The development of canopy management strategies suited to the different growing environments across Australia for increased profitability

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FINAL REPORT

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About This Report

This document is a final report containing the results and recommendations from a research program that investigated canopy management strategies being implemented by avocado growers across Australia. The effect of various plant growth regulators on shoot growth, flowering and yield were also investigated.

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Executive Summary

Canopy management is one of the major production issues confronting the Australian avocado industry. Cost effective means of tree size control to optimise light interception and penetration, maximise fruit quality and yield, and improve efficiency of harvesting and spraying operations are essential.

The objective of this study was to identify canopy management strategies that can be successfully implemented in all major avocado growing areas across Australia. Several canopy management strategies were evaluated, including selective limb removal, selective and mechanical pruning, staghorning, tree removal and plant growth regulator application. At many sites a combination of strategies are being used (eg. mechanical pruning, selective pruning and plant growth regulators).

The use of plant growth regulators as a canopy management tool was also evaluated. Trials were established to investigate the effect of naphthalene acetic acid (NAA) on regrowth in pruned trees, uniconazole (Sunny®) and paclobutrazol (Austar®) on shoot growth, flowering and yield in staghorned trees, and prohexadione-calcium (Regalis®) on shoot growth, fruit quality and yield.

Outcomes of the project include:

- Growers carry out canopy management operations to optimise light interception and penetration; maintain orchard access; reduce tree height (to increase efficiency of harvesting and spraying operations); rejuvenate tree health and productivity (particularly in crowded orchards) and maintain consistent cropping.

- Growers are using a range of canopy management strategies depending on tree age, planting density and extent of orchard crowding. In orchards where trees are less than 10 years old strategies to prevent crowding including selective and mechanical pruning and selective limb removal are used. In older orchards where crowding becomes an issue techniques including major limb removal, staghorning and tree removal are used.

- Geographic location will determine the relevance and suitability of various canopy management strategies.

  In north Queensland, central Queensland and the warmer coastal areas of south-east Queensland and northern New South Wales the crop can be harvested up to several months prior to flowering. In these growing areas pruning operations can be implemented after harvest and prior to flowering. Growers in these regions are using selective limb removal, mechanical and selective pruning techniques.

  In cooler, temperate climates of the hinterland areas of southern Queensland and northern New South Wales, central New South Wales, the Tri-State region and south-west Western Australia it is normal for the tree to carry two crops for a period of time (mature fruit from the previous season as well as current season's fruit). Growers in these regions typically adopt a selective limb removal strategy.

- Canopy management costs were generally highest at sites involving tree removal, staghorning and selective pruning where costs of mulching and removal of limbs was a major component. Costs were normally lowest in those systems involving mechanical pruning.

- The highest productivity was achieved using various methods of selective limb removal, selective and mechanical pruning, and plant growth regulator application. Productivity was lowest at sites involving staghorning and tree removal techniques. At these sites non-productive years significantly influence the productivity rating.

- Results of the plant growth regulator trials indicate that naphthalene acetic acid (NAA) reduced regrowth in pruned branches; uniconazole (Sunny®) and paclobutrazol (Austar®) reduced vegetative growth, increased flowering and tended to improve yields in staghorned trees; and prohexadione-calcium (Regalis®) reduced the spring growth flush and improved fruit quality when applied at flowering.

Part 1 Analysis of canopy management strategies used by growers across Australia

1.1 Introduction

Cost effective measures to control to manage tree size is a significant challenge for the Australian avocado grower. Due to increasing costs of production avocado growers need to be able to maintain consistent yields of high quality fruit to remain profitable. The avocado tree must produce new growth each year to remain productive (Whiley and Schaffer, 1994). However this continued growth will result in increased tree size that can eventually lead to orchard crowding and deterioration in fruit quality and yield.

The main problem with overcrowded orchards is insufficient light (Stadler and Stassen, 1985). Light is critical for flowering and fruit production. There are several systems to manage tree size and improve light interception and penetration, including selective limb removal (individual limbs are removed); mechanical pruning (trees are pruned to form a hedgerow); staghorning (trees are pruned back to a stump and allowed to re-grow); tree thinning (alternate rows or trees within a row are removed as orchards begin to crowd), tree removal (whole blocks are removed after 10-15 years and replaced with new trees); cincturing (ringbarking of individual branches) and plant growth regulator application (to reduce vegetative growth and increase fruit size).

Previous work identified several canopy management strategies currently employed by individual growers across Australia (Piccone, 2004). A method of analysing these strategies in terms of cost of production ($/hectare/year) and productivity (tonnes/hectare/year) was developed.

The objective of the current project was to identify canopy management strategies that can be successfully implemented throughout all production areas across Australia.

1.2 Materials and Methods

1.2.1 Selection of orchards

In Australia commercial avocado production occurs in a wide range of environments from the wet tropics of north Queensland (latitude 17°S) to the dry Mediterranean climate of southern Australia (latitude 34°S). A total of 22 sites were selected as case studies from the major production areas across Australia, including north Queensland, central/southern Queensland, northern/central New South Wales, the Tri-State and south-west Western Australia.

1.2.2 Data collection

Information on variety, tree age, planting density, row orientation and the timing of flowering, vegetative flushing, and harvesting was collected from each site. The timing and costs ($/ha) of the canopy management strategies and the impact of these strategies on yield (t/ha) was determined. Fruit size (pack-out figures) and quality (reject %'s) was also collected from some sites. The effectiveness of each canopy management system in terms of cost of operation ($/ha/year) and impact on yield (t/ha/year) was determined.

Details including an orchard description (including variety, tree age and spacing), the annual growth cycle, canopy management strategies including timing and costs of operations, and yields are presented for each study site.

1.3 Analysis of Canopy Management Sites

Site 1: Selective limb removal – North Queensland

Orchard description:
Variety: Shepard; Block size: 3.25 ha; Trees planted: 1993; Spacing: 10 x 5m (200 trees/ha); Row orientation: E-W

Growth cycle:
The annual growth cycle for 'Shepard' avocado grown on the Atherton Tablelands in north Queensland is shown below.

Growth cycle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering												
Spring flush												
Summer flush												
Harvest												

Canopy management history:
Individual limbs were removed after harvest (April-July) to improve light penetration, reduce tree height to increase the efficiency of harvesting and spraying operations and maintain inter-row access. Dead limbs were removed to reduce disease incidence and trees skirted each year for orchard maintenance and sprinkler efficiency. Limbs were mulched and exposed branches painted to prevent sunburn.

Year (Tree age)	Canopy management operations	Timing of operation	Costs of operation		Yield	
			$/ha	$/tree	t/ha	kg/tree
2000 (7)	Selective limb removal – outer limbs growing into the inter-rows and dead wood removed.	July	1000	5.00	28	140.0
2001 (8)	Selective limb removal – outer limbs growing into the inter-rows and dead wood removed.	July	1030	5.15	16	80.0
2002 (9)	Selective limb removal – outer limbs growing into the inter-rows and dead wood removed. Centre limbs removed to improve light penetration.	June	1130	5.65	10	50.0
2003 (10)	Half the tree was removed – to reduce tree size and to improve light penetration	April	1540	7.70	21	105.0
2004 (11)	Selective limb removal – to maintain open centres, tree height and inter-row access	April/May	930	4.65	17.6	88.0
2005 (12)	Selective limb removal – to maintain open centres, tree height and inter-row access	April/May	600	3.00	15.9	79.5
2006 (13)	Selective limb removal – to maintain open centres, tree height and inter-row access	June	760	3.80	22	110.0
2007 (14)	Selective limb removal – to maintain open centres, tree height and inter-row access	May/June	330	1.65	6.5	32.5
2008 (15)	Selective limb removal – to maintain open centres, tree height and inter-row access	May/June	420	2.10	17.8	89.0
			860 $/ha/yr	4.30 $/tree/yr	17.2 t/ha/yr	86kg /tree/yr

Site 2: **Mechanical and selective pruning – North Queensland**

Orchard description:
Variety: Shepard; Block size: 1.85 ha; Trees planted: 1989; Spacing: 11 x 6m (150 trees/ha); Row orientation: N-S

Growth cycle:
The annual growth cycle for 'Shepard' avocado grown on the Atherton Tablelands in north Queensland is shown below.

Growth cycle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering												
Spring flush												
Summer flush												
Harvest												

Canopy management history:
Trees were mechanically pruned after harvest (March-April) to reduce tree size and to maintain inter-row access. Large trees took 4 runs on each side using a pruner with a 3.2m cutting width. The pruning surface moves out about 5 cm each year from the previous cut. Trees were also selectively pruned to improve light penetration into the tree and to increase the efficiency of harvesting and spraying operations. Pole-saws were used to open up centres, to thin out overlapping branches and remove branches encroaching neighbouring trees within the row. Pruned limbs up to 15cm in diameter were mulched and larger limbs removed from the orchard. Exposed branches were sprayed with a clay preparation to prevent sunburn.

Year (Tree age)	Canopy management operations	Timing of operation	Costs of operation $/ha	$/tree	Yield t/ha	kg/tree
2004 (15)	Mechanical pruning of sides and tops. Selective pruning to open up trees, cutting up and windrowing branches. Mulching of branches. Sunburn protection.	March/April	420 1130 190 150	2.80 7.50 1.30 1.00	17.3	115.5
2005 (16)	Mechanical pruning of sides and tops; selective pruning to open up trees; cutting up branches; mulching of branches and sunburn protection.	March/April	1890	12.60	16.5	110.0
2006 (17)	Mechanical pruning of sides and tops; selective pruning to open up trees; cutting up branches; mulching of branches and sunburn protection.	March/April	1890	12.60	19.0	126.5
2007 (18)	Mechanical pruning of sides and tops; selective pruning to open up trees; cutting up branches; mulching of branches and sunburn protection.	March/April	1890	12.60	24.8	165.0
2008 (19)	Mechanical pruning of sides and tops; selective pruning to open up trees; cutting up branches; mulching of branches and sunburn protection.	March/April	1890	12.60	20.6	137.5
			1890 $/ha/yr	12.60 $/tree/yr	19.6 t/ha/yr	130.9kg /tree/yr

Site 3: **Mechanical and selective pruning – North Queensland**

Orchard description:
Variety: Shepard; Block size: 2.4ha; Trees planted: 2000; Spacing: 8 x 6m (208 trees/ha); Row orientation: N-S

Growth cycle:
The annual growth cycle for 'Shepard' avocado grown near Mareeba in north Queensland is shown below.

Growth cycle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering												
Spring flush												
Summer flush												
Harvest												

Canopy management history:
Trees were mechanically pruned after harvest (April) to reduce tree size and to maintain inter-row access. Individual branches were selectively removed to improve light penetration, cherry picker access and spray penetration. Lower branches were also removed. A light mechanical pruning is carried out during summer (January) to maintain tree size and shape. Branches were mulched after pruning.

Year (Tree age)	Canopy management operations	Timing of operation	Costs of operation $/ha	$/tree	Yield t/ha	kg/tree
2006 (6)	A light mechanical pruning of the sides and tops. Selective pruning and dragging out branches. Mulching of branches.	April	160 800 80 (1040)	0.80 3.80 0.40 (5.00)	9.1	43.8
2007 (7)	A light mechanical pruning of the sides and tops. Selective pruning and dragging out branches. Mulching of branches.	April	160 800 80 (1040)	0.80 3.80 0.40 (5.00)	18.3	88.0
2008 (8)	A light mechanical pruning to cut back the spring growth flush. Mechanical pruning to reduce tree size and maintain orchard access. Selective pruning, skirting of trees and dragging out of branches. Mulching of branches.	Jan April	160 320 900 80 (1460)	0.80 1.50 4.30 0.40 (7.00)	10.3	49.5
			1180 $/ha/yr	5.70 $/tree/yr	12.6 t/ha/yr	60.4kg /tree/yr

Site 4: Mechanical and selective pruning - North Queensland

Orchard description:
Variety: Hass; Block size: 5.25ha; Trees planted: 1997; Spacing: 11 x 8m (115 trees/ha); Row orientation: N-S

Growth cycle:
The annual growth cycle for 'Hass' avocado grown on the Atherton Tablelands in north Queensland is shown below.

Growth cycle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering												
Spring flush												
Summer flush												
Harvest												

Canopy management procedure:
Trees were mechanically pruned to form a barn shape after harvest in June. Sides were cut at an angle of 15° and tops at an angle of 60° from the vertical. Tree height was reduced to 4.6m. Trees were also selectively pruned with a minimum of 10% of the tree removed to improve light penetration and cherry-picker access. Branches were mulched after pruning.

Canopy management history:

Year (Tree age)	Canopy management operations	Timing of operation	Costs of operation $/ha	$/tree	Yields t/ha	kg/tree
2005 (8)	Trees are mechanically pruned after harvest. Chopping up branches ready for mulching Mulching of branches Selective limb removal to open up tree for light and cherry-picker access Mulching of branches	June	300 60 270 360 150	2.60 0.50 2.35 3.15 1.30		
2006 (9)	Trees are mechanically pruned after harvest. Chopping up branches ready for mulching Mulching of branches Selective limb removal to open up tree for light and cherry-picker access Mulching of branches	June	300 60 270 460 170	2.60 0.50 2.35 4.00 1.50	est.20*	est.173.9
2007 (10)	Trees are mechanically pruned after harvest. Chopping up branches ready for mulching Mulching of branches Selective limb removal to open up tree for light and cherry-picker access Mulching of branches	June	300 60 270 560 190	2.60 0.50 2.35 4.90 1.65	21	182.6
2008 (11)					15	130.4
			1260 $/ha/yr	10.95 $/tree/yr	18.7 t/ha/yr	162.3kg /tree/yr

***** Cyclone Larry reduce yields to 10t/ha in 2006

Site 5: **Major limb removal, selective/mechanical pruning and plant growth regulators - Central Queensland**

Orchard description:
Variety: Shepard; Block size: 3.5 ha; Trees planted: 1990; Spacing: 9 x 6m (185 trees/ha); Row orientation: N-S

Growth cycle:
The annual growth cycle for 'Shepard' avocado grown at this central Queensland site is shown below.

Growth cycle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering												
Spring flush												
Summer flush												
Harvest												

Canopy management history:
The western side of the tree was removed using chainsaws after harvest in May/June 2000. Tree height was reduced from 6.5 to 5m. Pruned branches were mulched and exposed branches painted to prevent sunburn. In 2001 and 2004 trees were tip pruned the after harvest on both sides using mechanical saws to maintain tree size. During 2002 and 2003 trees were both mechanically pruned to maintain tree size and selectively pruned to open up trees. Since 2005 a selective limb removal strategy was carried out to reduce tree height, maintain inter-row access and open up trees for light penetration and cherry-picker access. 0.5% Sunny® at 2 litres per tree was applied at flowering in September each year to reduce the spring growth and increase fruit size.

Year (Tree age)	Canopy management operations	Timing of operation	Costs of operation $/ha	$/tree	Yield t/ha	kg/tree
2000 (10)	One side of the tree removed after harvest. Mulching of branches.	May/June	3200	17.30	11.8	63.8
	Sunny® at flowering.	September	600	3.20		
2001 (11)	Tips pruned mechanically on both sides after harvest.	May/June	600	3.20	24.5	132.4
	Sunny® at flowering.	September	600	3.20		
2002 (12)	Tips pruned mechanically & selective limb removal after harvest. Mulching of branches.	May/June	1000	5.40	15.1	81.6
	Sunny® at flowering.	September	600	3.20		
2003 (13)	Tips pruned mechanically & selective limb removal after harvest. Mulching of branches.	May/June	1200	6.50	22.6	122.2
	Sunny® at flowering.	September	600	3.20		
2004 (14)	Tips pruned mechanically after harvest.	May/June	700	3.80	8.6	46.5
	Sunny® at flowering.	September	600	3.20		
2005 (15)	Selective limb removal after harvest.	May/June	1400	7.60	6.4	34.6
	Sunny® at flowering.	September	600	3.20		
2006 (16)	Selective limb removal after harvest.	May/June	1400	7.60	19.3	104.3
	Sunny® at flowering.	September	600	3.20		
2007 (17)	Selective limb removal after harvest.	May/June	1400	7.60	23.6	127.6
	Sunny® at flowering.	September	600	3.20		
			1960 $/ha/yr	10.60 $/tree/yr	16.5 t/ha/yr	89.1kg /tree/yr

Percentage of trays for each size category and the total number of trays packed for each year from 2000 to 2007

Year (Tree age)	16	18/20	22	23	25	28	2nds	Bulks (10 kg)	Total number of trays
2000 (10)	1.8	23.7	8.4	24.6	11.7	6.8	17.4	5.6	6191
2001 (11)	1.1	21.9		25.2	18.6	13.1	13.3	6.8	12428
2002 (12)	0.4	10.9		18.2	20.5	24.8	11.7	13.5	7436
2003 (13)	0.1	4.3		9.6	15.1	25.8	14.2	30.9	9599
2004 (14)	0.8	21.8		19.1	16.0	15.9	15.4	11.0	4458
2005 (15)	9.0	51.0		14.6	5.4	2.1	12.6	5.2	3459
2006 (16)	1.1	28.6		22.6	13.4	10.2	19.0	5.0	10416
2007 (17)		20.3		20.9	15.6	13.9	11.2	18.2	14177

Site 6: **Selective limb removal, mechanical pruning and plant growth regulators - Central Queensland**

Orchard description:
Variety: Hass; Block size: 3.36 ha; Trees planted: 1994; Spacing: 10 x 5m (200 trees/ha); Row orientation: N-S.

Growth cycle:
The annual growth cycle for 'Hass' avocado grown at this central Queensland site is shown below.

Growth cycle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering												
Spring flush												
Summer flush												
Harvest												

Canopy management history:
During 2000 to 2003 individual limbs were removed after harvest (July) to reduce tree height, maintain inter-row access and open up trees for light penetration and cherry-picker access. Pruned branches were mulched. In 2004 trees were mechanically pruned the after harvest to maintain tree size. Since 2005 a selective limb removal strategy was implemented. A 0.5% Sunny® at 2 litres per tree was applied at flowering in September each year to reduce the spring growth and increase fruit size.

Year (Tree age)	Canopy management operations	Timing of operation	Costs of operation $/ha	$/tree	Yield t/ha	kg/tree
2000 (6)	Selective limb removal after harvest and mulching of branches. Sunny® at flowering.	July September	1400 650	7.00 3.25	24.2	121.0
2001 (7)	Selective limb removal and mulching Sunny® at flowering.	July September	1400 650	7.00 3.25	28.5	142.5
2002 (8)	Selective limb removal and mulching. Sunny® at flowering.	July September	1400 650	7.00 3.25	16.8	84.0
2003 (9)	Selective limb removal and mulching. Sunny® at flowering.	July September	1400 650	7.00 3.25	23.7	118.5
2004 (10)	Trees pruned mechanically after harvest and mulching of branches Sunny® at flowering.	July September	700 650	3.50 3.25	12.3	61.5
2005 (11)	Selective limb removal to reduce tree height and width after harvest & mulching. Sunny® at flowering.	July September	1400 650	7.00 3.25	17.2	86.0
2006 (12)	Selective limb removal and mulching. Sunny® at flowering.	August September	1400 650	7.00 3.25	24.0	120.0
2007 (13)	Selective limb removal and mulching. Sunny® at flowering.	August September	1400 650	7.00 3.25	23.0	115.0
			1960 $/ha/yr	9.80 $/tree/yr	16.5 t/ha/yr	106.1kg /tree/yr

Percentage of trays for each size category and the total number of trays packed for each year from 2000 to 2007

Year (Tree age)	16	18/20	22	23	25	28	2nds	Blks S	Blks 3	Total number of trays
2000 (6)	2.1	43.0	17.0	10.5	11.6	6.1	7.3	2.3		13555
2001 (7)	0.7	20.9	14.3	13.1	19.4	9.5	14.5	6.3	1.4	15001
2002 (8)	0.2	10.8	10.0	13.0	23.7	23.2	9.9	9.2		8876
2003 (9)	2.2	20.2	11.1	8.1	11.0	8.7	24.4	2.8	11.5	11991
2004 (10)	0.03	14.6	1.7	20.8	19.5	15.9	14.5	5.7	7.3	6467
2005 (11)	0.1	19.1		23.0	19.0	19.8	10.6	2.2	6.1	9134
2006 (12)		14.2		20.9	21.2	21.9	11.5	7.1	3.2	12527
2007 (13)		10.4		20.5	26.0	14.4	12.3	8.7	7.8	13705

Site 7: **Mechanical and selective pruning – Central Queensland**

Orchard description:
Variety: Shepard; Block size: 4.72ha; Trees planted: 1993; Spacing: 10 x 5m (200 trees/ha); Row orientation: N-S

Growth cycle:
The annual growth cycle for 'Shepard' avocado grown at this central Queensland site is shown below.

Growth cycle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering												
Spring flush												
Summer flush												
Harvest												

Canopy management history:
Trees were mechanically pruned after harvest (May/June) to reduce tree size and to maintain inter-row access. Mechanical pruning involved three cuts each side (lower cut – vertical; middle cut – 10 to 15° from the vertical and top cut - 30° from the vertical). Trees were mechanically tip pruned during late spring/early summer to cut back the spring growth. In 2005 trees were cut back hard on one side using mechanical pruner. A follow-up hand pruning was carried out to remove bare branches. Pruned branches were mulch.

Year (Tree age)	Canopy management operations	Timing of operation	Costs of operation $/ha	$/tree	Yield t/ha	kg/tree
2002 (9)	Trees mechanically pruned after harvest. Trees mechanically tip pruned.	May/June Nov/Dec	500 300	2.50 1.50	8.1	40.5
2003 (10)	Trees mechanically pruned after harvest. Trees mechanically tip pruned.	May/June Nov/Dec	500 300	2.50 1.50	22.6	113.0
2004 (11)	Trees mechanically pruned after harvest. Trees mechanically tip pruned.	May/June Nov/Dec	500 300	2.50 1.50	9.5	47.5
2005 (12)	Trees mechanically pruned on one side Hand pruning to remove bare branches Mulching of branches	May/June	1500	7.50	13.3	66.5
2006 (13)	Trees mechanically pruned after harvest. Trees mechanically tip pruned.	May/June Nov/Dec	500 300	2.50 1.50	23.3	116.5
2007 (14)	Trees mechanically pruned after harvest.	May/June	500	2.50	16.9	84.5
			870 $/ha/yr	4.30 $/tree/yr	15.6 t/ha/yr	78.1kg /ha/yr

Percentage of trays for each size category and the total number of trays packed for each year from 2002 to 2007

Year (Tree age)	14	16	18	20	22	23	25	28	30	32	Pre-Pack	Bulk 1st (10kg)	Bulk 2nd (10kg)	Total number of trays
2002 (9)		0.7	5.2	14.2	8.8	13.7	20.5	12.5	3.5	4.6		16.2		6008
2003 (10)			0.6	6.5	6.3	14.3	23.6	23.0	2.0			14.1	9.6	15908
2004 (11)		0.6	4.0	15.2	8.9	23.5	20.2	9.3				3.7	14.6	9249
2005 (12)	0.1	1.2	6.0	27.4	6.7	20.4	17.2	4.1				2.8	14.2	9792
2006 (13)		0.2	0.6	15.2		15.9	36.0	10.8			1.2	8.6	11.4	16586
2007 (14)	11.5				47.8			40.7						14730

Reject level in 2007: 15.6 %

Site 8: **Mechanical and selective pruning – Central Queensland**

Orchard description:
Variety: Shepard; Block size: 4.67ha; Trees planted: 1994; Spacing: 10 x 5m (200 trees/ha); Row orientation: N-S

Growth cycle:
The annual growth cycle for 'Shepard' avocado grown at this central Queensland site is shown below.

Growth cycle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering												
Spring flush												
Summer flush												
Harvest												

Canopy management history:
Trees were mechanically pruned after harvest (May/June) to reduce tree size and to maintain inter-row access. Mechanical pruning involves three cuts each side (lower cut – vertical; middle cut – 10 to 15° from the vertical and top cut - 30° from the vertical). Trees were mechanically tip pruned during late spring/early summer to cut back the spring growth. In 2005-2007 trees were selectively pruned to reduce size and improve light penetration into the tree. Pruned branches were mulched.

Year (Tree age)	Canopy management operations	Timing of operation	Costs of operation $/ha	$/tree	Yield t/ha	kg/tree
2002 (8)	Trees mechanically pruned after harvest. Trees mechanically tip pruned.	May/June Nov/Dec	500 300	2.50 1.50	11.5	57.5
2003 (9)	Trees mechanically pruned after harvest. Trees mechanically tip pruned.	May/June Nov/Dec	500 300	2.50 1.50	23.0	115.0
2004 (10)	Trees mechanically pruned after harvest. Trees mechanically tip pruned.	May/June Nov/Dec	500 300	2.50 1.50	10.0	50.0
2005 (11)	Selectively pruned tops and sides Mulching of branches	May/June	1950	9.75	15.4	77.0
2006 (12)	Selectively pruned tops and sides Mulching of branches	May/June	1200	6.00	23.2	116.0
2007 (13)	Selectively pruned tops and sides Mulching of branches	May/June	1200	6.00	22.3	111.5
			1125 $/ha/yr	5.60 $/tree/yr	17.6 t/ha/yr	87.8kg /ha/yr

Percentage of trays for each size category and the total number of trays packed for each year from 2002 to 2007

Year (Tree age)	14	16	18	20	22	23	25	28	30	32	Pre-Pack	Bulk 1st (10kg)	Bulk 2nd (10kg)	Total number of trays
2002 (8)		0.8	5.2	15.3	9.4	16.6	21.2	3.2	2.6	4.0			11.61	8683
2003 (9)		0.1	0.79	8.4	6.7	19.2	25.4	20.8	0.6			8.0	10.0	16601
2004 (10)	0.2	2.0	7.1	17.1	7.6	17.7	16.8	10.9				5.6	14.7	7129
2005 (11)		0.2	3.3	20.5	6.7	22.3	22.5	8.7				4.5	11.3	11239
2006 (12)		0.2	0.5	14.7		16.5	34.3	11.6	1.8			9.7	10.7	16946
2007 (13)	10.4				51.0			38.6						19274

Reject level in 2007: 10.9 %

Site 9: **Mechanical pruning, major limb removal and plant growth regulators – Central Queensland**

Orchard description:
Variety: Hass; Block size: 2.5ha; Trees planted: 1993; Spacing: 10 x 5m (200 trees/ha); Row orientation: N-S

Growth cycle:
The annual growth cycle for 'Hass' avocado grown at this central Queensland site is shown below.

Growth cycle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering												
Spring flush												
Summer flush												
Harvest												

Canopy management history:
In 2002 and 2003 trees were mechanically pruned at an angle of 15° from the vertical after harvest (July) to reduce tree size and to maintain inter-row access. Trees were mechanically tip pruned during early summer to cut back the spring growth. In 2004 the western side of the tree were removed after harvest. Trees were mechanical pruned vertically 1½ m from the trunk. A follow up hand pruning was carried out to remove bare branches. Tree width was reduced from 8m to 5m. In 2005 tops on the eastern side were mechanically pruned at an angle of 55° from the vertical. Tree height was reduced from 9m to 6m. In 2006 and 2007 trees were mechanically pruned at a 15° angle after harvest and in December. Sunny® at 0.7% was applied at flowering in September.

Year (Tree age)	Canopy management operations	Timing of operation	Costs of operation $/ha	$/tree	Yield t/ha	kg/tree
2002 (9)	Trees mechanically pruned after harvest. Sunny® (0.7% @ 3 L/tree) at flowering. Trees mechanically tip pruned.	July September December	500 1200 300	2.50 6.00 1.50	17.0	85.0
2003 (10)	Trees mechanically pruned after harvest. Sunny® (0.7% @ 3 L/tree) at flowering. Trees mechanically tip pruned.	July September December	500 1200 300	2.50 6.00 1.50	20.8	104.0
2004 (11)	Western side of the tree pruned after harvest. Hand pruning to remove bare branches and mulching of branches. Sunny® (0.7% @ 2 L/tree) at flowering. Trees mechanically tip pruned.	July September December	2600 850 300	13.00 4.25 1.50	14.8	74.0
2005 (12)	Eastern side tops of trees were mechanically pruned. Branches mulched. Sunny® (0.7% @ 2 L/tree) at flowering. Trees mechanically tip pruned.	July September December	2100 850 300	10.50 4.25 1.50	20.0	100.0
2006 (13)	Trees mechanically pruned after harvest. Sunny® (0.7% @ 2 L/tree) at flowering. Trees mechanically tip pruned.	July September December	500 850 300	2.50 4.25 1.50	14.6	73.0
2007 (14)	Trees mechanically pruned after harvest. Trees mechanically tip pruned.	July December	500 300	2.50 1.50	28.6	143.0
			2240 $/ha/yr	11.20 $/tree/yr	19.3 t/ha/yr	96.5kg /tree/yr

Percentage of trays for each size category and the total number of trays packed for each year from 2003 to 2007

Year (Tree age)	14	16	18	20	22	23	25	28	30	Bulk 1st (10kg)	Bulk 2nd (10kg)	Total number of trays
2003 (10)		0.1	0.79	8.4	6.7	19.2	25.4	20.8	0.6	8.0	10.0	16601
2004 (11)	0.2	2.0	7.1	17.1	7.6	17.7	16.8	10.9		5.6	14.7	7129
2005 (12)		0.2	3.3	20.5	6.7	22.3	22.5	8.7		4.5	11.3	11239
2006 (13)		0.2	0.5	14.7		16.5	34.3	11.6	1.8	9.7	10.7	16946
2007 (14)	10.4				51.0			38.6				19274

Reject level in 2007: 10.3 %

Site 10: **Mechanical pruning and plant growth regulators – Central Queensland**

Orchard description:
Variety: Hass; Block size: 5.36ha; Trees planted: 2000; Spacing: 10 x 5m (200 trees/ha); Row orientation: N-S

Growth cycle:
The annual growth cycle for 'Hass' avocado grown at this central Queensland site is shown below.

Growth cycle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering												
Spring flush												
Summer flush												
Harvest												

Canopy management history:
In 2003 and 2004 trees were mechanically tip pruned at an angle of 25° from the vertical in December to shape trees. Young trees only required one cut on each side. In 2005 and 2006 trees were mechanically pruned at an angle of 10-15° from the vertical after harvest (July) and in December to maintain tree shape and inter-row access. Trees required two cuts on each side at an angle of 10-15°. In 2007 trees were mechanically pruned after harvest and in December to maintain tree shape and inter-row access. Trees required three cuts on each side (lower cut at 10-15°; middle cut 20° and top cut - 45°). Sunny® at 0.7% was applied at flowering in September since 2004.

Year (Tree age)	Canopy management operations	Timing of operation	Costs of operation $/ha	$/tree	Yield t/ha	kg/tree
2001 (1)	No pruning	-	0	0	0	0
2002 (2)	No pruning	-	0	0	3.7	18.5
2003 (3)	Trees mechanically tip pruned.	December	200	1.00	10.3	51.5
2004 (4)	Sunny® (0.7% @ 1.5 l/tree) at flowering. Trees mechanically tip pruned.	September December	600 200	3.00 1.00	8.4*	42.0
2005 (5)	Trees mechanically pruned. Sunny® (0.7% @ 1.5 l/tree) at flowering. Trees mechanically tip pruned.	July September December	400 600 300	2.00 3.00 1.50	26.3	131.5
2006 (6)	Trees mechanically pruned. Sunny® (0.7% @ 2 l/tree) at flowering. Trees mechanically tip pruned.	July September December	400 780 300	2.00 3.90 1.50	21.9	109.5
2007 (7)	Trees mechanically pruned. Sunny® (0.7% @ 2 l/tree) at flowering. Trees mechanically tip pruned.	July September December	500 780 300	2.50 3.90 1.50	23.4	117.0
			765 $/ha/yr	3.80 $/tree/yr	13.4 t/ha/yr	67.1kg /tree/yr

* Boron nutrition problems

Percentage of trays for each size category and the total number of trays packed for each year from 2002 to 2007

Year (Tree age)	14	16	18	20	22	23	25	28	30	Pre-Pack	Bulk 1st (10kg)	Bulk 2nd (10kg)	Total number of trays
2002 (2)	0.3	2.6	18.1	8.2	22.4	22.7	9.6	0.1	0.3		10.4	5.4	3126
2003 (3)		1.0	9.6	6.4	25.1	25.3	14.4	0.4			9.2	8.6	8509
2004 (4)	0.7	4.8	16.2	11.0	23.6	21.8	8.2	0.4			4.2	9.0	7189
2005 (5)	1.0	5.3	26.0	8.5	21.2	19.0	2.5			1.1	5.4	10.1	21973
2006 (6)	6.1	13.0	44.3		10.0	8.6	0.7			1.2	2.2	12.8	18440
2007 (7)	22.9				59.4			17.7					22417

Reject level in 2007: 7.3%

Site 11: **Mechanical/selective pruning and plant growth regulators – SE Queensland**

Orchard description:
Variety: Hass; Block size: 0.7ha; Trees planted: 1993; Spacing: 12 x 6m (200 trees/ha); Row orientation: N-S

Growth cycle:
The annual growth cycle for 'Hass' avocado grown at this site on the Sunshine Coast in south-east Queensland is shown below.

Growth cycle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering												
Spring flush												
Summer flush												
Harvest												

Canopy management history:
In 2001 trees were mechanically pruned after harvest (June) for the first time. Height was reduced from 10m to 6m and width from 8m to 5m. A follow up hand pruning was carried out to cut back bare branches. Pruned branches were mulched. Trees were mechanically tip pruned to cut back the spring growth was carried out in summer (December). During 2002-2004 trees were mechanical pruned on the sides after harvest and in summer to maintain tree shape and inter-row access. In 2005 tree tops were mechanically pruned after harvest to reduce tree height to 5m. A follow up hand pruning was carried out to cut back bare branches. Pruned branches were mulched. Exposed branches were painted for sunburn protection. In 2006 trees were mechanical pruned (tops & sides) after harvest and in summer to maintain tree shape and inter-row access. 0.5% Sunny® was applied at flowering in September each year.

Year (Tree age)	Canopy management operations	Timing of operation	Costs of operation $/ha	$/tree	Yield t/ha	kg/tree
2001 (8)	Trees mechanically pruned after harvest. Cutting back branches and mulching. Sunny® at flowering. Mechanical tip pruning.	June September December	1800 650 300	13.50 4.90 2.25	10.5	78.9
2002 (9)	Mechanical pruning of sides after harvest. Sunny® at flowering. Mechanical tip pruning.	June September December	300 650 300	2.25 4.90 2.25	6.7	50.4
2003 (10)	Mechanical pruning of sides after harvest. Sunny® at flowering. Mechanical tip pruning.	June September December	300 650 300	2.25 4.90 2.25	18.6	139.8
2004 (11)	Mechanical pruning of sides after harvest. Sunny® at flowering. Mechanical tip pruning.	June September December	300 650 300	2.25 4.90 2.25	10.5	78.9
2005 (12)	Mechanical pruning of tops after harvest. Cutting back branches, mulching and painting of exposed branches. Sunny® at flowering. Mechanical pruning of tops	July September December	4500 650 400	33.80 4.90 3.00	12.4	93.2
2006 (13)	Mechanical pruning after harvest. Application of Sunny® at flowering. Mechanical pruning (tip pruning).	June September December	300 650 300	2.25 4.90 2.25	10.0	75.2
			2215 $/ha/yr	16.70 $/tree/yr	11.5 t/ha/year	86.1kg /tree/yr

Site 12: **Staghorning and selective pruning – Southern Queensland**

Orchard description:
Variety: Hass; Block size: 2.5ha; Trees planted: 1989; Spacing: 10 x 5m (200 trees/ha); Row orientation: E-W

Growth cycle:
The annual growth cycle for 'Hass' avocado grown at this Southern Queensland site is shown below.

Growth cycle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering												
Spring flush												
Summer flush												
Harvest												

Canopy management history:
In 2002 trees were cut back using chainsaws to a stump after harvest (November). Branches were chipped and stumps painted to avoid sunburn. Minor thinning of the regrowth to improve light penetration and reduce crowding was carried out after harvest commenced in the second year after staghorning.

Tree age	Canopy management operations	Timing of operation	Costs of operation		Yield	
			$/ha	$/tree	t/ha	kg/tree
2002 (13)	Trees staghorned after harvest (including cutting up trees, chipping and painting of stumps)	November	3400	17.00	11.2	56.0
2003 (14)	No pruning	-	0	0	0	0
2004 (15)	Minor thinning (hand pruning) to improve light penetration and reduce crowding	November	600	3.00	1.1	5.5
2005 (16)	Minor thinning (hand pruning)	November	600	3.00	7.8	39.0
2006 (17)	Minor thinning (hand pruning)	November	600	3.00	10.1	50.5
			1040 $/ha/yr	5.20 $/tree/yr	6.0 t/ha/yr	30.2kg /tree/yr

Percentage of trays for each size category and the total number of trays packed in 2006

Year	16	18	20	22	23	25	28	30	Bulk (10kg)	Total number of trays
2006	4.0	9.3	20.9	39.6		16.5	7.3	1.5	0.9	4495

Site 13 Selective limb removal – Southern Queensland

Orchard description:
Variety: Hass; Block size: 3.02ha; Trees planted: 1982; Spacing: 9 x 9m (123 trees/ha); Row orientation: N-S

Growth cycle:
The annual growth cycle for 'Hass' avocado grown at this Southern Queensland site is shown below.

Growth cycle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering												
Spring flush												
Summer flush												
Harvest												

Canopy management history:
Trees were very large up to 10-12m in height with large unproductive areas in the lower canopy. In 2006 limbs were selectively removed after harvest (October/November) to reduce tree height, improve light penetration and to encourage shoot growth lower down the tree to improve efficiency of harvesting. The procedure was repeated in August 2007. Large branches were chipped – some of the chipped material was sold to compensate for the costs of pruning.

Tree age	Canopy management operations	Timing of operation	Costs of operation $/ha	Costs of operation $/tree	Yield t/ha	Yield kg/tree
2006 (24)	Selective limb removal to reduce tree height and improve light penetration & chipping of branches	Oct/Nov	2500*	20.30	26.9	218.7
2007 (25)	Further selective limb removal & chipping	August	3220*	26.20	1.7	13.8
			2860 $/ha/yr	23.25 $/tree/yr	14.3 t/ha/yr	116.3kg /tree/yr

* Value of chip can be subtracted from the cost of operation ($400/ha in first year; $850/ha in second year 2007)

Site 14: Selective pruning and limb removal – Northern New South Wales

Orchard description:
Variety: Hass; Block size: 1.0ha; Trees planted: 1994; Spacing: 7 x 5.5m (260 trees/ha); Row orientation: N-S

Growth cycle:
The annual growth cycle for 'Hass' avocado grown at this site northern New South Wales site is shown below.

Growth cycle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering												
Spring flush												
Summer flush												
Harvest												

Canopy management history:
Limbs were selectively removed or cut back to reduce tree height, improve light penetration and increase the efficiency of harvesting and spraying operations. The number of main limbs was reduced to 2 to 4 depending on tree and row spacing. In 2001 tree height was reduced from 7-8m to 5-6m after harvest. Selective pruning was carried out each year after harvest to maintain tree height and an open canopy. Pruned branches were mulched.

Year (Tree age)	Canopy management operations	Timing of operation	Costs of operation $/ha	$/tree	Yield t/ha	kg/tree
2001 (7)	Taking tops out of tree and selective limb removal after harvest. Tree height was reduced from 7-8 m to 5-6 m. Mulching of branches.	August	2800	10.80	12.8	49.2
2002 (8)	Maintain tree height and thinning to maintain an open canopy. Mulching of branches.	September	2500	9.60	1.6	6.2
2003 (9)	Maintain tree height and thinning to maintain an open canopy. Mulching of branches.	August	2500	9.60	10.6	40.8
2004 (10)	Maintain tree height and thinning to maintain an open canopy. Mulching of branches.	June/July	2500	9.60	1.2	4.6
2005 (11)	Maintain tree height and thinning to maintain an open canopy. Mulching of branches.	July	2500	9.60	20.3	78.1
2006 (12)	Maintain tree height and thinning to maintain an open canopy. Mulching of branches.	September	2300	8.80	12.2	46.9
2007 (13)	Maintain tree height and thinning to maintain an open canopy. Mulching of branches.	August	2300	8.80	27.8	106.9
			2485 $/ha/yr	9.50 $/tree/yr	12.4 t/ha/yr	47.5kg /tree/yr

Site 15: **Mechanical and selective pruning – Central New South Wales**

Orchard description:
Variety: Hass; Block size: 1.6ha; Trees planted: 1993; Spacing: 7 x 3m (476 trees/ha); Row orientation: N-S

Growth cycle:
The annual growth cycle for 'Hass' avocado grown at this central New South Wales site is shown below.

Growth cycle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering												
Spring flush												
Summer flush												
Harvest												

Canopy management history:
Trees were mechanically and selectively pruned after harvest to reduce tree size, maintain orchard access, improve light penetration and increase the efficiency of harvesting and spraying operations. Hand pruning was carried out to cut back or remove bare branches. A 45% reduction to each side was achieved. Pruned branches were mulched. Yields were significantly reduced in the first year after pruning.

Tree age	Canopy management operations	Timing of operation	Costs of operation		Yield	
			$/ha	$/tree	t/ha	kg/tree
2003 (10)	Trees were mechanically and selectively pruned after harvest. A 45% reduction to each side of one inter-row. Mulching of branches	December	4000	8.40	34	71.4
2004 (11)	No pruning	-	0	0	10	21.0
2005 (12)	No pruning	-	0	0	36	75.6
2006 (13)	No pruning	-	0	0	34	71.4
			1000 $/ha/yr	2.10 $/tree/yr	28.5 t/ha/yr	59.9kg /tree/yr

Site 16: **Selective pruning - Central New South Wales**

Orchard description:
Variety: Hass; Block size: 4.5ha; Trees planted: 1999; Spacing: 9 x 5m (222 trees/ha); Row orientation: E-W.

Growth cycle:
The annual growth cycle for 'Hass' avocado grown at this central New South Wales site is shown below.

Growth cycle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering												
Spring flush												
Summer flush												
Harvest												

Canopy management history:
Branches from the middle of the tree were selectively removed or cut back to reduce tree height, improve light penetration and increase the efficiency of harvesting and spraying operations. In 2005 tree height was reduced from 7-8m to 5-6m. At this site it is normal for the tree to carry two crops for a period of time (mature fruit from the previous season as well as current season's fruit). Trees were pruned during the winter in an "off" year to minimise fruit loss and the amount of regrowth. Branches were chopped up and chipped. No pruning occurred in 2007 trees were in a "on" year.

Year (Tree age)	Canopy management operations	Timing of operation	Costs of operation $/ha	$/tree	Yield t/ha	kg/tree
2004 (5)	No pruning	-	0	0	7.5	33.8
2005 (6)	Selective limb removal to reduce tree height and improve light penetration. Cutting up and chipping of branches.	June/July	3200	14.40	5.7	25.7
2006 (7)	No pruning	-	0	0	18.7	84.2
			1067 $/ha/yr	4.80 $/tree/yr	10.6 t/ha/yr	47.9kg /tree/yr

Site 17: Selective pruning and tree removal – Tri-State

Orchard description:
Variety: Hass; Block size: 1.84ha; Trees planted: 1998; Spacing: 6 x 3m (555 trees/ha); Row orientation: N-S.

Growth cycle:
The annual growth cycle for 'Hass' avocado grown at this site in the Tri-State region is shown below.

Growth cycle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering												
Spring flush												
Summer flush												
Harvest												

Canopy management history:
In 2002 and 2003 trees were selectively pruned in autumn (March/April) to maintain orchard access, improve light penetration into the tree and increase efficiency of harvesting. In 2004 every second row was removed after harvest (November) for access and improve light penetration into the orchard. Trees were planted at 6 x 3 m (555 trees/ha) and thinned to 12 x 3m (278 trees/ha). Since tree removal there has been no pruning operations.

Year (Tree age)	Canopy management operations	Timing of operation	Costs of operation $/ha	$/tree	Yield t/ha	kg/tree
2002 (4)	Light trim to allow access	March/April	200	0.40	8.4	15.1
2003 (5)	Light trim to allow access	March/April	300	0.50	3.4	6.1
2004 (6)	Every second row removed after harvest	November	1650	5.90	6.2	11.2
2005 (7)	No pruning		0		2.1	7.6
2006 (8)	No pruning		0		7.6	27.3
			430 $/ha/yr	1.70 $/tree/yr	5.5 t/ha/yr	13.5kg /tree/yr

Site 18: **Selective/mechanical pruning and plant growth regulators – Tri-State**

Orchard description:
Variety: Hass; Block size: 2.46ha; Trees planted: 1991; Spacing: 6 x 5m (333 trees/ha); Row orientation: N-S.

Growth cycle:
The annual growth cycle for 'Hass' avocado grown at this site in the Tri-State region is shown below.

Growth cycle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering												
Spring flush												
Summer flush												
Harvest												

Canopy management history:
In 2004 trees were selectively pruned in May to reduce tree size, maintain orchard access and improve light penetration. Trees were also mechanically hedged after harvest to maintain tree size and shape. Selective pruning was carried out to remove young vegetative growth that will not flower in the spring so mature growth will receive adequate sunlight for flowering. Trees were selectively pruned in May each year. Sunny® was applied at flowering to reduce the spring growth flush and increase fruit size.

Year (Tree age)	Canopy management operations	Timing of operation	Costs of operation $/ha	Costs of operation $/tree	Yield t/ha	Yield kg/tree
2004 (13)	Selective pruning and mulching Sunny® 1.0% at flowering Hedging to maintain tree size and shape	May October Aug/Sep	1600 2700 300	4.80 8.10 0.90	13.8	41.4
2005 (14)	Selective pruning and mulching Sunny® 1.0% at flowering	May October	1600 2760	4.80 8.30	20.3	61.0
2006 (15)	Selective pruning and mulching Sunny® 0.6% at flowering	May October	1720 1090	5.20 3.30	8.2*	24.6
2007 (16)	Selective pruning and mulching Sunny® 0.6% at flowering	May/June November	2200 1200	6.60 3.60	6.9	20.7
			3790 $/ha/yr	11.40 $/tree/yr	12.3 t/ha/yr	36.9kg /tree/yr

*Heavy fruit drop was noted two weeks after a severe heat wave in Jan 20th-23rd 2006. Temperatures reached 47 °C. Fruit drop and canopy damage occurred after severe frosts in June/July 2006 which also affected the 2007 flowering.

Percentage of trays for each size category packed for each year from 2004 to 2006

Year (Tree age)	14	16	18	20	23	25	28	30	32	Bulk
2004 (13)		0.1	1.1	10.9	31.6	28.8	11.1	1.8		14.5
2005 (14)		4.8	13.4	25.2	36.4	8.2	6.7	0.9	1.4	3.1
2006 (15)	0.7	1.7	13.1	27.8	34.0	11.6	8.4	0.5	1.7	0.5

Site 19: **Selective pruning – Western Australia**

Orchard description:
Variety: Hass; Block size: 1.5ha; Trees planted: 1988; Spacing: 6 x 5m (333 trees/ha); Row orientation: N-S

Growth cycle:
The annual growth cycle for 'Hass' avocado grown at this Western Australian site is shown below.

Growth cycle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering												
Spring flush												
Summer flush												
Harvest												

Canopy management history:
Trees were manually pruned after harvest (August/September) to reduce tree size, maintain orchard access and improve light penetration into the tree. This pruning technique involved selective pruning of some of the terminals and limbs. Overlapping branches were thinned out, centre branches removed and the length of side branches reduced. About 3—40% of the terminals or branches are pruned each year. The remainder of the terminals set fruit and fruit is also set further back along the pruned branches.

Year (Tree age)	Canopy management operations	Timing of operation	Costs of operation		Yield	
			$/ha	$/tree	t/ha	kg/tree
2002 (14)	Selective pruning and mulching of branches	Aug/Sep	1500	4.50	27	81.1
2003 (15)	Selective pruning and mulching of branches	Aug/Sep	1500	4.50	32	96.1
2004 (16)	Selective pruning and mulching of branches	Aug/Sep	1500	4.50	25	75.1
2005 (17)	Selective pruning and mulching of branches	Aug/Sep	1500	4.50	24	72.1
2006 (18)	Selective pruning and mulching of branches	Aug/Sep	1500	4.50	28	84.1
2007 (19)	Selective pruning and mulching of branches	Aug/Sep	1500	4.50	19	57.1
			1500 $/ha/yr	4.50 $/tree/yr	25.8 t/ha/yr	77.6 kg/tree/ yr

Site 20 Selective limb removal, mechanical pruning, staghorning, tree removal and replanting – Western Australia

Orchard description:
Variety: Hass; Block size: 2.3ha; Trees planted: 1982; Spacing: 7 x 7m (204 trees/ha); Row orientation: E-W. Rootstocks: older trees – Topa Topa; new trees – Velvick.

Growth cycle:
The annual growth cycle for 'Hass' avocado grown at this Western Australian site is shown below.

Growth cycle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering												
Spring flush												
Summer flush												
Harvest												

Canopy management history:
A number of strategies have been used at this site to reduce tree size, maintain orchard access, improve light penetration and improve the efficiency of harvesting and spraying operations. In 1998 limbs were selectively removed after harvest in November/December. In 1999 trees in every second row were stumped after harvest to a height of 2-3m leaving lower branches. The non-stumped trees in 2000 and the stumped trees in 2001 were mechanically pruned. In 2002 every second row was removed after harvested and replanted in January/February the next year. Old trees on Topa Topa rootstock planted at 7m spacing were replaced with new trees on Velvick rootstock at 3.5m spacing. Older trees were A selective limb removal strategy was carried out on the older trees in 2003 and 2004. Since 2005 a strategy of removing older trees, replanting and shaping young trees to a centre leader was carried out. Tree removal costs of $30/tree in 2002 & $40/tree in 2005-2007. Replanting costs at $20/tree. Pruned branches were mulched and large limbs removed from the orchard and later burnt.

Year	Canopy management operations	Timing of operation	Costs of operation ($/ha)	Yield (t/ha)
1998	Selective limb removal after harvest	Nov/Dec	800	
1999	Every second row stumped at 2-3m leaving lower branches	Nov/Dec	2100	17.1
2000	Mechanically pruned untouched rows	Nov/Dec	200	16.3
2001	Mechanically pruned stumped rows	Nov/Dec	200	14.7
2002	Removed every second row	Nov/Dec	3000	14.5
2003	Replanted every second row (at 7m x 3.5m) Selective limb removal on older trees	Jan/Feb Nov/Dec	4080 500	15.2
2004	Selective limb removal on older trees Young trees shaped to a central leader	Nov/Dec Nov/Dec	800 200	8.7
2005	Removed older trees on Topa Topa (15% removed) Young trees shaped to a central leader	Nov/Dec Nov/Dec	1200 200	5.0
2006	Replant Hass on Velvick at 7m x 3.5m Removed older trees on Topa Topa (5% removed) Young trees shaped to a central leader	Jan/Feb Nov/Dec Nov/Dec	1360 400 200	14.9
2007	Replant Hass on Velvick at 7m x 3.5m Removed older trees on Topa Topa (5% removed)	Jan/Feb Nov/Dec	400 400	12.7
			1600 $/ha/yr	13.2 t/ha/yr

Site 21: **Selective limb removal and tree removal – Western Australia**

Orchard description:
Variety: Hass; Block size: 1.5ha; Trees planted: 1997; Spacing: 7 x 3.5m (408 trees/ha); Row orientation: E-W

Growth cycle:
The annual growth cycle for 'Hass' avocado grown at this Western Australian site is shown below.

Growth cycle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering												
Spring flush												
Summer flush												
Harvest												

Canopy management history:
In 2000 to 2004 trees were manually pruned to a Christmas tree shape to maintain tree size and inter-row access and improve light penetration in the orchard. Branches were pruned back to the spring growth in winter prior to harvesting. Since 2005 a selective limb and tree removal strategy was carried out after harvest. Limbs were selectively removed to improve light penetration into the orchard. Overcrowded and salt-affected trees were also removed. Pruned branches were mulched and large limbs removed from the orchard and later burnt.

Year (Tree age)	Canopy management operations	Timing of operation	Costs of operation ($/ha)	Yield (t/ha)
1998 (1)				
1999 (2)				0.5
2000 (3)	Manually pruned trees to a Christmas tree shape	July	800	2.0
2001 (4)	Manually pruned trees to a Christmas tree shape	July	800	3.4
2002 (5)	Manually pruned trees to a Christmas tree shape	July	1200	16.0
2003 (6)	Manually pruned trees to a Christmas tree shape	July	1200	20.0
2004 (7)	Manually pruned trees to a Christmas tree shape	July	1200	14.8
2005 (8)	Removal of overcrowded & salt-affected trees. Selective limb removal - opening up windows for light penetration	Nov/Dec Nov/Dec	600 800	17.0
2006 (9)	Removal of overcrowded & salt-affected trees. Selective limb removal - opening up windows for light penetration	Nov/Dec Nov/Dec	1200 800	21.4
2007 (10)	Removal of overcrowded & salt-affected trees. Selective limb removal - opening up windows for light penetration	Nov/Dec Nov/Dec	1200 800	14.3
			1060 $/tree/yr	10.9 t/ha/yr

Site 22: Selective limb removal - Western Australia

Orchard description:
Variety: Hass; Block size: 5.18ha; Trees planted: 1995; Spacing: 8 x 7m (178 trees/ha); Row orientation: E-W

Growth cycle:
The annual growth cycle for 'Hass' avocado grown at this south-west Western Australian site is shown below.

Growth cycle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering												
Spring flush												
Summer flush												
Harvest												

Canopy management history:
At this site the tree carries two crops for a period of time (mature fruit from the previous season as well as current season's fruit). To minimise fruit loss trees are often pruned in an "off" year. In 2006 limbs were selectively removed or cut back after harvest (March/April) to reduce tree height, improve light penetration, maintain orchard access and improve the efficiency of harvesting. In 2007 a heavier prune was carried out as trees were in an "off" year. Pruned branches were chipped.

Year (Tree age)	Canopy management operations	Timing of operation	Costs of operation $/ha	$/tree	Yield t/ha	kg/tree
2006 (11)	Selective limb removal to reduce tree height, improve light penetration and maintain orchard access after harvest. Chipping of branches.	March/April	2600	14.60	13.1	97.7
2007 (12)	Selective limb removal to reduce tree height, improve light penetration and maintain orchard access after harvest. Chipping of branches. Painting of exposed branches.	March/April	3800	21.35	31.3	173.8
			3200 $/ha/yr	18.0 $/tree/yr	17.6 t/ha/yr	124.7kg /tree/yr

1.4 Outcomes

There are several canopy management strategies being implemented by growers throughout the different producing regions across Australia, including selective limb removal, selective and mechanical pruning, staghorning, tree removal and plant growth regulator application. At many sites a combination of strategies are being used (eg. mechanical pruning, selective pruning and application of plant growth regulators).

A summary of each site including an orchard description (variety, year planted, tree spacing and density), canopy management strategies, length of the recorded cycle, and costs ($/ha/year) and productivity (t/ha/year) is presented in Table 1.

The objective of this study was to identify canopy management strategies that can be successfully implemented in all major avocado growing areas across Australia.

- Canopy management costs ranged from $430 to $3790 per hectare per year depending on tree age, planting density and the strategies being implemented.

- Costs were generally highest at sites involving tree removal, staghorning and selective pruning where costs of mulching and removal of limbs was a major component. With costs of tree removal of $30-40 per tree reported at Site 20.

- Pruning costs were usually lower when using mechanical saws and ranged from $160 – 800 /ha ($0.80 – 4.00/tree). However in many cases a selective pruning strategy is performed in conjunction with mechanical pruning to remove bare limbs or to open up trees for better light penetration and cherry-picker access.

- The highest productivity was achieved at Site 15 (28.5 t/ha/year) using mechanical and selective pruning techniques. Medium to high yields (>15 t/ha/year) were achieved using various methods of selective limb removal, selective and mechanical pruning and plant growth regulator application.

- Productivity was lowest (<10 t/ha/year) at sites involving staghorning and tree removal techniques. At these sites non-productive years significantly influence the productivity rating. For example at Site 12 yields of 0, 1.1, 7.8 and 10.1 t/ha were achieved 1, 2, 3 and 4 years after staghorning the trees.

- The decision on which canopy management system growers employ often depends on geographic location.

  In north Queensland, central Queensland and the warmer coastal areas of south-east Queensland and northern New South Wales the crop can be harvested up to several months prior to flowering. In these growing areas mechanical pruning can be implemented after harvest to establish tree size and shape. A light mechanical pruning to maintain tree shape and reduce the length of the spring growth is often done during early summer. At these sites selective limb/branch removal strategies to reduce tree height and to improve light penetration are also used and in many cases a combination of both mechanical and selective pruning are being implemented.

In cooler, temperate climates of the hinterland areas of southern Queensland and northern New South Wales, central New South Wales, the Tri-State region and south-west Western Australia it is normal for the tree to carry two crops for a period of time (mature fruit from the previous season as well as current season's fruit). In these regions the decision on when to prune is often more difficult. In many cases growers perform pruning operations after harvest and when trees are going into an "off" year so branches can be pruned with minimal fruit loss. However due to the light crop load (in an "off" year) managing the regrowth from these pruning operations can be more difficult. Growers in these regions typically adopt a selective limb removal method to reduce tree size and improve light penetration. However strategies involving mechanical pruning, staghorning, tree removal and plant growth regulators have also been used.

Table 1: A summary of the canopy management sites analysed in the project.

Region (Site)	**Orchard description** (Including variety, year planted, tree spacing & density)	**Canopy management system/s**	**Length of recorded cycle (years)**	**Canopy management costs (S/ha/yr)**	**Productivity (t/ha/yr)**
N Qld (Site 1)	Shepard planted:1993 Spacing: 10 x 5m (200 trees/ha)	Selective limb removal	9	860	17.2
N Qld (Site 2)	Shepard planted:1989 Spacing: 11 x 6m (150 trees/ha)	Mechanical and selective pruning	5	1890	19.6
N Qld (Site 3)	Shepard planted:2000 Spacing: 8 x 6m (208 trees/ha)	Mechanical and selective pruning	3	1180	12.6
N Qld (Site 4)	Hass planted:1997 Spacing: 11 x 8m (115 trees/ha)	Mechanical and selective pruning	3	1260	18.7
Central Qld (Site 5)	Shepard planted:1990 Spacing: 9 x 6m (185 trees/ha)	Major limb removal, selective and mechanical pruning and plant growth regulators	8	1960	16.5
Central Qld (Site 6)	Hass planted:1994 Spacing: 10 x 5m (200 trees/ha)	Selective limb removal, mechanical pruning and plant growth regulators	8	1960	21.2
Central Qld (Site 7)	Shepard planted:1993 Spacing: 10 x 5m (200 trees/ha)	Mechanical and selective pruning	6	870	15.6
Central Qld (Site 8)	Shepard planted:1994 Spacing: 10 x 5m (200 trees/ha)	Mechanical and selective pruning	6	1125	17.6
Central Qld (Site 9)	Hass planted:1993 Spacing: 10 x 5m (200 trees/ha)	Mechanical pruning, major limb removal and plant growth regulators	6	2240	19.3
Central Qld (Site 10)	Hass planted:2000 Spacing: 10 x 5m (200 trees/ha)	Mechanical pruning and plant growth regulators	7	765	13.4
South-east Qld (Site 11)	Hass planted:1993 Spacing: 12½ x 6m (133 trees/ha)	Mechanical/selective pruning and plant growth regulators	6	2215	11.5
Southern Qld (Site 12)	Hass planted:1989 Spacing: 10 x 5m (200 trees/ha)	Staghorning and selective pruning	5	1040	6.0
Southern Qld (Site 13)	Hass planted:1982 Spacing: 9 x 9m (123 trees/ha)	Selective limb removal	2	2860	14.3
Northern NSW (Site 14)	Hass planted:1994 Spacing: 7 x 5½m (260 trees/ha)	Selective pruning and limb removal	7	2485	12.4
Central NSW (Site 15)	Hass planted: 1993 Spacing: 7 x 3m (476 trees/ha)	Mechanical and selective pruning	4	1000	28.5
Central NSW (Site 16)	Hass planted: 1999 Spacing: 9 x 5m (222 trees/ha)	Selective pruning	3	1065	10.6

Tri-State (Site 17)	Hass planted:1998 Spacing: 6 x 3m (555 trees/ha)	Selective pruning and tree removal	5	430	5.5
Tri-State (Site 18)	Hass planted:1991 Spacing: 6 x 5m (333 trees/ha)	Selective/mechanical pruning and plant growth regulators.	4	3790	12.3
WA (Site 19)	Hass planted:1988 Spacing: 6 x 5m (333 trees/ha)	Selective pruning	6	1500	25.8
WA (Site 20)	Hass planted:1982 Spacing: 7 x 7m (204 trees/ha)	Selective limb removal, mechanical pruning, staghorning, tree removal and replanting	10	1600	13.2
WA (Site 21)	Hass planted:1997 Spacing: 7 x 3.5m (408 trees/ha)	Selective limb removal and tree removal	10	1060	10.9
WA (Site 22)	Hass planted:1995 Spacing: 8 x 7m (178 trees/ha)	Selective limb removal	2	3200	22.2

Part 2 Plant growth regulator trials

2.1 Introduction

Several plant growth regulators have been successfully used to manipulate vegetative growth, and increase flowering, yield and fruit size in avocado.

Auxins such as naphthalene acetic acid (NAA) have been shown to control regrowth on avocado stumps following top-working (Boswell *et al.*, 1976) and to minimise regrowth following pruning in 'Reed' avocado in California (Whiley and Anderson, 2002).

Triazoles are a group of plant growth retardants that inhibit gibberellin biosynthesis (Davis *et al*., 1988). Within this group paclobutrazol and uniconazole have been reported to reduce vegetative growth and increase fruit size in avocado (Köhne and Kremer-Köhne, 1987; Köhne, 1988; Adato, 1990; Wolstenholme *et al.*, 1990; Whiley *et al.*, 1991; Erasmus and Brooks, 1998; Penter *et al.*, 2000; Leonardi, 2001; Whiley, 2001).

Prohexadione-calcium (Apogee® and Regalis®) an inhibitor of gibberellin biosynthesis has been reported to delay the elongation of the vegetative shoot of indeterminate floral shoots, increase early fruit set (Lovatt, 2001) and improve yield (Whiley and Anderson, 2002) in avocado when applied at flowering.

The aim of this research was to investigate the effect of the plant growth regulators, naphthalene acetic acid (NAA) on regrowth control in pruned trees, uniconazole (Sunny®) and paclobutrazol (Austar®) on shoot growth, flowering and yield in staghorned trees, and prohexadione-calcium (Regalis®) on shoot growth, yield and fruit quality.

2.2 Materials and methods

2.2.1 Naphthalene acetic acid (NAA)

Six-year-old 'Hass' trees in a commercial orchard located in central Queensland (lat. 25°S) were selectively pruned after harvest in June 2005. Branches 5-8 cm in diameter were either painted with acrylic paint, treated with a 0.5 or 1% NAA + paint formulation or hand sprayed with water, or prayed with a 0.5 or 1% NAA + water formulation. Treatments were applied to the cut surface and 40 cm along the branch to 10 branches in each of four trees.

The number and length of regrowth shoots within and below the treated section of the branch were measured six months after treatment. Statistical analyses were by ANOVA and the least significant difference (l.s.d.) test at $P \leq 0.05$ was used to separate treatment means.

2.2.2 Uniconazole (Sunny®) and Paclobutrazol (Austar®)

Trials were established in south-east Queensland (lat. 27°S) to investigate the effect of uniconazole (Sunny®, Sumitomo Chemical Australia Pty Ltd) and paclobutrazol (Austar®, Chemicals Direct Pty Ltd) application on shoot growth, flowering and yield in staghorned 'Hass' trees.

In the first trial trees were staghorned (cut back to a stump approximately one metre above the graft union) in July 2005. Foliar applications of 1 or 2% Sunny® were made in February 2006 to young vegetative growth and in May 2006 prior to floral bud development. Trees were sprayed to the point of run-off using a motorised, backpack spray unit at 1.1 litres per tree. An

unsprayed control was included for comparison. There were seven treatments with five trees per treatment arranged in a completely randomised design. The effect of treatment on shoot growth and flowering was assessed in 10 shoots in each of five trees in August 2006. Fruit was harvested at maturity in May 2007 and the number and weight from each tree recorded. Average fruit weight was calculated from the data. Statistical analyses were by ANOVA and the least significant difference (l.s.d.) test at $P \leq 0.05$ was used to separate treatment means.

In the second trial trees were staghorned in June 2006. Foliar applications of 0.5 and 1..0% Sunny® and Austar® were applied in January 2007 to young vegetative growth and in April 2007 prior to floral bud development. Trees were sprayed to the point of run-off using a motorised, backpack spray unit at 1.0-1.2 litres per tree. An unsprayed control was included for comparison. There were thirteen treatments with five trees per treatment arranged in a completely randomised design. The effect of treatment on shoot growth and flowering was assessed in 10 shoots in each of five trees in September 2007. Fruit was harvested at maturity in May 2008 and the number and weight from each tree recorded. Average fruit weight was calculated from the data. Statistical analyses were by ANOVA and the least significant difference (l.s.d.) test at $P \leq 0.05$ was used to separate treatment means.

2.2.3 Prohexadione-calcium (Regalis®)

In 2004, a trial was established in central Queensland (lat. 25°S) to investigate the effect of prohexadione-calcium (Regalis®, Nufarm Australia Ltd; 100 g ai/kg) on shoot growth, yield and fruit quality in 'Hass' avocado. Foliar applications at 0.5, 0.75 and 1.0 grams of product per litre were applied to five-year-old trees at full-bloom on the 15 September and again two weeks later. Treatments were reapplied at full-bloom in 2005 on the 5 September and 10 days later.

Trees were sprayed to the point of run-off using 1.7 and 2.0 litres per tree in 2004 and 2005, respectively. An unsprayed control was included for comparison. There were seven treatments with six trees per treatment arranged in a completely randomised design. Data was analysed by ANOVA and the least significant difference (l.s.d.) test at $P \leq 0.05$ was used to separate treatment means.

The length of the spring growth flush was measured in 10 shoots per tree in December 2004 and 2005. Fruit was harvested at maturity in May 2005 and 2006 and the number and weight from each tree recorded. Average fruit weight was calculated from the data.

In May 2006, 20 fruit were harvested from each tree from all treatments, ripened at 20°C and assessed for quality. Fruit quality was assessed using the Avocare Quality Assessment Manual (White *et al.*, 2001). Fruit firmness was assessed using gentle hand pressure, and the days to ripe (DTR) determined as the number of days fruit were stored at 20°C until ripe. Ripe fruit were then longitudinally cut into quarters, the seed removed, and the skin peeled from the flesh. The quarters were visually rated for the severity of rots and internal disorders as the percentage of flesh volume affected. Body rots were characterised as those developing from the skin into the body of the fruit, caused mainly by the pathogen, *Colletotrichum gloeosporioides*, and stem-end rots as those starting from the stem-end of the fruit, caused by several pathogens, mainly *C. gloeosporioides* and *Dothiorella* spp. (Coates *et al*., 1995). Diffuse discolouration was characterised as areas of grey or grey/brown discolouration with poorly defined margins (White *et al*., 2001) and vascular browning was rated as the percentage of the flesh rendered non-useable by the disorder. The incidence or percentage of fruit affected with these rots and disorders were determined.

2.3 Results

2.3.1 Naphthalene acetic acid (NAA)

NAA reduced the number and length of regrowth shoots in the treated section of the branch (Table 2.1). There was no difference in the number and length of shoots that developed below the treated area.

Table 2.1 Effect of NAA treatment on regrowth in pruned branches in six-year-old 'Hass' trees. Data are means of 10 branches from four trees. Means followed by the same letters are not significantly different ($P > 0.05$).

Treatment	No. of shoots in treated area (40cm)	Length of shoot (cm)	No. of shoots below treated area	Length of shoot (cm)
Paint only	2.9 a	151.8 a	3.2 a	98.9 a
Paint + 0.5% NAA	0.2 b	10.9 b	3.4 a	136.4 a
Paint + 1% NAA	0 b	0 b	3.8 a	101.8 a
Water only	3.0 a	140.9 a	3.2 a	100.3 a
Water + 0.5% NAA	0.2 b	17.3 b	3.3 a	129.9 a
Water + 1.0% NAA	0 b	0 b	3.0 a	112.4 a

2.3.2 Uniconazole (Sunny®) and Paclobutrazol (Austar®)

In the first trial all Sunny® treatments significantly ($P > 0.05$) reduced shoot length and increased flowering in staghorned trees (Table 2.2). There was no significant effect of treatment on the number of fruit, average fruit weight and yield, although there was a trend towards an increase in fruit numbers and yield in trees treated with a 1 or 2% Sunny® in May.

Table 2.2 Effect of Sunny® treatment on shoot growth, flowering, number of fruit, average fruit weight and yield in staghorned 'Hass' avocado trees. Trees were staghorned in July 2005 and treatments were applied in February and/or May 2006.Shoot growth and flowering data are means of 50 shoots from five trees per treatment. Yield data are means of five trees per treatment. Means followed by the same letter are not significantly different ($P > 0.05$).

Treatment	Shoot length (cm)	% of shoots flowering	No. of Fruit	Av. fruit wt (g)	Yield (kg/tree)
Unsprayed control	88.8 a	60 a	25.8 a	267.0 a	6.8 a
1% Sunny® in February	51.1 b	96 c	41.0 a	262.8 a	10.4 a
2% Sunny® in February	58.5 b	84 b	29.6 a	267.7 a	7.9 a
1% Sunny® in May	62.7 b	96 c	63.2 a	261.1 a	16.3 a
2% Sunny® in May	64.1 b	96 c	66.4 a	273.8 a	17.8 a
1% Sunny® in February & May	58.9 b	94 c	45.6 a	270.2 a	11.9 a
2% Sunny® in February & May	55.3 b	96 c	34.8 a	260.8 a	9.0 a

In the second trial all Sunny® and Austar® treatments significantly ($P > 0.05$) reduced shoot length and increased flowering in staghorned trees (Table 2.3). There was a trend for all treatments to increase fruit size and yield in staghorned trees.

Table 2.3 Effect of Sunny® and Austar® treatment on shoot growth, flowering, number of fruit, average fruit weight and yield in staghorned 'Hass' avocado trees. Trees were staghorned in June 2006 and treatments were applied in January and/or April 2007. Shoot growth and flowering data are means of 50 shoots from five trees per treatment. Yield data are means of five trees per treatment. Means followed by the same letter are not significantly different ($P > 0.05$).

Treatment	Shoot length (cm)	% of shoots flowering	No. of Fruit	Av. fruit wt (g)	Yield (kg/tree)
Unsprayed control	106.6 a	76 a	11.0 a	268.8 a	3.0 a
0.5% Sunny® in January	80.8 b	98 b	58.8 a	292.9 a	17.1 a
1.0% Sunny® in January	76.6 b	94 b	44.6 a	285.0 a	12.5 a
0.5% Sunny® in April	83.1 b	100 b	38.8 a	287.8 a	10.9 a
1.0% Sunny® in April	83.6 b	100 b	43.6 a	285.9 a	12.2 a
0.5% Sunny® in January & April	71.6 b	100 b	42.2 a	287.7 a	12.0 a
1.0% Sunny® in January & April	70.8 b	100 b	46.6 a	290.2 a	13.0 a
0.5% Austar® in January	78.1 b	96 b	49.4 a	297.2 a	14.5 a
1.0% Austar® in January	75.4 b	100 b	50.2 a	287.4 a	14.3 a
0.5% Austar® in April	84.1 b	96 b	43.8 a	285.1 a	12.0 a
1.0% Austar® in April	81.1 b	100 b	59.8 a	292.6 a	16.9 a
0.5% Austar® in January & April	75.2 b	98 b	43.2 a	296.0 a	12.9 a
1.0% Austar® in January & April	66.6 b	100 b	56.8 a	283.9 a	15.6 a

2.3.3 Prohexadione-calcium (Regalis®)

Regalis® had no significant ($P > 0.05$) effect on yield or average fruit weight (Table 2.4). However, the product at all concentrations significantly reduced the length of the spring growth flush. The severity and incidence of stem rots and incidence of body rots was least in fruit harvested from trees treated twice with Regalis® at 1.0 g/l (Table 2.5).

Table 2.4 Effect of prohexadione-calcium (Regalis®) on shoot growth, number of fruit, average fruit weight and yield in 2004/05 and 2005/06 and the cumulative yield for 2005+2006 in 'Hass' avocado. Shoot growth data are means of 60 shoots from six trees per treatment. Fruit yield data are means of six trees per treatment. Means followed by the same letter are not significantly different ($P > 0.05$).

Treatment	2004/05				2005/06				Cumulative yield (2005+2006) (t/ha*)
	Shoot growth (cm)	No. of fruit	Av. fruit wt (g)	Yield (t/ha*)	Shoot growth (cm)	No. of fruit	Av. fruit wt (g)	Yield (t/ha*)	
Unsprayed control	12.3 a	416 a	219.5 a	18.1 a	12.0 a	412 a	208.2 a	17.0 a	35.1 a
Regalis® at 0.5 g/l	10.4 b	409 a	223.4 a	17.9 a	10.4 b	421 a	218.2 a	17.9 a	35.8 a
Regalis® at 0.75 g/l	8.9 c	475 a	214.2 a	20.1 a	8.8 c	516 a	208.6 a	21.1 a	41.2 a
Regalis® at 1.0 g/l	9.1 c	457 a	215.7 a	19.1 a	8.8 c	407 a	215.0 a	17.1 a	36.2 a
Regalis® at 0.5 g/l x 2	8.9 c	497 a	218.8 a	21.6 a	9.0 c	480 a	216.7 a	20.7 a	42.3 a
Regalis® at 0.75 g/l x 2	8.8 c	538 a	209.1 a	22.2 a	8.4 cd	441 a	208.5 a	18.3 a	40.5 a
Regalis® at 1.0 g/l x2	8.9 c	401 a	233.6 a	18.3 a	7.9 d	422 a	228.2 a	18.7 a	37.0 a

* t/ha was calculated from the tree spacing of 10 x 5 m (200 trees/ha)

Table 2.5 Effect of prohexadione-calcium (Regalis®) application on the severity and incidence of stem-end and body rots in 'Hass' fruit ripened at 20ºC. Fruit was harvested in May 2006. Data are means of 120 fruit from six trees per treatment. Means followed by the same letters are not significantly different ($P > 0.05$).

Treatment	Stem-end rots		Body rots	
	Severity (% of flesh)	Incidence (% of fruit)	Severity (% of flesh)	Incidence (% of fruit)
Unsprayed control	1.82 a	27.5 a	0.53 a	17.5 a
Regalis® at 0.5 g/l	1.54 ab	17.5 bc	0.37 a	13.3 ab
Regalis® at 0.75 g/l	1.13 abc	15.0 bcd	0.27 a	8.3 bc
Regalis® at 1.0 g/l	1.00 bcd	11.7 cd	0.35 a	10.0 abc
Regalis® at 0.5 g/l x 2	1.64 ab	19.2 b	0.35 a	12.5 ab
Regalis® at 0.75 g/l x 2	0.75 cd	10.0 d	0.23 a	10.0 abc
Regalis® at 1.0 g/l x2	0.31 d	9.2 d	0.13 a	2.5 c

2.4 Discussion

The results of the plant growth regulator trials indicate that naphthalene acetic acid (NAA) reduced regrowth in pruned branches; uniconazole (Sunny®) and paclobutrazol (Austar®) reduced vegetative growth, increased flowering and tended to improve yields in staghorned trees; and prohexadione-calcium (Regalis®) reduced the spring growth flush and improved fruit quality when applied at flowering. At this stage only Sunny® is registered for use by the Australian avocado industry to reduce vegetative growth and increase fruit size.

NAA has been successfully used to control regrowth on avocado stumps following top-working. Boswell *et al*. (1976) controlled regrowth by spraying stumps with either a 1% ethyl ester or sodium salt formulation of NAA in a 30% aqueous solution of white acrylic paint when shoots were 10-80 mm long. Shoots were killed by both NAA formulations 45 days after treatment with no negative effect on the newly grafted scions which were shielded at the time of treatment. NAA has been reported to effectively control regrowth for up to 18 months following pruning of the central leader in 'Reed' avocado in California (Whiley and Anderson, 2002). In this experiment NAA treatments were applied immediately after pruning treatment, so there was no shoots present at the time of application and no shoots developed in the treated area six months after treatment. Leaves in the treated area especially at the higher rates also abscised.

A mid-bloom application of uniconazole and paclobutrazol have been reported to reduce vegetative growth and increase fruit size and in some cases increase yield in avocado (Köhne and Kremer-Köhne, 1987; Köhne, 1988; Adato, 1990; Wolstenholme *et al.*, 1990; Whiley *et al.*, 1991; Erasmus and Brooks, 1998; Penter *et al.*, 2000; Leonardi, 2001; Whiley, 2001). Application of uniconazole to regrowth resulting from summer pruning has also been shown to reduce regrowth length and increase flowering the following spring (Leonardi *et al*. 2005). In the current experiment application of uniconazole (Sunny®) and paclobutrazol (Austar®) to the summer and autumn flush significantly reduced shoot growth, increased flowering and tended to increase yield in staghorned trees.

Prohexadione-calcium is a plant growth retardant which acts through the inhibition of gibberellin biosynthesis, leading to a suppression of shoot elongation and hence modification of

canopy growth. There are two products that have been used on avocado Apogee® (27.5% prohexadione-Ca) and Regalis® (10% prohexadione-Ca). Application of Apogee® at 0.25 g/l delayed the elongation of the vegetative growth of indeterminate floral shoots and increase early fruit retention, however there was no increase in yield (Lovatt, 2001). While in Chile Apogee at 1.25 g/l applied at full bloom significantly increased yield from 14.8 to 22.1 t/ha (Whiley and Anderson, 2002). Mandemaker *et al.* (2005) found that prohexadione-Ca applied when shoots were rapidly increasing in length and at rates of 1 and 1.4% active ingredient decreased shoot growth by 10 to 20% but did not affect fruit set and retention in Hass avocado grown in New Zealand. In the current trial prohexadione-calcium applied at mid-bloom reduced of the spring growth. Although there was no increase in yield, an improvement in fruit quality suggests that treatment reduced the vegetative:reproductive competition during flowering and fruit set. Further investigation looking at higher rates of application, increasing the number of applications during flowering and applying treatments to the late summer/autumn flush to improve flowering intensity in the spring may have some merit.

Technology Transfer

Field days

Regional field days to demonstrate canopy management options.

In 2007 canopy management field days were conducted at 11 locations across Australia. These field days gave growers an opportunity to observe a range of canopy management strategies and identify systems that may be suitable for their own production situations.

Field days were held in Renmark, SA (9th May), Mildura, Vic (12th May), Pemberton, SW WA (16th May), Walkamin/Tolga, north Qld (24th May), Glass House Mountains, SE Qld (17th July), Childers/Bundaberg, Central Qld (19th July), Alstonville, northern NSW (17th August), Stuarts Point, Mid North Coast NSW (21st August), Somersby, Central Coast NSW (23rd August), Karbala, southern Qld (25th October) and Carabooda, WA (6th December).

A summary of each field day and a description of the canopy management systems being adopted in each region are outlined below:

Renmark (9th May) (27 attended):
This field day was held at two sites. At the first site strategies involving selective pruning and plant growth regulator application (Sunny®) were discussed. Trees were selectively pruned in autumn to remove summer growth that would not flower in the spring. This technique reduced tree size, maintained orchard access and improved light interception for flowering and cropping. At the second site a high planting density strategy was being implemented on more upright varieties such as 'Lamb Hass'. The use of cincturing/scoring of branches in autumn to reduce vegetative growth and increase flowering and cropping was also discussed by the group.

Mildura Region (12th May) (17 attended):
Selective pruning techniques on younger trees used to reduce tree height, maximise light interception for flowering and cropping, and maintain orchard access were observed. Strategies on managing a block of large trees including tree removal, staghorning/stumping and major limb removal were also discussed.

At both the Renmark and Mildura field days managing limited water resources was one of the main concerns. Several growers have either stumped or are considering stumping large trees to minimise water use. When to stump and how long before stumped trees come back into production were the main issues discussed.

Pemberton (16th May) (40 attended):
Selective pruning and major limb removal strategies on large trees were demonstrated. The main reasons for these operations were to reduce tree height, improve harvesting efficiency and maximise light interception for flowering and cropping. The timing of pruning operations was one of the main concerns. In this region it is normal for the tree to carry two crops for a period of time (mature fruit from the previous season as well as the current season's fruit). The decision on when to prune is often more difficult. At this site trees were pruned after harvest (Feb-May) when trees were going into an "off" year so branches can be pruned with minimal fruit loss. Application of Sunny® to control regrowth and follow-up pruning techniques were

discussed. The use of cincturing/scoring of branches performed during autumn to reduce vegetative vigour and improve flowering and cropping was also demonstrated. The effect of this technique on flowering and fruiting in 3 year old trees will be monitored.

North Queensland (24th May) (44 attended):
Strategies involving selective limb removal, selective and mechanical pruning and Sunny® application were discussed. This field day was conducted at two sites. At the first site selective limb removal techniques on 'Shepard' trees were demonstrated. This technique was used to reduce tree height, to improve the efficiency of spraying and harvesting operations and to maximise light interception for flowering and cropping. At the second site mechanical pruning of 'Hass' trees was demonstrated. Trees were hedged with a mechanical pruner. Selective pruning techniques to keep trees open for light penetration and cherry-picker access were also discussed.

Sunshine Coast (17th July) (60 attended):
Several techniques were demonstrated including mechanical and selective pruning, staghorning/stumping and plant growth regulator application. Results of the trial established at this site to investigate the effect of Sunny® on shoot growth, flowering and yield in stumped 'Hass' trees were also discussed. Trees stumped after harvest in June 2005 were treated with foliar applications of Sunny® in February 2006 to young vegetative growth and in May 2006 prior to floral bud development. All Sunny® applications significantly reduced shoot growth and increased flowering and tended to increase yield when applied in May.

Central Queensland (19th July) (24 attended):
Two sites were visited during the field day. At the first site selective limb removal, mechanical pruning and plant growth regulator application were discussed in both 'Shepard' and 'Hass' trees. In this region trees are pruned after harvest and prior to flowering (May-June for 'Shepard" & June-August for 'Hass'). Selective limb removal techniques to reduce tree height and width and application of Sunny® at flowering in September to reduce the spring growth flush and increase fruit size were outlined.

At the second site looked at major limb removal technique where trees were pruned on one side (the eastern side) after harvest in June. Minimal pruning occurred on the other side to allow fruit production. The western side of the tree will be pruned when regrowth on the eastern side produces a crop. The use of Sunny® to control regrowth and increase flowering in pruned trees was also discussed. Mechanical and selective pruning strategies on younger trees were also demonstrated. Young trees are tipped pruned after harvest and internal branches are removed to allow light penetration into the tree.

Northern NSW (17th August) (50 attended):
Selective pruning and limb removal techniques were demonstrated. This strategy involved pruning the tops to reduce tree height and pruning trees to 2-3 major limbs. The main reasons for these operations were to maximise light interception for flowering and cropping, to improve the efficiency of spraying and harvesting operations and to improve fruit quality.

Mid North Coast NSW (21st August) (20 attended):
Strategies involving mechanical pruning and major limb removal were demonstrated at this site. Mechanical pruning is used to maintain orchard access, maximise light penetration into the orchard for flowering and cropping, and improve the efficiency of spraying and harvesting

operations. In orchards where crowding was an issue major limb removal techniques like the "V" shape prune were discussed.

Central Coast NSW (23rd August) (12 attended):
Systems being used in the region include selective limb removal, major limb removal ("V" shape prune), mechanical pruning and use of Sunny® at flowering. The issue of timing of pruning operations was also examined because trees in this region can carry two crops for a period of time (mature fruit from the previous season as well as the current season's flowers and fruit).

Southern Queensland (25th October) (25 attended):
Several canopy management strategies were demonstrated including selective limb removal, tree removal and staghorning/stumping. The timing of pruning operations were also discussed because in this region trees can carry two crops for a period of time. Results of a trial established at this site to investigate the effect of Sunny® on shoot growth, flowering and yield in stumped 'Hass' trees were also discussed.

Perth Region (6th December) (10 attended):
Strategies involving selective limb removal and tree removal/replacement were demonstrated. The use of Sunny® at flowering and cincturing to reduce vegetative growth and improve flowering and yield were also discussed.

Conference and 'Talking Avocados' papers

World Avocado Congress
A paper titled "The development of canopy management strategies across Australia" was presented at the VI World Congress in Chile on the 16th November 2007.

Leonardi, J. (2005) New strategies and tools for avocado canopy management. *The New Zealand and Australian Avocado Growers' Conference 'Profit together'*. 20-22 September, Tauranga, New Zealand.

Autumn 2005: The development of canopy management strategies across Australia. *Talking Avocados* 16(1), 15-16.

Winter 2005: Update on the development of canopy management strategies across Australia. *Talking Avocados* 16(2), 23.

Summer 2005: Update on the development of canopy management strategies across Australia. *Talking Avocados* 16(4), 12-13.

Winter 2006: Update on the development of canopy management strategies across Australia. *Talking Avocados* 17(2), 22-25.

Spring 2006: Update on the development of canopy management strategies. *Talking Avocados* 17(3), 20-21.

Summer 2006: Update on canopy management strategies. *Talking Avocados* 17(4), 27-29.

Autumn 2007: Canopy management strategies. *Talking Avocados* 18(1), 19-21.

Winter 2007: Analysis of canopy management strategies. *Talking Avocados* 18(2), 38-39.

Spring 2007: Canopy management field days. *Talking Avocados* 18(3), 24-25.

Summer 2007/2008: Canopy management update. *Talking Avocados* 18(4), 22-28.

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