

PROGRESS IN CANOPY MANAGEMENT OF AVOCADOS

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Introduction

Canopy management is one of the most important production issues confronting the Australian avocado industry. Due to its flowering and fruiting characteristics, the avocado tree must produce new extension growth each year to remain productive (Whiley and Schaffer, 1994). However, if left unchecked this will result in increased tree size that eventually leads to orchard crowding with a subsequent deterioration in fruit quality and yield. In addition, tree size presents a problem with regard to harvesting, spraying for effective pest and disease control and other orchard operations. Trees become inefficient with large unproductive areas at their base and inside the canopy. Avocado flowering and fruiting occurs in well-lit terminal sites on the surface of the canopy. During the crowding process the productivity of side canopies is lost due to insufficient light reaching lower levels of the tree.

Tree size control will ultimately be assisted through the selection of rootstock/scion combinations that sustain high production levels. In the absence of dwarfing rootstocks, management strategies must be designed to maintain effective lighting of the side canopies of individual trees as the orchard matures and trees begin to crowd (Whiley and Schaffer, 1994). Systems to manage tree size and improve light interception that include tree thinning, stag-horning and selective limb removal have been tried without long-term success. Advances have been made in the development of mechanised pruning techniques together with the application of growth retardants, however recommendations on canopy management strategies for the Australian grower have not yet been defined.

This paper reports on the results of summer pruning and growth retardant application on shoot growth, flowering and yield in 'Hass' avocado. The objectives of the current canopy management research are also outlined.

Summer pruning and growth retardant application

Materials and Methods

The effect of summer pruning and growth retardant application on shoot growth, flowering and yield of 'Hass' avocado was investigated in three commercial orchards in southeast Queensland. Trees were pruned during the summer following maturation of the spring growth flush. Foliar applications of the growth retardant, uniconazole (Sunny[®], Sumitomo Chemical Australia Pty Ltd) were made when regrowth following pruning reached a maximum of 150 mm in length. Trees were sprayed to the point of run-off using a backpack misting unit. Agral[®] at 0.05% was added to all Sunny[®] applications. At each experimental site five treatments were applied to the regrowth that were:

1. Untreated control (No Sunny[®] application);
2. A single foliar spray of Sunny[®] at 0.25%;
3. Two foliar sprays of Sunny[®] at 0.25% (the second spray 14 days after the first);
4. A single foliar spray of Sunny[®] at 0.5%; and
5. Two foliar sprays of Sunny[®] at 0.5% (the second spray 14 days after the first).

The experiments were laid out as fully randomised, replicated blocks and the data was analysed by ANOVA.

Experiment 1: Childers

Four-year-old 'Hass' trees were pruned to form a pyramid at an angle of 15° on the 5th Jan 1999. Sunny[®] was first applied to the regrowth on the 9th Feb 1999 at 1.75 L/tree. A second foliar spray was applied on the 23rd Feb 1999 at 1.5 L/tree for treatments 3 and 5. Another application at 1 L/tree was made on the 27th Apr 1999 to all treated trees. At the time of the first Sunny[®] application trees were approximately 4 m tall. The length of regrowth and percentage flowering was assessed for 10 shoots from five trees of each treatment on the 13th Jul 1999.

Experiment 2: Hampton

Five-year-old 'Hass' trees were pruned to form a pyramid at an angle of 18° on the 10th Jan 1999. Sunny[®] was first applied on the 24th Feb 1999 at 1.75 L/tree. A second foliar spray was applied on the 10th Mar 1999 at 1.5 L/tree for treatments 3 and 5. Another application at 1 L/tree was made on the 12th Apr 1999 to all treated trees. At the time of the first Sunny[®] application trees were approximately 4.5 m tall. Regrowth length and percentage flowering was assessed for 10 shoots from six trees of each treatment on the 16th Jun 1999.

Experiment 3: Goodwood

Four-year-old 'Hass' trees were pruned during summer at an angle of 20° to form a pyramid on the 16th Dec 1999, 24th Jan 2000 or 21st Feb 2000. Trees pruned in December received the first Sunny[®] application on the 24th Jan 2000. A second treatment was applied on the 3rd Feb 2000 for treatments 3 & 5. Trees pruned in January received the first Sunny[®] application on the 21st Feb 2000. A second treatment was applied on the 3rd Mar 2000 for treatments 3 & 5. Trees pruned in February received the first Sunny[®] application on the 27th Mar 2000. A second treatment was applied on 7th Apr 2000 for treatments 3 & 5. Trees received 1.25 L of spray formulation each time. At the time of the first Sunny[®] application trees were approximately 4 m tall. Regrowth length and percentage flowering was assessed for 10 shoots from four trees of each treatment on the 17th Jul 2000. Tree growth measurements were made after pruning and at flowering. The increase in tree height and width were calculated.

At all sites fruit was harvested at maturity and the number and weight from each tree recorded. Mean fruit size was calculated from the data. An unpruned control treatment was included for yield assessments.

Results and Discussion

Experiment 1: Childers

A single foliar application of Sunny[®] at 0.5% and two applications at 0.25 or 0.5% significantly ($P \leq 0.05$) reduced the length of shoot regrowth following summer pruning. All Sunny[®] treatments increased the percentage of flowering on regrowth shoots (Table 1). There was no effect of summer pruning, with or without Sunny[®] sprays on yield in the 1998/99 fruiting season (Table 2). However, there was a trend towards a reduction in fruit size following summer pruning without Sunny[®] compared with the unpruned control (209.1 vs 224.5g). The reduction in fruit size may be a result of competition for resources between regrowth shoots and fruit development. In most instances Sunny[®] applied to the regrowth following pruning maintained fruit size relative to unpruned trees.

Table 1 Effect of summer pruning and foliar applications of Sunny[®] on length and percentage flowering of regrowth shoots on ‘Hass’ trees at Childers. Data in columns are mean values of five trees. Values followed by different superscript letters are significantly different ($P \leq 0.05$) as tested by ANOVA.

Treatments*	Regrowth length (cm)**	Regrowth flowering (%)**
Pruned (no Sunny)	32.2 ^a	74 ^b
Pruned + Sunny 0.25%	29.8 ^{ab}	90 ^a
Pruned + Sunny 0.25% (2 sprays)	23.6 ^c	100 ^a
Pruned + Sunny 0.5%	24.1 ^c	98 ^a
Pruned + Sunny 0.5% (2 sprays)	24.9 ^{bc}	96 ^a

*Four-year-old trees were pruned at an angle of 15° to form a pyramid on the 5th Jan 1999. Foliar treatments of Sunny[®] were first applied on the 9th Feb 1999 at 1.75 L/tree. A second treatment was applied on the 23rd Feb 1999 at 1.5 L/tree for treatments 3 and 5. Another treatment at the rate of 1 L/tree was applied on the 27th Apr 1999 to all treated trees.

**The length and percentage flowering of the regrowth shoots was recorded on the 13th Jul 1999.

Table 2 Effect of summer pruning and foliar applications of Sunny[®] on ‘Hass’ yield and fruit size at Childers in the 1998/99 fruiting season. Data in columns are mean values of five trees. Values followed by different superscript letters are significantly different ($P \leq 0.05$) as tested by ANOVA.

Treatments*	Yield (kg/tree)	Fruit No./tree	Mean fruit size (g)
Pruned only	24.4 ^a	116.2 ^a	209.1 ^a
Pruned + Sunny 0.25%	20.6 ^a	91.6 ^a	226.6 ^a
Pruned + Sunny 0.25% (2 sprays)	23.0 ^a	109.2 ^a	214.3 ^a
Pruned + Sunny 0.5%	24.2 ^a	111.0 ^a	218.9 ^a
Pruned + Sunny 0.5% (2 sprays)	30.7 ^a	143.8 ^a	213.1 ^a
Unpruned control	25.6 ^a	115.6 ^a	224.5 ^a

*Four-year-old trees were pruned at an angle of 15° to form a pyramid on the 5th Jan 1999. Foliar treatments of Sunny[®] were first applied on the 9th Feb 1999 at 1.75 L/tree. A second treatment was applied on the 23rd Feb 1999 at 1.5 L/tree for treatments 3 and 5. Another treatment at the rate of 1 L/tree was applied on the 27th Apr 1999 to all treated trees. Trees were harvested on the 2nd Jun 1999.

Experiment 2: Hampton

All Sunny[®] treatments significantly ($P \leq 0.05$) reduced the length of shoot regrowth following summer pruning (Table 3). There was a trend towards an increase in flowering on regrowth shoots in the pruned plus Sunny[®]-treated trees compared to pruned trees without Sunny[®] (85-93% vs 77%) however, the differences were not significant. Summer pruning significantly ($P \leq 0.05$) reduced the yield in the 1998/99 fruiting season (Table 4). In the 1999/00 fruiting season there was no significant difference in yield between the treatments although there was a trend for a higher yield in the pruned plus Sunny[®] at 0.5% sprayed twice and the unpruned control treatments. There was also a trend towards an increase in fruit size following summer pruning compared with the unpruned control in the 1999/00 season (212.5g vs 181.8g). It is likely that the reduction in yield and associated increase in fruit size in the pruning treatments were due to the removal of fruit during the summer pruning. Fruit loss could be avoided if tree shape was established after harvest and prior to flowering and fruit set via a light winter prune.

Table 3 Effect of summer pruning and foliar applications of Sunny[®] on length and percentage flowering of regrowth shoots on ‘Hass’ trees at Hampton. Data in columns are mean values of six trees. Values followed by different superscript letters are significantly different ($P \leq 0.05$) as tested by ANOVA.

Treatments*	Regrowth (cm)**	length	Regrowth (%)**	flowering
Pruned (no Sunny)	43.9 ^a		77 ^a	
Pruned + Sunny 0.25%	31.3 ^b		85 ^a	
Pruned + Sunny 0.25% (2 sprays)	30.2 ^b		90 ^a	
Pruned + Sunny 0.5%	30.5 ^b		90 ^a	
Pruned + Sunny 0.5% (2 sprays)	26.3 ^b		93 ^a	

*Five-year-old trees were pruned at an angle of 18° to form a pyramid on the 10th Jan 1999. Foliar treatments of Sunny[®] were first applied on the 24th Feb 1999 at 1.75 L/tree. A second treatment was applied on the 10th Mar 1999 at 1.5 L/tree for treatments 3 and 5. Another treatment at the rate of 1 L/tree was applied on the 12th Apr 1999 to all treated trees.

**The length and percentage flowering of the regrowth shoots was recorded on the 16th Jun 1999.

Table 4 Effect of summer pruning and foliar applications of Sunny[®] on ‘Hass’ yield and fruit size at Hampton in the 1998/99 and 1999/00 fruiting seasons. Data in columns are mean values of six trees. Fruit size values are adjusted means following a significant ($P \leq 0.05$) covariate analysis. Values followed by different superscript letters are significantly different ($P \leq 0.05$) as tested by ANOVA.

Treatments*	1998/99			1999/00		
	Yield (kg/tree)	Fruit No./tree	Mean fruit size (g)	Yield (kg/tree)	Fruit No./tree	Mean fruit size (g)
Pruned only	47.5 ^b	197 ^b	245.3 ^a	119.7 ^a	578 ^a	212.5 ^a
Pruned + Sunny 0.25%	56.1 ^b	239 ^b	240.4 ^a	138.5 ^a	670 ^a	208.3 ^a
Pruned + Sunny 0.25% (2 sprays)	50.5 ^b	205 ^b	246.0 ^a	122.9 ^a	614 ^a	195.8 ^a
Pruned + Sunny 0.5%	39.8 ^b	166 ^b	227.9 ^a	138.0 ^a	653 ^a	213.3 ^a
Pruned + Sunny 0.5% (2 sprays)	61.5 ^{ab}	254 ^b	249.1 ^a	151.6 ^a	804 ^a	197.1 ^a
Unpruned control	89.3 ^a	418 ^a	254.5 ^a	141.6 ^a	814 ^a	181.8 ^a

*Five-year-old trees were pruned at an angle of 18° to form a pyramid on the 10th Jan 1999. Foliar treatments of Sunny[®] were first applied on the 24th Feb 1999 at 1.75 L/tree. A second treatment was applied on the 10th Mar 1999 at 1.5 L/tree for treatments 3 and 5. Another treatment at the rate of 1 L/tree was applied on the 12th Apr 1999 to all treated trees. Trees were harvested on the 27th Jul 1999 and the 7th Aug 2000.

Experiment 3: Goodwood

There was a significant effect ($P \leq 0.05$) of pruning time and Sunny[®] applications on the length and percentage flowering of regrowth shoots (Tables 5 and 6). For example, the length and flowering percentage of regrowth shoots was reduced when pruning was delayed until February. Also, Sunny[®] applications reduced the length and increased flowering of regrowth shoots, particularly when applied to trees pruned in December and January. Split applications of Sunny[®], either at 0.25 or 0.5%, were more effective in reducing regrowth shoot length than the single applications of the growth retardant. There was a significant effect of pruning time on tree growth (Tables 8 and 9). The increase in tree height and width was less in trees pruned in February. There was no effect of pruning time and Sunny[®] application on yield, the number of fruit per tree, and mean fruit size (data not shown).

Table 5 Effect of pruning time and foliar applications of Sunny[®] on regrowth length in ‘Hass’ at Goodwood in the 1999/2000 fruiting season. Data in columns are mean values of 4 trees. Values followed by different superscript letters are significantly different ($P \leq 0.05$) as tested by ANOVA.

Treatments*	Regrowth shoot length (cm)					Pruning mean
	No Sunny	Sunny 0.25%	Sunny 0.25% (two sprays)	Sunny 0.5%	Sunny 0.5% (two sprays)	
<u>Pruning time</u>						
December	90.4	61.0	45.0	57.3	54.8	61.7 ^a
January	79.4	58.9	45.1	50.8	40.4	54.9 ^b
February	51.4	47.9	39.8	45.1	41.0	45.0 ^c
Sunny mean	73.7 ^w	55.9 ^x	43.3 ^z	51.1 ^y	45.4 ^z	

*Four-year-old trees were pruned at an angle of 20° to form a pyramid on the 16th Dec 1999, 24th Jan 2000 or 22nd Feb 2000. Trees pruned in December received the first Sunny[®] application on the 24th Jan 2000. A second treatment was applied on the 3rd Feb 2000 for treatments 3 & 5. Trees pruned in January received the first Sunny[®] application on the 21st Feb 2000. A second treatment was applied on the 3rd Mar 2000 for treatments 3 & 5. Trees pruned in February received the first Sunny[®] application on the 27th Mar 2000. A second treatment was applied on the 7th Apr 2000 for treatments 3 & 5. Trees received 1.25 L of spray formulation each time.

**The length of the regrowth shoots was measured on the 17th Jul 2000.

Table 6 Effect of pruning time and foliar applications of Sunny[®] on regrowth flowering in ‘Hass’ at Goodwood in the 1999/2000 fruiting season. Data in columns are mean values of 4 trees. Values followed by different superscript letters are significantly different ($P \leq 0.05$) as tested by ANOVA.

Treatments*	Percent of regrowth shoot that flowered**					
	No Sunny	Sunny 0.25%	Sunny 0.25% (two sprays)	Sunny 0.5%	Sunny 0.5% (two sprays)	Pruning mean
<u>Pruning time</u>						
December	50.0	97.5	95.0	97.5	95.0	87.0 ^a
January	47.5	100.0	100.0	100.0	100.0	89.5 ^a
February	40.0	70.0	97.5	77.5	95.0	76.0 ^b
Sunny mean	45.8 ^y	89.2 ^x	97.5 ^x	91.7 ^x	96.7 ^x	

*Four-year-old trees were pruned at an angle of 20° to form a pyramid on the 16th Dec 1999, 24th Jan 2000 or 22nd Feb 2000. Trees pruned in December received the first Sunny[®] application on the 24th Jan 2000. A second treatment was applied on the 3rd Feb 2000 for treatments 3 & 5. Trees pruned in January received the first Sunny[®] application on the 21st Feb 2000. A second treatment was applied on the 3rd Mar 2000 for treatments 3 & 5. Trees pruned in February received the first Sunny[®] application on the 27th Mar 2000. A second treatment was applied on 7th Apr 2000 for treatments 3 & 5. Trees received 1.25 L of spray formulation each time.

**The percentage flowering of the regrowth shoots was assessed on the 17th Jul 2000.

Table 7 Effect of pruning time and foliar applications of Sunny[®] on tree height in ‘Hass’ at Goodwood in the 1999/2000 fruiting season. Data in columns are mean values of 4 trees. Values followed by different superscript letters are significantly different ($P \leq 0.05$) as tested by ANOVA.

Treatments*	Increase in tree height (cm)**					
	No Sunny	Sunny 0.25%	Sunny 0.25% (two sprays)	Sunny 0.5%	Sunny 0.5% (two sprays)	Pruning mean
<u>Pruning time</u>						
December	125.0	112.5	102.5	127.5	127.5	119.0 ^a
January	117.5	112.5	110.0	107.5	96.2	108.7 ^{ab}
February	102.5	102.5	105.0	108.7	80.0	99.7 ^b
Sunny mean	115.0 ^x	109.2 ^x	105.8 ^x	114.6 ^x	101.2 ^x	

*Four-year-old trees were pruned at an angle of 20° to form a pyramid on the 16th Dec 1999, 24th Jan 2000 or 22nd Feb 2000. Trees pruned in December received the first Sunny[®] application on the 24th Jan 2000. A second treatment was applied on the 3rd Feb 2000 for treatments 3 & 5. Trees pruned in January received the first Sunny[®] application on the 21st Feb 2000. A second treatment was applied on the 3rd Mar 2000 for treatments 3 & 5. Trees pruned in February received the first

Sunny[®] application on the 27th Mar 2000. A second treatment was applied on 7th Apr 2000 for treatments 3 & 5. Trees received 1.25 L of spray formulation each time.

**Tree height measurements were made after pruning and at flowering and the difference calculated.

Table 8 Effect of pruning time and foliar applications of Sunny[®] on tree width in ‘Hass’ at Goodwood in the 1999/2000 fruiting season. Data in columns are mean values of 4 trees. Values followed by different superscript letters are significantly different ($P \leq 0.05$) as tested by ANOVA.

Treatments*	Increase in tree width (cm)**					Pruning mean
	No Sunny	Sunny 0.25%	Sunny 0.25% (two sprays)	Sunny 0.5%	Sunny 0.5% (two sprays)	
<u>Pruning time</u>						
December	155.0	132.5	125.0	142.5	152.5	141.5 ^a
January	137.5	125.0	131.3	105.0	112.5	122.2 ^b
February	90.0	98.7	87.5	77.5	71.2	85.0 ^c
Sunny mean	127.5 ^x	118.7 ^x	114.6 ^x	108.3 ^x	112.1 ^x	

*Four-year-old trees were pruned at an angle of 20° to form a pyramid on the 16th Dec 1999, 24th Jan 2000 or 22nd Feb 2000. Trees pruned in December received the first Sunny[®] application on the 24th Jan 2000. A second treatment was applied on the 3rd Feb 2000 for treatments 3 & 5. Trees pruned in January received the first Sunny[®] application on the 21st Feb 2000. A second treatment was applied on the 3rd Mar 2000 for treatments 3 & 5. Trees pruned in February received the first Sunny[®] application on the 27th Mar 2000. A second treatment was applied on 7th Apr 2000 for treatments 3 & 5. Trees received 1.25 L of spray formulation each time.

**Tree width measurements were made after pruning and at flowering and the difference calculated.

Conclusions

The results of the summer pruning and growth retardant application trials in ‘Hass’ avocado are:

- Pruning stimulates shoot growth and the timing of the summer pruning influences the length of this regrowth and the ultimate increase in tree size.
- Foliar application of the growth retardant, Sunny[®] can reduce regrowth shoot length and increase the percentage of regrowth shoots that flower.
- Summer pruning may reduce fruit size, possibly as a result of competition for resources between regrowth and fruit development. Sunny[®] application negates the effect of pruning on fruit size.

Current canopy management research

The objectives of the current research is to:

- Determine the timing of pruning (phenological stage of development) to achieve optimal results in terms of tree size control, improved light interception and penetration, and yield sustainability.
- Identify the tree shape, height and width to optimise light interception by the canopy.
- Develop strategies to control regrowth through the utilisation of pruning and chemical growth retardants.
- Define the minimum light interception required to sustain flowering and fruiting down the side canopies of avocado trees.
- Determine the impact of canopy management strategies on fruit size and quality.

Time of pruning

There are basically two periods each year when avocado trees can be pruned, immediately following harvest (winter in subtropical Australia) or during summer. Research in South Africa suggests that trees that have borne a crop should be pruned as soon as possible after harvest (Snijder and Stassen, 1995; Snijder and Stassen, 1999). Trees to be pruned should be harvested as soon as fruit is mature to provide sufficient time for remaining shoots to develop strong flower buds that will set and retain fruit. Summer pruning is dependent on establishing and maintaining a tree shape at fruit set so that mechanical pruning can be implemented in the presence of the crop.

In the current project, trees have been pruned following the harvest (hard prune) and subsequent regrowth was pruned at monthly intervals during the summer (light prune).

Tree size and shape

The main objective of any canopy management strategy is to maximise light interception and control tree size. Research has indicated that trees pruned to form a pyramid in a hedgerow system to produce a maximum height that does not exceed 80% of the inter-row spacing is the most efficient way of improving light interception into the orchard.

The objective of this research is to identify the optimal pruning angle that will maintain effective light penetration into the orchard. Trees have been pruned with side canopies at the angles of 15, 18 and 20° to form a pyramid.

Controlling regrowth following pruning

Promotion of vegetative growth is a normal response to pruning trees. Control of regrowth is achieved by either a light follow-up pruning, or the application of chemical growth retardants. Sunny[®] a triazole growth retardant has become available for use in the avocado industry as a foliar application to trees during flowering. This product is being trialed to control vegetative growth following pruning during summer.

Light management

Avocado flowering and fruiting occurs on well-lit terminal sites on the surface of the canopy. Research (A.W. Whiley, Nambour, unpublished data) indicates that a minimum of 30% of the daily incoming light must reach the orchard floor for sustainable production.

Light interception of the side canopies in existing orchards at various stages of inter-tree shading will be measured and compared with yield data. Comparisons will also be made between pruned and non-pruned trees at critical stages of phenological development (eg. floral initiation, flowering and fruit set).

Impact on fruit quality

Factors affecting vegetative growth in avocado (eg. overcrowding, nitrogen fertilisation, irrigation, crop load, cultural practices and the use of plant growth regulators) can have an effect on fruit mineral content, particularly calcium. Excess spring growth has been shown to have a detrimental effect on fruit quality through competition for Ca and other nutrients during the first 6 to 10 weeks of fruit growth (Witney *et al.* 1990). Low Ca levels have been associated with several undesirable fruit characteristics in avocado including rapid softening after harvest (Wills and Tirmazi, 1982), susceptibility to chilling injury (Chaplin and Scott, 1980) and flesh disorders (Bower and Cutting, 1988).

The effect of pruning strategies on fruit quality aspects including size, severity and incidence of anthracnose and stem end rot, flesh discolouration, vascular browning, days to eating soft (stored at 20°C) and mineral content will be investigated.

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