Productivity research in NZ, moving towards a collaborative learning environment

A. Vidiella, P. West, D. Vanderheijden

New Zealand Avocado Growers' Association, Tauranga, New Zealand

A comprehensive R&D programme has been developed by NZ Avocado in the last two years. The programme is aligned to the industry strategy and is aimed to optimize the productivity of our orchards to meet customer needs.

The programme has a holistic approach to productivity, intending to identify and understand the main factors that limit productivity in our main production areas. Understanding that integrating scientific and local knowledge in this process is highly desirable and notoriously difficult to achieve, the programme is based on coproduction principles, with a significant portion of stakeholders involved in the development of the programme during all of its stages. This approach is having a significant impact on the programme, mainly directing it in the right direction, increasing its effectiveness, and developing, sharing and implementing new knowledge from the onset of the programme.

Following a preliminary analysis of the factors that seem to affect productivity in NZ, the factors were prioritized considering the impact that addressing them would have on productivity. This led to a plan that has allowed the programme to increase the investment in R&D in avocados in New Zealand four times in the last two years, with the consequent increase in capability, with Plant & Food Research being instrumental in this process.

INTRODUCTION

As in the majority of orchards around the world, in New Zealand avocado production has been erratic in most of its orchards as data per orchard held by the industry demonstrates. Detailed analysis of this data has shown that among this majority of orchards that have erratic production there are a number with high productivity. Geographic analysis shows that most of these high productivity orchards are scattered through the country and often surrounded by other orchards that are not producing well.

Analysis of high productivity orchards and their neighbours has highlighted the areas in which research and development activities need to be developed to identify and understand their differences. The hope is that the effort of identifying and these differences will allow for the development of management strategies that will impact positively on productivity.

MATERIALS AND METHODS

NZ Avocado keeps records of annual production of every orchard that exports fruit. An Orchard Performance Chart was developed to map the orchards according to their productivity, i.e. their yield and regularity. In this chart orchard can be plotted as a dot were the y axis is the average annual yield in t/ha for a number of years and the x axis is the average irregular bearing index (absolute value of yield of year one minus yield of year two divided by the sum of the yield of year one and the yield of year two), with 0 being consistent production while 100 is absolute alternate bearing (Figure 1).

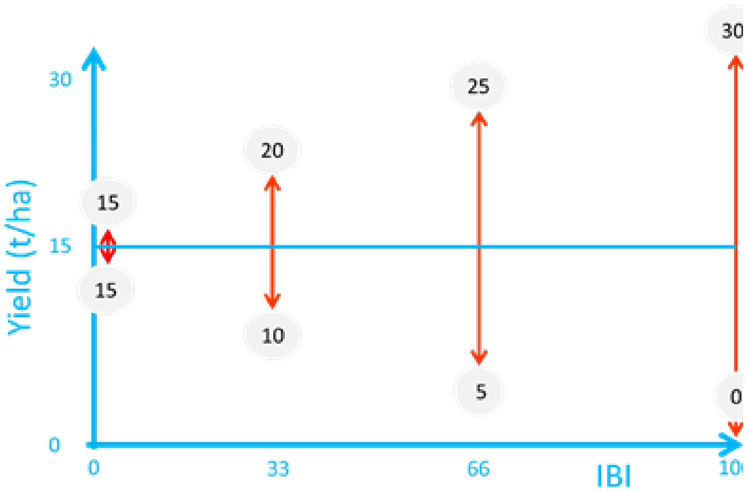

Figure 1. Orchard Performance Chart showing the increase in the range of annual yield with increasing IBI for an orchard with average annual yield of 15 t/ha

The Orchard Performance Graph was used to map the industry orchards using the historical data recorded for each orchard (Figure 2). The period of time that was used to map the industry was 2011 to 2013 The plotting area was divided in three parts, each area representing a different performance degree. The orchards that fall on the top area belong to what we have denominated as our high productivity or "best" orchards, the middle area groups the "good" orchards, and the bottom part groups the "standard" orchards.

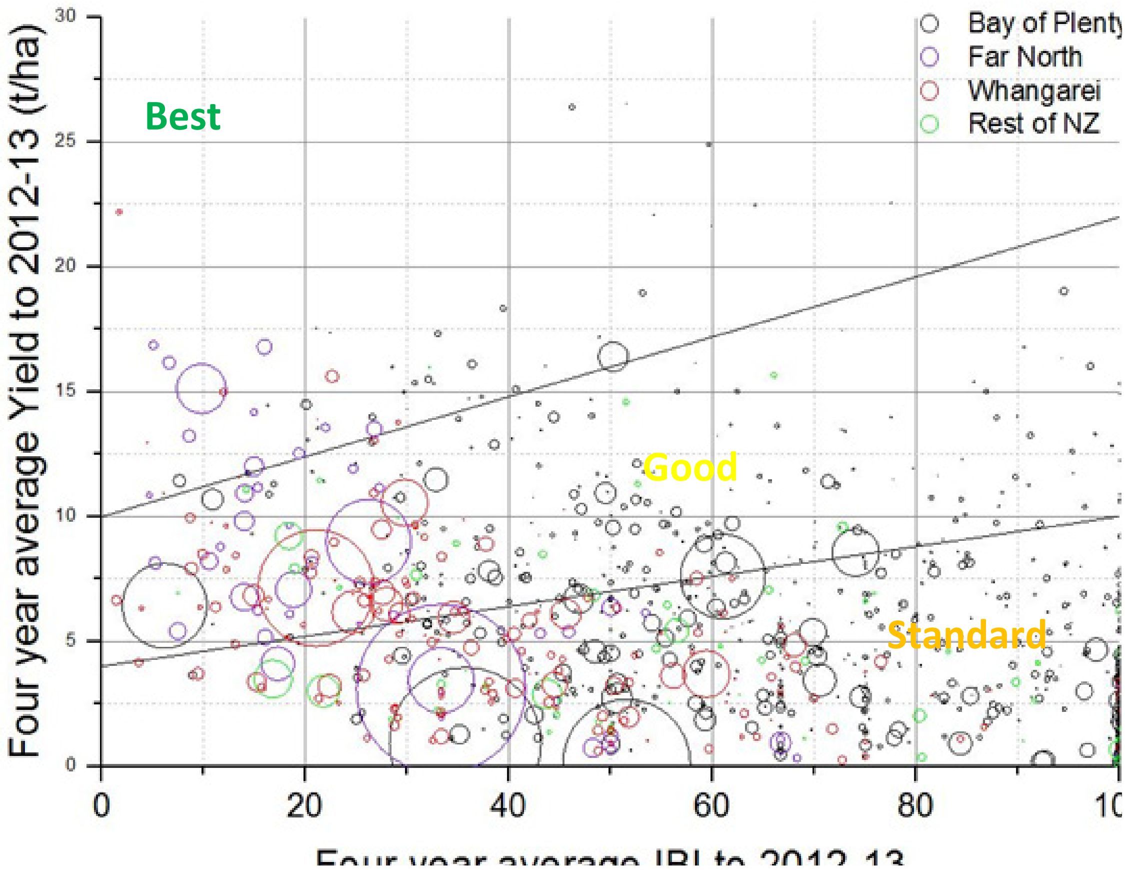

Figure 2. Orchard Performance Chart showing the situation of the New Zealand avocado orchards for the period 2109-2013. IBI stands for irregular bearing index. The size of the circles is proportional to the size of each orchard. The colour of the circle represents the region of the orchard.

The geographic distribution of the orchards shows that Best orchards are found across all of New Zealand's avocado growing regions and that they are often surrounded closely by orchards that belong to the other two categories. Kauri Point area, near Katikati represents a good example of the distribution of orchards in the different regions (Figure 3). This area is densely populated with avocado orchards of different ages, with a wide range of microclimates and management strategies.

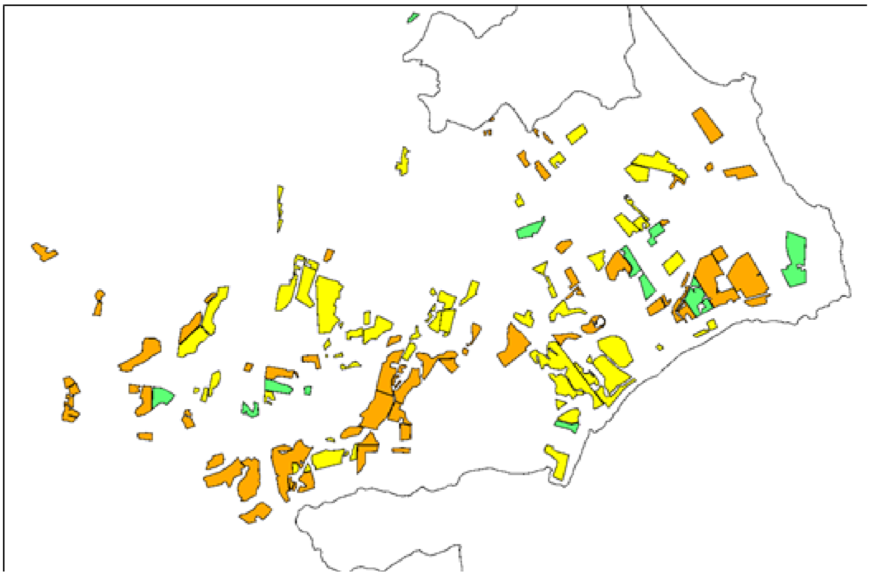

Figure 3. Geographic distribution of orchards from the three different performance categories from Figure 2: green corresponds to the "Best" orchards, "Yellow" to the good orchards, and "Orange" to the standard orchards. The area depicted corresponds to the Kauri Point area near Katikati, Bay of Plenty.

The differences in performance of the orchards can be due to environmental factors, differences in management, or differences in characteristics inherent to the trees. A survey was carried out to capture and analyse the differences and similarities between the orchards in the area and how they relate to their production history.

RESULTS

Production history data of the area and of the individual orchards and the survey data have highlighted a number of factors that seem to affect orchard productivity in the area in a significant way. Some of the factors that were highlighted during the analysis were frost damage, low spring temperatures, alternate bearing, spring drought, pruning, nutrition, pollination, and tree health.

In collaboration with Plant and Food Research and with funding from the Ministry of Business and Innovation and from the Ministry of Primary Industries, a thorough program has been implemented to understand to what extent these factors contribute to the productivity of our orchards and to develop best practice guidelines that will allow the implementation of effective management strategies by growers.
For more information about the programme, please visit our website www.nzavocado.co.nz

Growing avocados under shadenetting in South Africa

R.J. Blakey[1], Z. van Rooyen[1], J.S. Köhne[1], K.C. Malapana[2], E. Mazhawu[2], S.Z. Tesfay[2] and M.J. Savage[2]

[1]. Westfalia Technological Services, Tzaneen, South Africa

[2]. School of Agricultural, Earth & Environmental Science, University of KwaZulu-Natal, Pietermaritzburg, South Africa

ABSTRACT

There is a global trend to high intensity horticulture, including high density plantings, use of superior cultivars, greater plant manipulation, and protected cultivation. The avocado industry is lagging in the use of the latter.

Two shadenet structures were erected over existing orchards. The first in the warm, dry subtropical area of Mooketsi (Limpopo) and another in the cool subtropical area of Karkloof (KwaZulu-Natal), South Africa. At Mooketsi, the 1.0 ha orchard, planted to 'Mendez #1' ('Carmen®-Hass') on Dusa®, was covered with 20% white shadenet. At Karkloof, the 1.6 ha orchard, planted to '3-29-5' ('Gem®') on Dusa®, was covered with 30% clear shadenet. These orchards were selected because the fruit of these cultivars are of high value because they are earlier and later than 'Hass', and because of the contrasting abiotic stress factors at each location. Microclimate and various horticultural aspects were compared inside and outside the shadenetting structures. 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 respectively. At Karkloof, the air temperature was between 0.5°C and 0.9°C higher under the shadenet, but with a higher relative humidity. The shadenet has reduced wind speed to negligible levels and also reduced the rate of evapotranspiration.

The shadenet resulted in improved fruit quality due to reduced wind damage and sunburn, particularly at of the '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 study will continue for the medium term to also determine the financial viability of growing avocados under shadenet.

Hay una tendencia global hacia la horticultura intensiva, la que incluye plantaciones de alta densidad, uso de variedades superiores, mayor manipulación de plantas y el uso de variedades protegidas. La industria de la palta está quedando atrás en cuanto a la implementación de esta última.

Keywords: Abiotic stress, Fruit quality, Micro-climate, Protected cultivation.

INTRODUCTION

Shadenetting 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). Solar radiation in South Africa is excessive for optimal avocado tree growth and development, resulting in heat and light stress for the trees (Bower *et al.* 1977). South Africa is a water-scarce country, with high variability in annual rainfall (Blignaut & van Heerden 2009). A shadenetting structure has potential to address both of these limiting factors.

About 60% of total production is classified as export grade. The South African avocado industry is export-orientated, with approximately 40% of the total production volume being exported (Blakey & Wolstenholme 2014). 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. Export offers a significantly higher return for the grower. Therefore, it would be commercially advantageous for a grower to improve the export grade percentage.

Shadenetting is widely used on deciduous fruit crops and citrus, but avocados have specific challenges that need to be addressed before shadenetting 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, and vigorous vegetative growth, and relatively low yields per ha.

As part of a multi-site long-term study, we will attempt to answer the following questions before the large scale use of shadenets over avocados is considered:

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

OBJECTIVES

Determine the long-term effect of shadenet over avocado orchards on: yield, fruit quality, fruit maturity, cultural management, tree pheno-physiology, and pollination. These will be used to ascertain whether growing avocados under shadenet is economically viable.

MATERIALS & METHODS

Trial Sites

Two Westfalia Fruit farms in 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 shadenet trials at Mooketsi, and Karkloof.

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

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

[2] Trees were thinned to 6m x 3m 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 30s and average and record every 20min.

Soil matrix water potential is recorded three time per week using tensiometers at depths of 30cm and 60cm. Tree phenology was monitored according to Alcaraz *et al.* (2013) and (Ish-Am 2008). 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. Fruit moisture content was measured gravimetrically on 10 fruit weekly or fortnightly.

RESULTS AND DISCUSSION

Microclimate

A summary of the effect of shadenet on microclimate is given in Table 2 and Table 3.

At Mooketsi, the air temperature and relative humidity have only been modified slightly under shadenet, with the most pronounced differences in in winter (air temperature 0.8°C lower and canopy temperature 3.3°C lower under shadenet). 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 shadenet, but with a higher relative humidity indicating a lower vapour pressure deficit (VPD) which should reduce evapotranspiration under the shadenet. The winter maximum canopy temperature was 0.6°C lower under the shadenet, and there was no difference in the winter minimum canopy temperature. Unfortunately the infrared radiometer failed in January 2015.

The average wind speed at both sites is low but constant. Under the shadenet the wind speed has been reduced to negligible levels. At Mooketsi especially, this has resulted in reduced damage to leaves (Figure 1) and fruit (Figure 3). What still needs to be determined is what proportion of the difference in leaf size is due to leaf tattering and what is due to increased leaf size under that shadenet. Due to cultivar differences between 'Carmen®-Hass' and '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 shadenet has less of an effect (Figure 5).

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 (60L/tree) was applied in the third quarter of 2014 and eucalyptus wood chips (100L/tree) were applied in mid-2015 to reduce soil water loss, because the tree condition outside the net declined due to transient day-time water stress. The evapotranspiration at 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.

Table 2: Minimum and maximum air temperatures (Tair), canopy temperatures (Tcanopy), 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
Tair (°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
Tcanopy (°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: Effect of shadenet on microclimate at Mooketsi and Karkloof in 2014/5. All values are in reference to shadenet compared to the uncovered orchard

	Mooketsi	Karkloof
Wind speed (WS)	Maximum reduced from 3.5m/s to 0.6m/s	Maximum reduced from 4.0m/s to 0.1m/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)

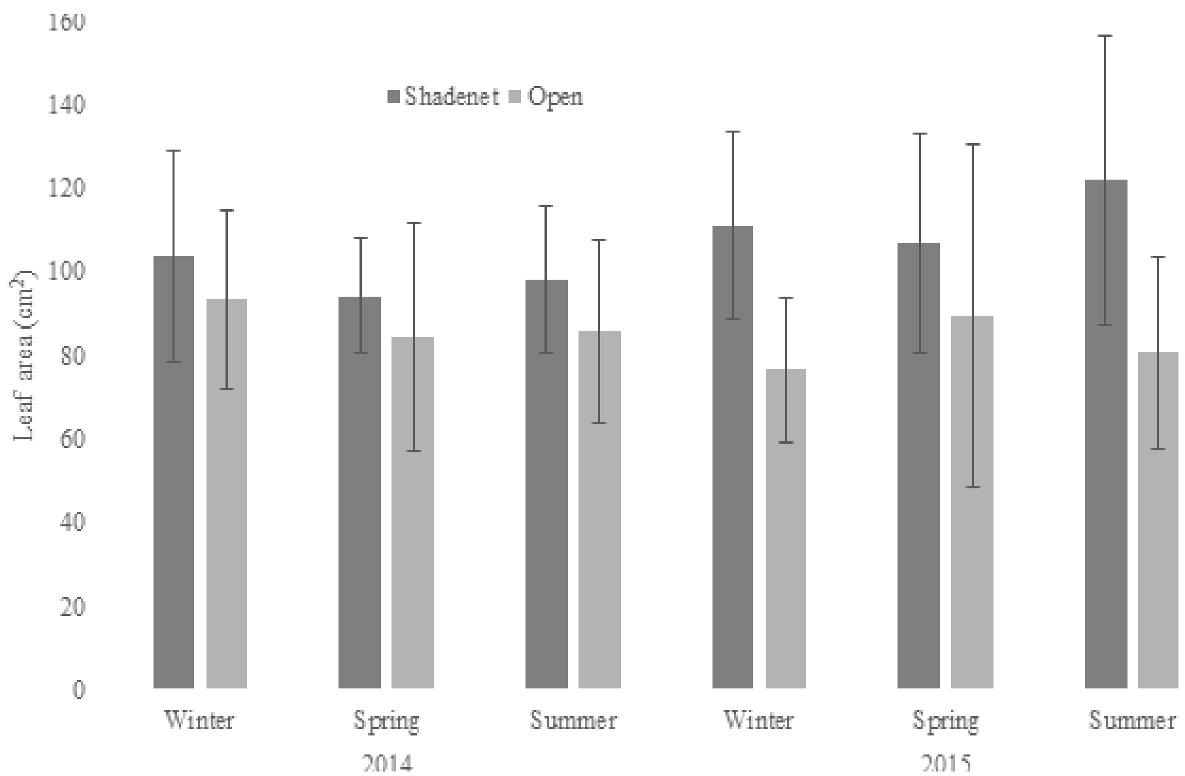

Figure 1: Leaf area from three flushes in 2014 and 2015 for 'Carmen®-Hass' trees grown under shadenet and the open at Mooketsi

Fruit maturity

'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 shadenet compared to the open orchard in 2015 and 2015 (Figure 2). The treatments were harvested together in week 14 in 2014 and week 13 in 2015.

'Gem®' fruit at Karkloof are harvested for the late season market. As such, minimum maturity is of no consequence. There was only a 1% MC difference in the 2014 season, when fruit were harvested in week 46; the fruit grown under the shadenet had a moisture content of 63.0% MC (37.0% DM) and the fruit grown in the open 62.0% MC (38.0% DM) (data not presented).

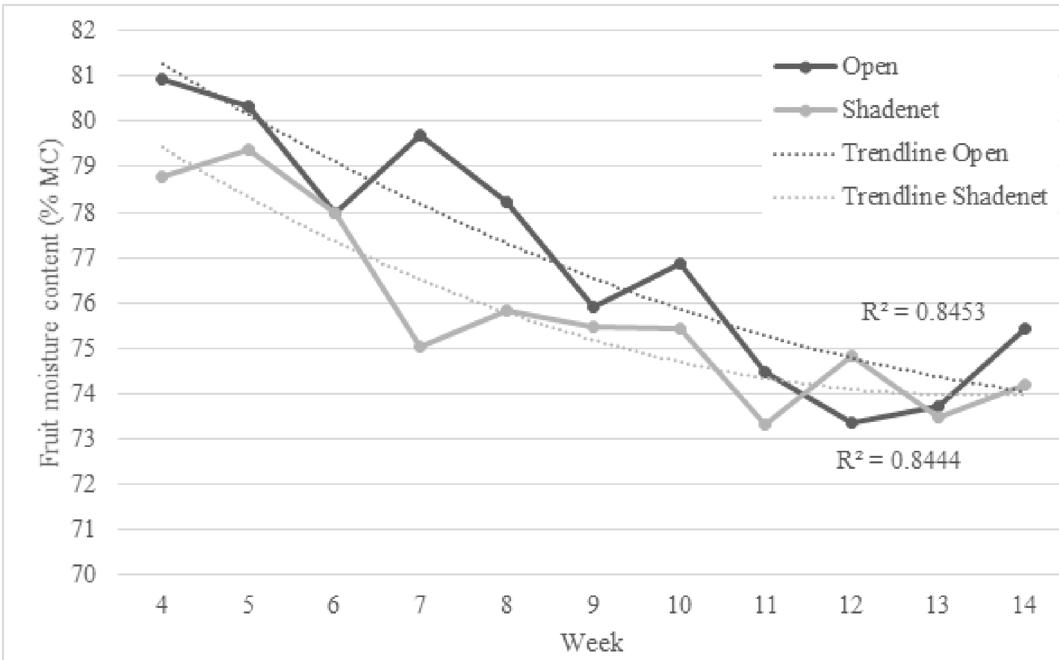

Figure 2: Fruit moisture content of 'Carmen®-Hass' fruit from Mooketsi shadenet trial for 2014 and 2015, tree spacing of 6m x 3m. Minimum fruit moisture content is 77% MC. Fruit were harvested in week 14 in 2014 and week 13 in 2015. The standard deviation for shadenet and open orchards was 3.6% MC and 3.2% MC, respectively.

Yield, packout, fruit size distribution, and fruit quality

Mooketsi

The two standout results at Mooketsi are (i) the much-improved packout achieved under the shadenet, contrasted with (ii) the poor yields achieved under the shadenet, especially in the wider spacing (Figure 3). The improved packout is due to a reduction in sunburn, wind damage and small fruit, the major cull factors at Mooketsi.

This orchards used for the Mooketsi trial site have a history which complicates the interpretation of the results. The packout for the 3m x 3m spacing under the shadenet in 2015 was lower than expected because of leafroller damage to the fruit. This was because the trees were too dense to permit proper insect control. The higher yield in the "Open, 6m x 3m" treatment in 2014 is because this orchard was on microsprinkler irrigation while the other three orchards were previously on inadequate drip irrigation and the irrigation changed to microsprinkler (27L/h) in June 2013. The reduced yield in the out-of-season (OOS) crop is because bees were intentionally not introduced into the orchard. This was done to determine whether fruit set from the OOS flower could be largely eliminated. It is apparent that fruit set was greatly reduced when bees were not introduced, providing an option to set a single crop for 'Carmen®-Hass' if the grower so desires.

Like Hass, 'Carmen®-Hass' fruit is generally medium to small. Under the shadenet the fruit were generally larger than those grown in the open (Figure 4), 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 shadenet to obtain much higher yields.

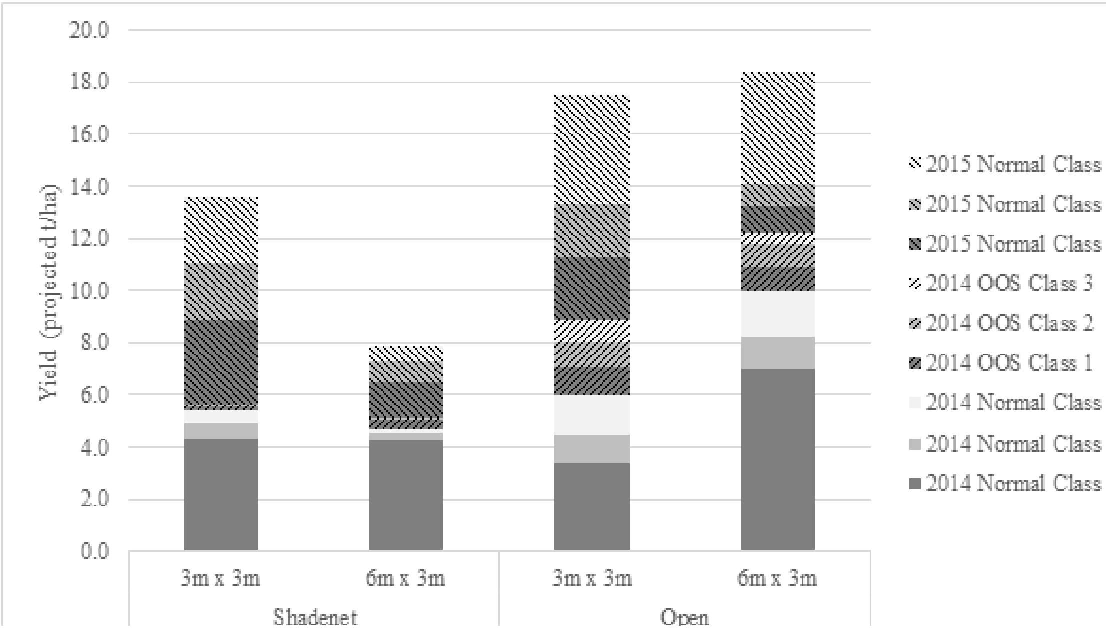

Figure 3: Yield and packout for 2014 normal season (March) and out-of-season (OOS - November) for 'Carmen®-Hass' from Mooketsi. Bees were intentionally excluded from the OOS flower. Class 1 is export grade, Class 2 is local market grade, and Class 3 is factory grade.

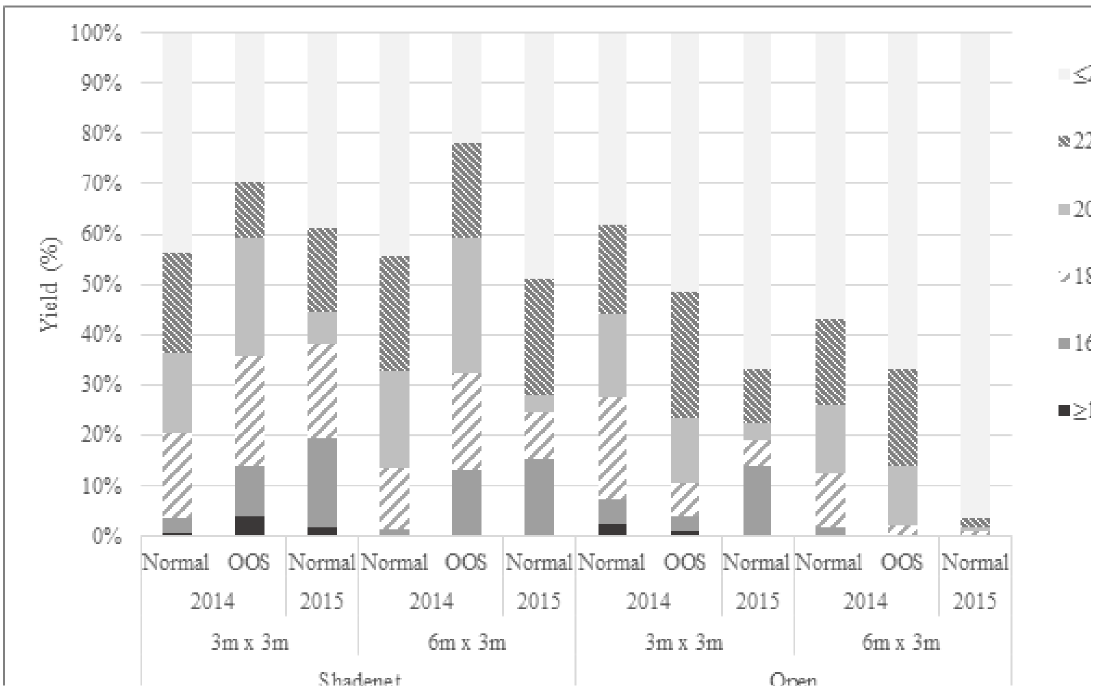

Figure 4: Fruit size distribution for 2014 and 2015 normal season (March) and 2014 out-of-season (OOS - November) for 'Carmen®-Hass' from Mooketsi. Larger fruit have a smaller count number.

Karkloof

The yield was very encouraging for a four year old orchard, and the 8% increase in the class 1 percentage, considering the orchard was covered three months after fruit set was promising (Figure 5A). The difference in packout is not anticipated to be as pronounced in 'Gem®' because the cultivar naturally bears fruit on the inside of the canopy, protecting the fruit from sunburn and wind damage.

'Gem®' fruit are typically larger than Hass and 'Carmen®-Hass'. The FSD from 2014 (Figure 5B) indicated that there was a reduced proportion of very large fruit (count 8 and 10) under the shadenet. This shift in the FSD is promising, because a medium-sized fruit is preferred commercially.

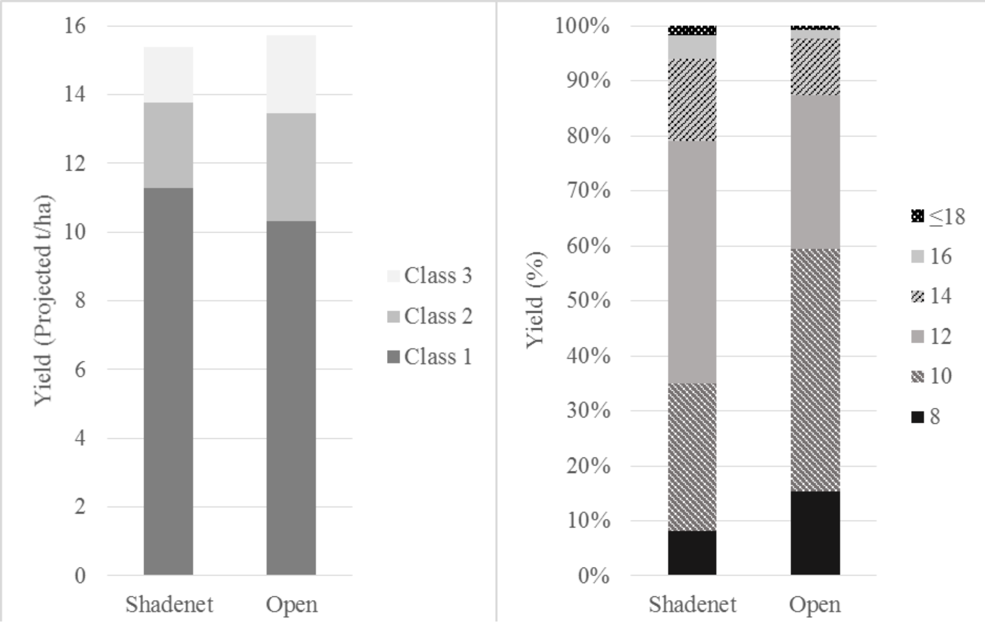

Figure 5: (A) Yield and packout for 'Gem®' at Karkloof in 2014. Class 1 is export grade, Class 2 is local market grade, and Class 3 is factory grade. (B) Fruit size distribution for 'Gem®' from Karkloof in 2014. Larger fruit have a smaller count number.

Bee Activity

It was concluded that there was insufficient bee activity under the shadenet (especially at Mooketsi) with four hives under the shadenet to set an adequate crop in 2014 and 2015. The 3m x 3m 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 shadenet at Mooketsi and 20 hives at Karkloof during flowering in 2015. At the time of publication, the trees at Mooketsi had just completed flowering, and the trees at Karkloof just began flowering. As such, there are no definite results available for this manuscript, but it has been noticed that there are more bees visiting the trees under the shadenet at Mooketsi, compared to the open orchard.

CONCLUSION

There are promising results in this shadenet 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 shadenet is to optimise pollination to obtain high yields (along with a high packout) to make the shadenet structures economically viable. We are confident this will be achieved and conclusive results will be obtained in the medium-term.

ACKNOWLEDGEMENTS

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