COMPARISON OF REFLECTIVE MULCH POSITION IN PISTACHIO TREE APPLICATION

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To fully utilize sunlight, reflective mulch has been used in horticultural production. Covering the orchard floor with reflective mulch has been shown to be effective in increasing light intensity in the tree canopy and improving fruit colouration (Moreshet et al, 1975; Andris and Crisosto, 1996). Reflective mulch has been mainly used for colour improvement for apples (Funke and Blanke, 2006), peaches (Layne et al, 2001), mangoes (Shahak et al, 2001) or quality improvement on citrus (Richardson et al, 1993). These reflective mulches are normally laid at a relatively late stage in fruit maturation in order to have maximum impact on the colour of the fruit (Layne et al., 2001). Since these treatments are of short duration it is unlikely that they have a major impact on the overall development of the trees.

Work on yield increases were reported by Costa (2003) on kiwifruit, by Grout et al (2004) on apples and by Zhang (2011) on pistachio. These authors applied reflective mulch at bud burst and left them in situ up to harvest. This presents a new direction for reflective mulch application.

In Zhang's (2011) 4-year study, the author reported yield and return increases when reflective mulch was placed between the rows. The question yet to be considered is whether the mulch when place under the canopy can show better results than that between rows. Another 4-years trial has been designed to investigate this question.

MATERIALS AND METHODS

Yield Comparison

This trial was conducted at CMV Farms in Robinvale, Victoria. The tree row direction was 38° from north to east. This trial design was 3 treatments by 6 replicate plots by 3 trial trees within each plot. The treatments were

- 4 metre wide Extenday between rows on each side of the tree;
- 2 metre wide Extenday under tree canopies on each side of the tree;
- control (no reflective mulch).

The mulch was fixed during or before bloom and removed just before harvest. Each growing season there were 2 shakes for nut harvest on each tree. About 10 kg nut samples were collected from each treatment and each of the 2 replicates. These samples were weighed accurately, then de-hulled and dried on the second day. After drying, the nuts were delivered to the APPC laboratory for analysis as part of the normal process. Returns per tree were based on prices in 2004. Data was analysed by two-way

analysis of variance (treatment x replicate). Analysis of variance for percentages, p-values were calculated based on transformed data according the following formula: $\arcsin\sqrt{\frac{percentage}{100}}$.

Comparison on Nut per Rachis

In an endeavour to understand the reasons for yield increases through the use of reflective mulch, 3 trees in control and 3 trees with the mulch under canopy in plot 1 were hand harvested on rachis basis in 2010 and 2011. Then nut numbers were counted on a rachis basis and then calculated on tree basis.

Comparison on Flower Bud Formation

In an endeavour to understand the influence of reflective mulch on flower bud formation, 3 trees in the control and 3 trees with the mulch under canopy in plot 1 were counted for flower bud numbers in the winter of 2011 and 2012.

Comparison of Reflective Capacity in Different Mulch Layout

Reflection measurements for the mulch trials were conducted on a day in October and November 2007, and January and February 2008. Unfortunately no clear days were found in mid December 2007 and no measurement was taken in December 2007.

A Decagon's AccuPAR model LP-80 PAR/LAI Ceptometer was used for this measurement. In Reflective light measurements, the Ceptometer was facing downwards to the ground at 1 metre above the ground surface. A spirit level was added above the Ceptometer to control the horizontal balance. Four readings from 4 directions for each of the trees tested were recorded.

Within each treatment, there were 5 trees. Tree 1 and tree 5 were boundary trees. In production with long mulches, boundary trees do not really show treatment value in the test. Thus analyses were only carried on the middle trees, i.e. trees 2, 3 and 4.

To understand continuous change between hours within a day, this test measured reflective light hourly from 8 am to 5 pm on 15 November 2007.

Soil Temperature Measurements

Eight temperature data loggers were installed before the reflective mulch was fixed in 2009. Among these 8, 4 loggers were installed 20 cm outside and 4 loggers were installed 20 cm inside the drip lines for each treatment. All data loggers were removed before harvest. Unfortunately one data logger among the total of 8 data loggers did not work which led to the loss of some readings from inside the treatment area for Extenday between the trees.

RESULTS

Yield Comparison

In season 2007/08, there was no significant difference of fresh in-hull yield between treatments. Season 2007/08 was an 'off' season. Trees cannot produce more crops than the number of flower buds and as a result the mulch had no influence in increasing flower buds or nuts. In season 2008/09, Extenday both under canopy and between rows had significantly higher yields in hull per tree than the control. In season 2009/10, Extenday under canopy had significantly higher yields in hull per tree than the control. In the industry plan it was proposed that the 2010/11would be the last season of the trial. Unfortunately that season was affected by flooding and anthracnose. Severe disease cannot provide useful yield for research purpose. Thus, this trial left industry with only results from 3 seasons.

Table 1: Yields, count size and returns

Season	Treat	Yield in hull/tree (kg)	Accumulated Yield in hull/tree	Return /tree ($)	Count	% jumbo	% total non split	% other stain
2007/08	Under	7.0		18.7	89.1	6.0	1.18	0.09
	Between	3.7		9.2	94.8	5.9	1.59	0.14
	Control	5.9		14.3	92.9	5.5	1.46	0.10
2008/09	Under	68.2a	75.2a	149.3	89.13b	0.35b	6.35ab	3.73b
	Between	66.7a	70.3ab	151.7	88.13b	1.59a	5.06b	3.75b
	Control	59.7b	65.5b	123.1	91.58a	0.47b	6.87a	5.78a
2009/10	Under	11.7a	86.9b	28.3	79.6	4.79	2.18	3.52
	Between	8.3ab	78.6ab	19.8	82.3	2.93	2.81	3.78
	Control	6.0b	71.6a	11.5	81.1	4.42	4.01	4.25

In accumulated yield, Extenday under canopy showed significantly higher accumulated yield than the control. Extenday between rows had 2 lower yields in off-years and did not show a statistical higher accumulated yield than the control. However, if another on-year result was available, Extenday between rows would have resulted in a statistical difference of accumulated yield from the control. This was proved in Zhang (2011).

In season 2008/09, there was a $27 per tree difference in the return. Extrapolated out this represents an $8100 benefit per hectare (300 female tree/ha). This difference would be enough to cover the installation costs for Extenday. In season 2009/10, there was a $16.8 per tree difference with the return representing a $5040 benefit per hectare. These figures highlight the likely extra benefit for orchards when using reflective mulch.

Extenday treatments showed a benefit in count size in season 2008/09 only. Both Extenday treatments showed significant larger nuts than the control. In that season, Extenday between rows also showed very significantly higher percentages of Jumbo nuts. This is another way to show the benefit for nut size from reflective mulches. In season 2008/09, the control had the highest percentages of total non-split

nuts and significantly higher percentages than Extenday between rows. In season 2009/10, although it did not reach a p-value ≤ 0.05, p-value = 0.076 the results shows this benefit. In season 2008/09 the control showed significantly higher percentages of other stain compared with the Extenday treatments.

Nut Number per Rachis

In the 'off-season' 2009/10, nuts per rachis showed a significant difference between these 2 treatments (Table 2). The p-value of 0.014 was from nested analysis of variance. Trees with Extenday under canopy on average had 16 more nuts per rachis in this 'off-season'. Trees with Extenday under canopy showed more rachis per tree, however, it was not at a significant level. In the 'on-season' 2010/11, trees with Extenday under canopy had 0.7 more nuts per rachis than the control. In the nested analysis of variance, it does not show a significant level. However, trees with Extenday had significantly more numbers of rachis than the control.

Table 2 Nuts rachis and nut/rachis in 2010 and 2011

Treatment	2009/10		2010/11	
	No rachis/tree	Nut/Rachis	No rachis/tree	Nut/Rachis
control	65.7	43.62b	1637.3B	15.65
under	68.0	59.69a	2136.7A	16.34

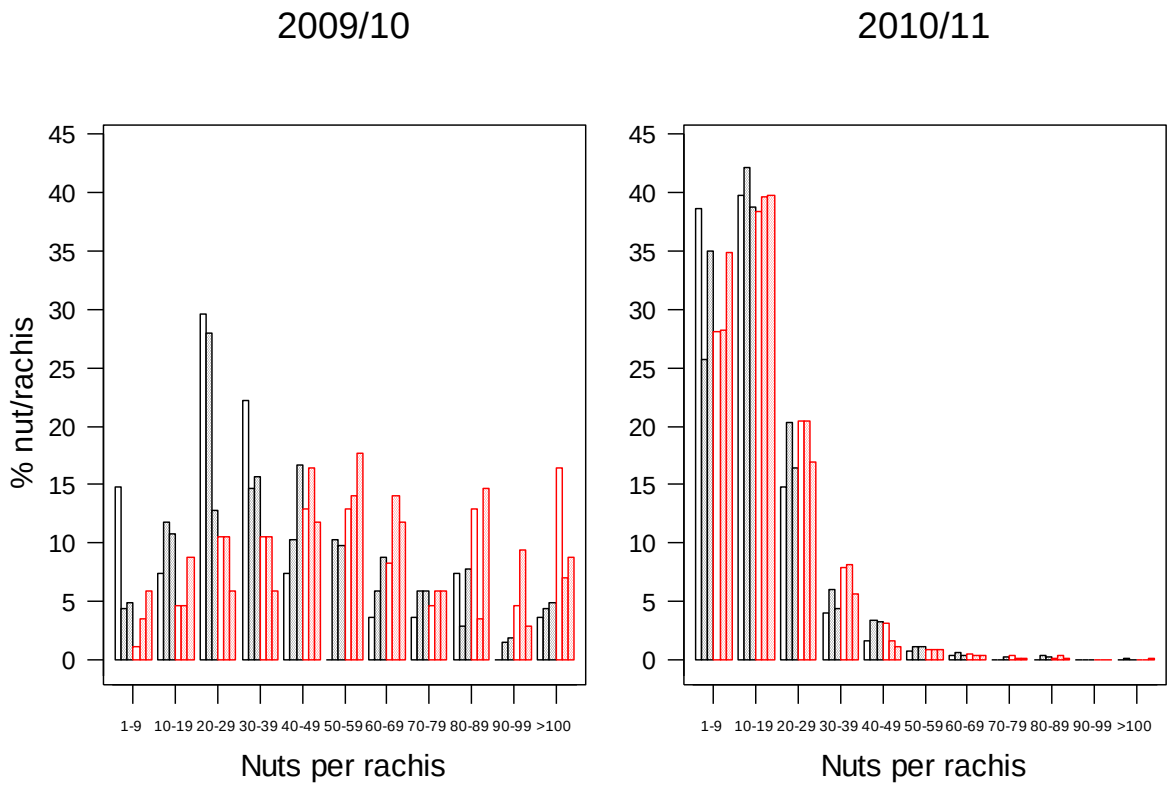

Figure 1 Frequencies and percentages of nuts per rachis in different ranges under different treatments

To highlight the major benefit of nut setting the range of nuts per rachis were divided into 11 groups, they are 1-9, 10-19, 20-29, 30-39, 40-49, 50-59, 60-69, 70-79, 80-89, 90-99 and ≥100. Figure 1 shows the percentages of nuts per rachis in the different ranges under these 2 treatments. Black bars represent control trees while red bars represent trees with Extenday under canopy. In 'off-season' 2010, the major nuts per rachis were mainly distributed in the range 10 – 80. However, in the 'on-season' 2011, the major nuts per rachis were mainly distributed in the range 1 – 19 but with some in the range 20 – 29. This is the difference between an 'on' and 'off-season'. For treatment comparison the trees with Extenday under canopy show dominant results in higher nut ranges in both seasons.
In 2010 the control trees showed higher percentages of nuts per rachis in the range 0 – 39, while trees with Extenday under canopy showed higher percentages in the range 50-59 and above, even from range 40 - 49. It can be inferred that in an 'off-season', the major way for yield increase is as a result of an increase in nuts per rachis when there were limited flower buds. In 2011 the control trees showed higher percentages of nuts per rachis in ranges 0 – 19, while trees with Extenday showed higher percentages from range 30 – 39 and some in the range 20 - 29. Although the dominance was not strong as in 'off-season', more nuts per rachis in the 'on-season' were still seen highlighting the benefit for trees with Extenday under the canopy.

Comparison on Flower Bud Formation

Table 3 shows that on average the control had more flower buds than trees with reflective mulch in the winter of 2011 (before an 'off-season') but did not reach a statistical difference. This, at least, shows that reflective mulch does not benefit flower bud formation, especially during an 'on-season' with a huge crop.

Table 3 Flower buds per in winter 2011 and 2012

Treatment	Winter 2011	Winter 2012
control	205.7	860.0
under	166.0	Counting now

Comparison of Reflective Capacity in Different Mulch Layout

Figure 2 shows the reflective light measurement results. There are 4 sub-graphs showing results in October, November, January and February. In the graphs, each point was obtained from 2 replicates and 3 trees, i.e. averages and standard errors are from 6 measurements. In each sub-graph the X-axes represents hours in a 24 hours period and the Y-axes represents reflective light in $\mu mol/m^2 \bullet s$. The different colours represent different treatments as shown in legend.

The graphs show significant differences between treatments in all months and all hours. Measurement comparisons showed that 3 pm had the highest averages while 12 pm had the lowest averages. This probably shows that when the Sun position was low, the reflection was more useful.

The reflection results were clear for all three treatments in the following order - Extenday under canopy, Extenday between rows and control. Besides significant differences between treatments, measurement time also showed significant differences, especially around 12 pm. The reflective mulch under canopy showed lower values of reflection. This is because around mid-day, sunlight is seen between the rows

and there is more shade under the canopy. This leads to low reflection from the mulch under the canopy. This is also shown in Figure 3.

However, from the results above, we cannot make a conclusion that reflection from Extenday under canopy is definitely better than that between rows. We tested the reflection under canopy at 1 metre above the ground. However, Extenday between rows should have more reflection on the side of the trees. This may be the reason for large nut production in season 2008/09.

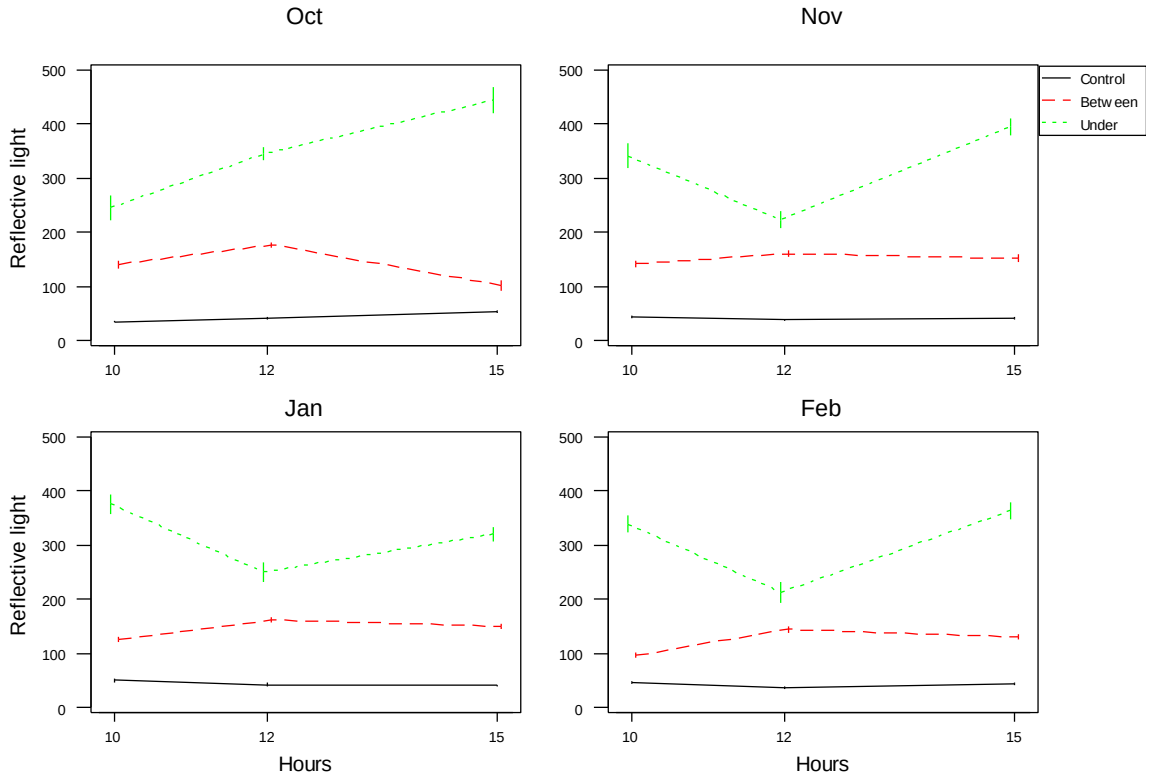

Figure 2: Comparison of reflective light of mulch between treatments and time

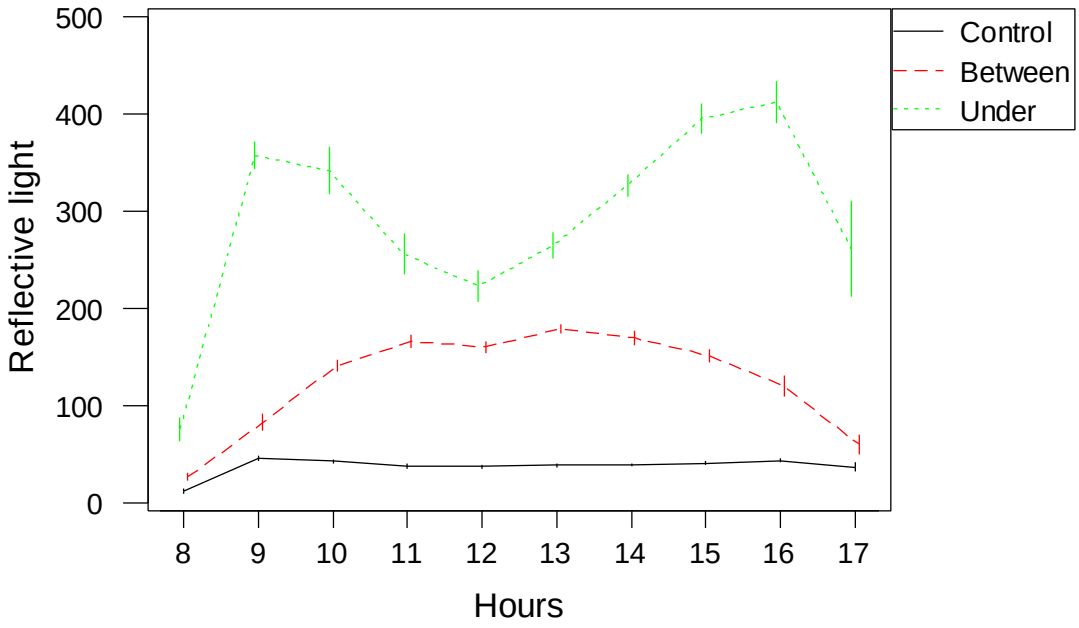

Figure 3: Reflective light in different times in different tree locations

From Figure 3, there was continuous change through time. Each point was still obtained from the 6 measurements.

Soil Temperature Test

Figure 4 showed hourly temperature changes between 18 September 2009 and 4 March 2010 in different locations. As per the legend red and pink are for Extenday, blue for white plastic and green for the control. Figure 4 clearly shows that red and pink were at the bottom while green and blue were at the top. This indicated that the mulch reduced instead of increasing soil temperature.

Under the mulch the temperature reduction compared with the control was different in different hours. The maximum difference between the mulch and control was usually around 18:00 or 19:00. After 18:00 or 19:00, this difference reduces, until 10:00 the next day; then this difference increases gradually until 18:00. In the data logger recording, no day light saving hours were applied. Thus 18:00 here in summer time was actually17:00 in normal circumstances.

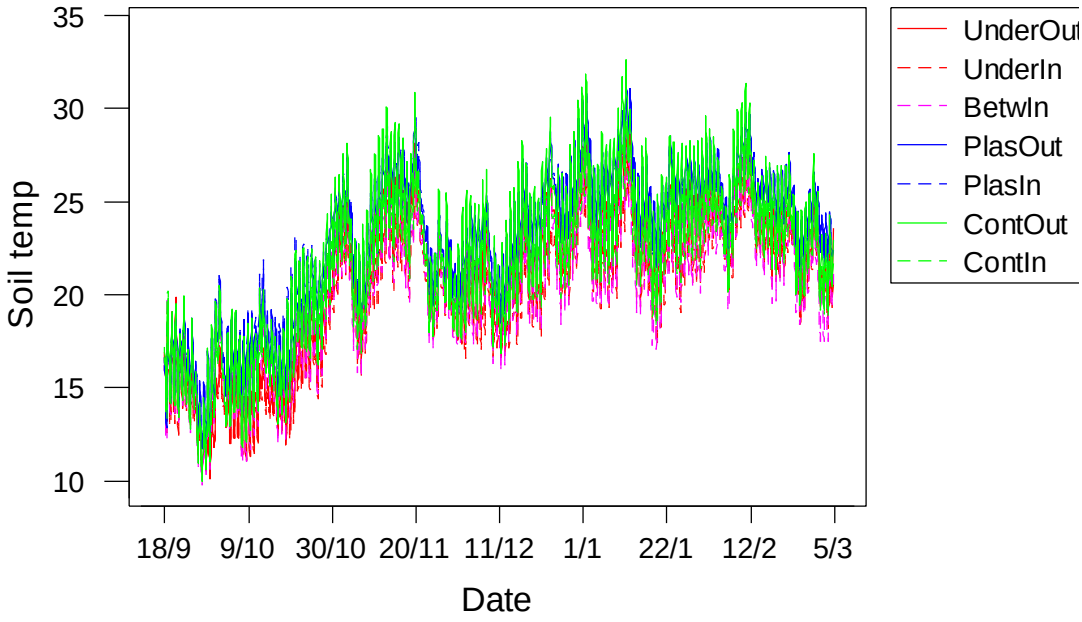

Figure 4: Soil temperatures in different locations

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