	15.8	25.4	6.6	19.4
	Shadenet	19.4	30.4	9.4	24.0	15.9	26.3	6.5	19.9
T_{canopy} (°C)	Open	18.7	29.9	11.4	26.6	16.7	25.2	6.3	17.9
	Shadenet	19.1	31.2	11.3	23.3	-[3]	-	6.3	17.3
RH (%)[2]	Open	89.4	54.0	82.8	35.6	97.6	73.6	82.0	47.5
	Shadenet	89.8	54.9	83.7	39.8	97.2	76.7	82.3	49.1
Time of day of min/max		05:00	14:00	05:00	13:00	05:00	12:00	05:00	13:00

[1] Summer measurements from January and winter measurements from June.
[2] Minimum RH occurs at maximum air temperature and vice versa.
[3] No data because of instrument failure.

Table 3. The effects of shade net on microclimate at Mooketsi and Karkloof in 2014/15. All values are in reference to shade net compared to the uncovered orchard.

	Mooketsi	Karkloof
Wind speed (WS)	Maximum reduced from 3.5 m/s to 0.6 m/s	Maximum reduced from 4.0 m/s to 0.1 m/s
Solar irradiance (SI)	Midday SI reduced by 18%	Midday SI reduced by 19%
Leaf wetness duration (LWD)	12% higher	7% lower
Evapotranspiration (ET)	14% lower	19% lower

[1]Average monthly temperatures in January (summer) and June (winter).

Karkloof was reduced by 19% but due to the higher annual and winter rainfall at Karkloof, supplemental irrigation is only used a few times a year, and no difference is expected.

Fruit maturity

The same trend with regards to the 2014 and 2015 season was observed whereas the 'Carmen®-Hass' fruit at Mooketsi reached the (South African) legal minimum maturity level of 77% MC [(23% dry matter :DM)] two weeks earlier under the shade net compared to the open orchard. The treatments were harvested together in week 14 in 2014, week 13 in 2015 and week 11 in 2016 (data not presented). 'Gem®' fruit at Karkloof are harvested for the late season market. Minimum fruit maturity is therefore not a concern at Howick because fruit are left on until Nov-Dec.

Yield, packout, fruit size distribution, and fruit quality

Mooketsi

As with the previous seasons, the two standout results at Mooketsi are still (i) the much-improved packout achieved under the shade net, contrasted with (ii) the poor yields achieved under the shade net, especially in the wider spacing (2). As mentioned in previous reports, the improved packout is due to a reduction in sunburn, wind damage and small fruit – the major cull factors at Mooketsi. Like 'Hass', 'Carmen®-Hass' fruit is generally medium to small. Under the shade net the fruit were generally larger than those grown in the open (Fig. 2), but it is acknowledged that fruit size distribution (FSD) is greatly affected by yield. A conclusion on FSD and yield will only be possible once we have tailored the cultural management – especially pollination – of avocados under shade net to obtain much higher yields.

Karkloof

Blakey *et al*., 2015, indicated that there was an 8% increase in Class 1 fruit under the net vs. the open orchard for the 2014 season. Figure 3 demonstrates

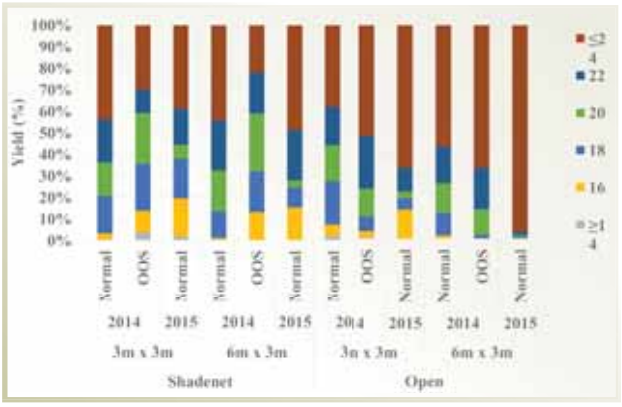

Figure 2. Fruit size distribution for 2014 and 2015 normal season (March) and 2014 out-of-season (OOS - November) for 'Carmen®-Hass' from Mooketsi. Larger fruit have a smaller count number.

the same trend with a 5.9 % (1.4 ton) increase in Class 1 fruit under the net vs. the open orchard for the 2015 season. From Figure 3 it can be deducted that there is not as much a difference between the volumes of Class 1 fruit under the net vs. open orchard. This is to be expected as 'Gem®' bears its fruit on the inside of the tree. There was a 4.7 ton/ha yield difference between the 2014 and 2015 season with regards to the open orchard due to frost experienced during flowering.

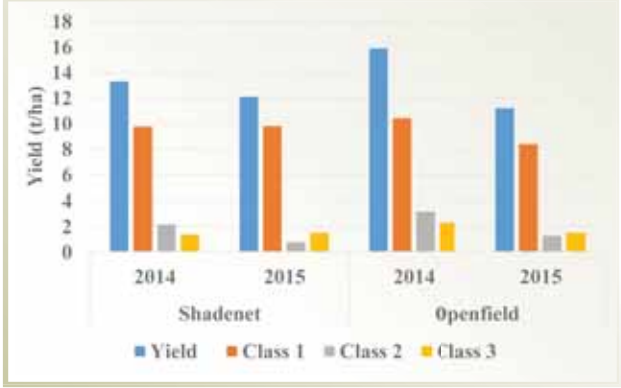

Figure 3. Yield data for Karkloof 2014 and 2015 seasons.

It was also stated that there was a shift in the fruit size distribution (FSD) from very large fruit (count 8 and 10) under the net towards more medium size fruit (count 12) for the 2014 season. The 2015 season did not achieve the same results. Larger fruit (count 10 and count 12) was more prevalent under the net, regardless of the higher crop load. Outside the net, medium size fruit (count 12 and count 14) was more prevalent regardless of a smaller crop load. These results are demonstrated in Figure 4.

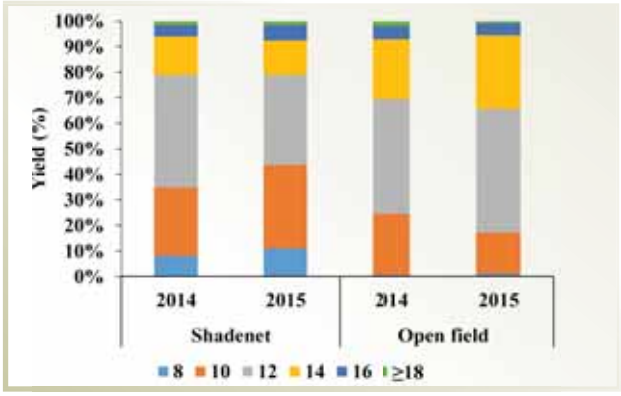

Figure 4. Fruit size distribution (FSD) for Karkloof 2014 – 2015 season.

Bee activity

It was concluded that there was insufficient bee activity under the shade net (especially at Mooketsi) with four hives under the shade net to set an adequate crop in 2014 and 2015. The 3 m x 3 m spacing was also too close for bees to navigate down the rows. As such, an intensive effort has been put in to better understand pollination and bee activity in this study. Ten bee hives were placed under the shade net at Mooketsi and 20 hives at Karkloof during flowering in 2015. At the time of publication, the trees at Mooketsi had not been harvested, as well as Karkloof, to determine if an adequate crop was set in the 2016 season. As such, there are no definite results available for this manuscript, but it has been noticed that there were more bees visiting the trees under the shade net at Mooketsi, compared to the open orchard.

FUTURE WORK

The 2016/17 season will be the final year of this project. The main focus of the last year will be on the cultural management of the orchards under the net and bee management under nets. The yield and fruit quality will again be measured. This would aid in answering and making recommendations on questions 1, 2 and 3 in the introduction section of this report. In order to recommend on the best structure design, it is unfortunate to say, but a hail storm is needed. In an absence of hail, the feasibility study will concentrate more on benefits directly related to packout and yield (if any).

CONCLUSION

There are promising results in this shade net study in terms of improving fruit quality and modifying the micro-climate. As with any method to modify the natural environment for agriculture, additional effort and energy is required to maintain the desired state and any mistakes are amplified, compared to lower intensity forms of farming. The major challenge with growing avocados under shade net is to optimise pollination to obtain high yields (along with a high packout) to make the shade net structures economically viable. We are confident this will be achieved and conclusive results will be obtained in the medium-term.

ACKNOWLEDGEMENTS

Thanks to the South African Avocado Growers' Association (SAAGA) and Westfalia Fruit Estates for funding, the Hans Merensky Foundation for providing bursaries to K.C. Malapana and E. Mazhawu, and J. van Eyk and C. Hackney for their assistance on the farms.

REFERENCES

BLAKEY, R.J. & WOLSTENHOLME, B.N. 2014. '35 Years of the SAAGA Yearbook: A Review', p.155, DOI: 10.13140/2.1.4156.7040.

BLAKEY, R.J., VAN ROOYEN, Z., KÖHNE, J.S., MALAPANA, K.C., MAZHAWU, E., TESFAY, S.Z. & SAVAGE, M.J. 2015. Growing Avocados under shade netting. Progress report - Year 2. *South African Avocado Growers' Assosiation Yearbook* 38: 76-79.

BLIGNAUT, J. & VAN HEERDEN, J. 2009. The impact of water scarcity on economic development initiatives. *Water SA* 35: 415-420.

SMIT, A. 2007. Apple tree and fruit responses to shade netting. MScAgric, Stellenbosch: University of Stellenbosch.