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Final Report: Australian Avocado Canopy Management Summit

Queensland Department of Agriculture and Fisheries



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REPORT ON THE SUMMIT HELD ON AVOCADO CANOPY MANAGEMENT

Part of project AV17005

Brisbane, 13 – 14 September 2022

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INITIAL DISCUSSION POINTS

Delegates discussed in pairs –

- *What are the ‘big picture’ challenges that you and/or the industry faces around canopy management?*
- *What do you think needs to change and/or have a better understanding of?*
- *Where do you think the biggest opportunities lie for improving canopy management of avocados?*

Stewart Ipsen (SW WA)

- In SW WA trees always have fruit on them
- Many orchards in this area are older and little canopy management has been undertaken
- A proportion of younger orchards now

Henk Van Niekerk (NQ)

- Shepard vs Maluma
- What is canopy management practices are cost effective and produce a crop?

Dudley Mitchell (SW WA)

- Need labour to have the necessary skills
- Dudley has different pruning strategies for different times of the year

Dale Schneider (CQ)

- The tree doesn't stop growing
- Need a more cost-effective method of canopy management

Col Douglas (DAF CQ)

- Mung beans (which used to be the crop Col worked on) used to be referred to as ‘mongrel beans’ but Col thinks that avocados are more ‘mongrel’
- In Bundaberg the vigorous tree growth of avocado is supplemented further by the vigour-inducing soils of the area
- Growers need tools and a suite of options

Chris Searle (CQ)

- Labour skills are needed
- Pruning has implications for the economics of spraying and harvest
- The negative aspects of avocado tree vigour in managing canopies need to be balanced by the tree vigour needed to counteract the predations of Phytophthora root rot

Tony Dugdell (SQ)

- In SQ they don't get the degree of tree vigour experienced on the coast
- Labour is a big issue
- Maintaining yield whilst also managing the canopy
- Trees were ‘out of control’ – needed to get them under control

Eric Carney (CQ)

- The effect of variety and rootstock on canopy management

- The avocado genome has been mapped – now we need to use this information to speed up the breeding process

John Tyas (AAL)

- Gene editing is needed
- Don't have to register varieties where genes have been modified

Simon Grabbe (CQ)

- The issue of getting labour and getting it at the right time
- We need canopy management systems that result in consistent cropping

Nicola Mackay (NQ)

- Access to labour and training for labour are big issues

Colin Partridge (NZ)

- Timing of pruning is important
- Trying to reduce labour need with some mechanisation

Denis Roe (SQ)

- We need to get back to mechanical pruning (for reasons of cost)
- There is an opportunity to use PGRs for the management of re-growth
- Having dwarfing rootstocks would be a massive advancement

DOMESTIC SURVEY RESULTS – DISCUSSION POINTS

Please refer to the [‘Domestic canopy management survey results’](#) in the BPR for a detailed report of the results.

The notes below report on the discussion of survey results at the summit.

When to start shaping trees after planting in the orchard?

- What the pruning strategy is from the start dictates the approach.
- After planting, young trees need two leaf flushes (before starting to shape the tree) in order to put carbohydrates into the root system for it to develop. You want root development ASAP, root development relies on a supply of carbohydrates, and these have to be generated by the canopy, so don't prune too early.
- How often to conduct tipping? Once per year, or once per leaf flush.
- Early shaping – one delegate likes to create columns, another likes to create complexity.
- Some believe tipping creates too much shading.

What age to start major pruning producing trees?

- According to the survey, the average age that major pruning is commenced in Australia is 4½ years old.
- Don't leave pruning too late, one of the consequences is a poor root/canopy balance.
- Start major pruning once trees have 'filled the space'.
- Start time is a function of the pruning aim, strategy and shape.

Timing of pruning producing trees

- Timing of pruning – this is governed by region and physiology.
- In many cases the preferred time is soon after harvesting.
- The timing of the first prune is dependent on the planting density and the region.
- In high density plantings it was suggested that dominant laterals should be removed to create leaders early, in low density plantings some would argue the opposite action.

Pruning techniques used in Australia

- The use of mechanical hedging has dropped significantly, & selective limb removal has become very popular. Mechanical hedging may come back due to shortage & cost of labour.
- Hedging will remain as part of the 'tool kit' of practices.
- Hedging first makes it easier (by revealing the internal tree structure) to then make decisions for selective limb removal.
- Open vase is an easy concept to grasp and conduct by an unskilled workforce, however, the 'hole' in the centre of the canopy soon fills up again.
- A four to five multiple leader approach can lead to an open vase, depending on where the major branches have been removed from, for example, often the tallest branch is removed first, and this is usually in the centre of the tree.
- 2D (two dimensional) tree structure – a grower in WA is having a go – but not getting yields.

Sunburn control

- Sunburn management is important, a lot of disease can start in trees that are sun damaged.
- Importance of applying sunscreen either prior to pruning or immediately afterwards was stressed – sunburn happens very quickly. Analogy of someone going to the beach – they need to put the sunscreen on before going to the beach, it's too late to put it on afterwards.

One approach used in SW WA

One grower aims to have different stages of re-growth within the same tree – thought to help to spread the risk of differences in fruitset potential and alternate bearing management. This entails pruning more than once per year in different ways, e.g. removing:

- Vegetative growth at flowering
- Non-productive limbs (those with no flower or fruit)
- Internal branches and those that haven't set fruit
- Branches that interfere with access - with or without fruit

The downside of pruning all year is that there is always new growth on the tree and phosphorous acid injections will burn any tender new leaf present at the time.

Extending lifespan of leaves

- Leaves are short lived in avocado, average 10 months, one way to extend their life (may be important in SW WA where leaves fall off at flowering with consequences for sunburn and fruit retention) is to spray urea at the cauliflower stage.

Planting density

- Delegates were surprised that the survey revealed few orchards at close planting.

Clonal rootstocks

- Low numbers of clonal rootstocks in Australia. This leads to less consistency/more variability.
- One grower reported more consistent fruiting in a clonal Dusa® block. Heavy crops are the best way to manage vigorous vegetative growth.

Trellising & robotics

- Trellising is very expensive with Australia's high labour costs and therefore difficult to justify from a cost:benefit point of view.
- In stonefruit robotics are coming for fruit thinning and harvesting.

Cincturing/Girdling

- This is a complex issue as several factors are involved and the result can be unpredictable, and inconsistent from one season to another. The aim is to retain higher levels of carbohydrate in the cinctured branch (they can't be exported from the branch because of the cincture) which theoretically will then flower more heavily and have a greater chance of setting and retaining fruit. However once carbohydrate levels reach a certain level there is a negative feedback loop which will slow photosynthesis.
- Timing of cincturing is important; it is usually recommended in autumn and typically results in earlier and heavier flowering on the cinctured branch but smaller fruit (probably because there are more fruit on the branch)
- In California they have experimented with cincturing alternate branches each year, e.g. half the branches get cinctured in the current year and then two years later, and the other half get cinctured next year and two years after that.
- The depth and width of the cincture will affect the outcome. They can be shallow or deep, and wide or narrow, e.g. range from a knife blade width to a 10mm ring of bark removed.
- The deeper the cincture the longer the effect.
- Cincturing is labour intensive, but a cordless angle grinder has been used by some growers to save time.
- In California they have experimented with a spiral cut.
- A WA grower tried cincturing; he increased flowering but got smaller fruit.

Other discussion points

- In SW WA it is the spring flush that generally bears the flowers in the next season, whereas on the east coast it is the autumn flush.
- The positive benefits of 'columns' vs vases.
- Take out sick and unproductive limbs
- You can't 'flush cut' everything.
- If you have to 'flat top' prune, then it is very important for a follow up 'groom' to take out any vertical growth.
- If you are going to measure light, it must be done immediately after pruning.
- Use of quadrants on the orchard floor to measure light penetration. Is there a light threshold and how do you measure it?
- Most of the fruit in a tree is at the top and on the northern aspect.
- A delegate mentioned that he sees better quality fruit on young branches vs old branches.

Extension methods for canopy management amongst Australian growers

- Recommended that farm tours be organised that allow growers to see what is being done in different places.
- Field day walks, where growers can see first-hand what is being done in different places (visit several different orchards during the event).
- Unless it is a field day, you don't get growers to discuss.
- Macadamias vs avocados – there is more sharing amongst macadamia growers probably partly because there is less competition between growers (most of the crop is exported and the product is sold to a small number of processing factories). Suggested that this might change when avocado growers get together in export groups. In NZ the large export packing sheds facilitate learning between their grower suppliers.

Research

- This is a difficult area because canopy management is never going to be an exact science.
- More research on PGRs was suggested.
- Research on optimum light interception may be useful.
- Chris Searle's quadrant system for measuring light interception.
- Cost:benefit of different pruning options – comment that it was very hard to determine.
- Case studies might be an easier way to try and address cost:benefit.
- Guidelines for the cost of pruning vs. production. How much money can you justify spending on your pruning programme – based on the expected benefit? What is the upper limit of spend? How does this compare with removing alternate trees?
- We need a better understanding of flower induction.

INTERNATIONAL SURVEY RESULTS – DISCUSSION POINTS

Please refer to the [‘International canopy management survey results’](#) in the BPR for a detailed report of the results.

The notes below report on the discussion of survey results at the summit.

Optimum % of canopy to remove each year

- A CQ delegate said that if you only remove 16 to 20% of the canopy each year, then after 5 years the tree has ‘beaten’ you because it is always growing. 20% removed each year for 5 years does not = 100% replacement, i.e., it does not result in the same sized tree.
- The CQ delegate suggested that to ‘beat’ the tree (in terms of keeping tree size constant) you need to remove about 30% per year but then it becomes a balance between maintaining tree size and maintaining yield.
- A WA grower said that the % that needs to be removed each year varies according to region.

PGRs

- Researcher Carol Lovatt in California increased fruitset using GA applications
- Pollen tube growth is affected by GA synthesis – Harley Smith, CSIRO
- Uniconazole – increases fruit retention and size
- Paclobutrazol is long lived in the plant
- For canopy management purposes a grower in SW WA targets the flush, not the flowers. The aim is to stunt the size of the leaf flushes. The frequency of use is tailored according to the strength and vigour of the flush. Low rates of about 2L/ha are applied on a needs basis, this could be three times in a season over spring and summer. Generally applied to 100-150mm sized flush. It is often applied to re-growth following hedging.
- Hedging has produced an increase in flush and subsequently a need to increase PGR use.
- Timing is critical. Tony Whiley used 0.7% strength in the first spray followed by 0.3% a fortnight later.
- Paclobutrazol is avoided sometimes because of greater residual effect and expensive – late summer flush is targeted.
- In CQ PGR trials with soil drench resulted in no MRL detected
- The point was raised – should we be relying on PGRs if potentially they won’t be an available tool in the future?

LITERATURE REVIEW – DISCUSSION POINTS

Please refer to the 47 page [‘Canopy management literature review’](#) authored by Dr Helen Hofman which can be accessed in the BPR.

The notes below report on the discussion of literature review at the summit.

- Trees pruned too early had fruit with more body rots (a finding from researcher John Leonardi’s work about 15 years ago).
- Tree removal (orchard thinning) is old technology and growers are reluctant to do it.
- What % shade cloth is best? What colour should be used?
- Shade cloth can be used for different purposes in different environments e.g. wind, hail, sunburn, humidity . . .
- Exposure to full sunlight is needed for flowering – a personal observation was that only the buds that receive direct sunlight produce flowers.

- In the density trials at Bundaberg Research Facility, the trees at higher density gave lower yields – attributed to shading of lower canopy by a roof of canopy at the tops of the tree.
- Not enough attention/research on the role/effect of tree carbohydrate levels in canopy management. Note: A [desk top study](#) was conducted by Harley Smith, CSIRO Adelaide on potential non-destructive methods of measuring carbohydrates in trees. [Project AV19006 'Carbohydrate monitoring to predict yield'](#)
- Reported that a spray of 33% potassium nitrate in combination with PGRs resulted in better fruit retention.
- Phosphorous acid- avoid injecting it before pruning.

What could be adopted from this review?

- Potassium nitrate for fruit retention.

What has potential for incorporation but requires more research?

- Light interception.
- Canopy management vs. profitability – this is a challenge due to many variables.
- Timing of pruning – how to make the first flush from the pruning become reproductive instead of vegetative.
- It would be good to have a tool to help with the decision-making (how much is the cost of the pruning and production cost vs yield).
- Cost benefits – use case studies (successful and non-successful approaches)

MESSAGES FROM DAY 1

- “It’s complicated!”
- Start pruning earlier and subsequent canopy management will be easier. “Earlier will result in easier”.
- Do something even if it turns out to be wrong. There have been many mistakes made but we are learning from these errors.
- Growers are reluctant to remove trees, there is also the added risk of *Phellinus noxius* (brown root rot) in tropical and subtropical regions on stumps of removed trees which can spread to retained trees.
- The industry needs access to good training and information.
- Canopy management needs to be part of a holistic approach, it shouldn’t be viewed in isolation.
- Nothing very new except perhaps Dusa® rootstock, Dusa® reported to make it easier but sometimes Dusa® trees are not pruned correctly early on.
- The principle of “columns” is relatively new.
- Each region has its own needs, learn by trial and error and from your neighbours

SHORT PRESENTATIONS

CQ - PRUNING TECHNIQUES YOU SHOULD PROBABLY AVOID ON MATURE TREES

Simon Grabbe & Dale Schneider (CQ) – Refer to PPT.

Region, environment, variety

- Childers, Central Queensland.
- Warm to hot temperatures, predominantly summer rainfall
- Hass and some Shepard.

What was tried and what worked and didn't work

Cutting too long/too high

- Resulted in shoots developing lower in canopy but this was then shaded out by growth above it – next time would work on reducing tree width first, or width and height.

Cutting too short

- Didn't take enough limbs out because cut limbs didn't receive enough light to re-shoot (they were shaded out by limbs that were left)

Not cutting enough limbs in follow-up after staghorning

- Made access for harvesting difficult. The remaining limbs competed and got too long and spindly. Solution is to only keep 2 or 3 limbs per tree in 7m rows, and 5 or 6 limbs in 11m rows.

Hedging

- Good access down inter-rows and orchard looked good, but poor yields and more deadwood.
- Solution – only hedge if necessary for access, use vertical cuts,

Taking middle out of trees (vase concept)

- Tree soon filled up the space inside the vase.
- Solution – remove shoulder first, only take out central limb first where necessary for height control and only if shoulders are removed first.

Current ideal plan

- 'Little trees' within a tree.
- Each 'little tree' (which is in fact one branch) is like a 'column' with full light all around it
- Columns about 800mm in diameter
- About 3 major limbs ('columns' / 'little trees')
- Tree height 70% of planting row width



Example of 'little trees' within a big tree at Simpson Farms

- Dense lower canopy (this is possible because enough light is reaching them) – this lower growth is important
- Easy access for pickers and good spray coverage
- Skirted at about 0.75m

CQ & NQ - PRUNING THE 'SHEPARD' VARIETY

Chris Searle, MacAvo Consulting, Central Queensland

- Very little is known about pruning the 'Shepard' variety.
- It is a more spreading tree than 'Hass'.
- You need to start pruning it for canopy shape earlier than Hass.
- More windows need to be pruned into 'Shepard'
- It can't be pruned mechanically; it is more difficult to prune and needs skilled labour.
- Need to wait till autumn (cooler temperatures) to prune, otherwise you will get very vegetative regrowth.
- A CQ grower felt that 'Shepard' was actually easier to prune than 'Hass'.
- A NQ grower said Shepard likes to have windows on the top and sides that are 1m in diameter. It is more susceptible to insect attack. They flower earlier so you need the windows in winter to encourage bees into them.
- 'Shepard' needs to be more open.

FNQ - PRUNING THE 'MALUMA' VARIETY

Henk Van Niekerk, DBC Farming, Dimbulah, NQ

- It is now obvious that 'Maluma' behaves very differently from Hass and Shepard and therefore needs a different canopy management approach.
- 'Maluma' may be better adapted to warm conditions BUT it is more susceptible to temperature extremes. The Dimbulah area where Henk farms experiences temperature extremes.
- The farm has 'Maluma' planted at:
 - 7x5m = 285 trees/ha
 - 9x2x6m on staggered double row beds = 370 trees/ha
 - 7x3m = 470 trees/ha.
- Henk has learnt to start pruning early in the life of the tree.
- Maluma has an upright growth habit and a weak root system.
- Select one of the two leaders (remove the other).
- Henk aims for a small, strong tree.
- Getting about 3t/ha in Year 2 and 8t/ha in Year 3.
- Maluma and Shepard are planted together for cross pollination.
- Mechanical hedgers are used to prune the tops and sides, then 'chicken feet' re-growth is knocked out by hand.
- Maluma will flower out of the new flush (unlike Hass and Shepard which flower on older wood) and has vigorous flowering.
- In Maluma, flowers, leaf flush and root flush all happen at once so if you are not ready for it you are in trouble.
- Prune in winter – it looks awful – like a lot of sticks.

- The root system needs to be in balance with leaf flush.
- The Dimbulah area is too hot for trellises.
- Henk aims for a 1.5m 'wall' of canopy – with this tree width the row spacing could be reduced to 4.5 to 5m.

SW WA - CANOPY MANAGEMENT IN A REGION THAT ALWAYS HAS FRUIT ON THE TREES

Stewart Ipsen, SW WA

- Harvest extends from mid-October till as late as March
- Flowering generally takes place from mid-October till mid-November
- If you had a very small orchard, you would ideally pick everything in early October and prune in late October.
- The reality is that in this region you can't avoid cutting off fruit when conducting canopy management.
- Main row spacing is 7m and trees are 7 to 8m tall which is 2m too high.
- Trees were yielding 19 to 20 t/ha.
- Some trees were then staghorned but then there was no yield for 3 years.
- Harvesting rates:
 - Harvesting from a cherry picker, in a high yielding block averaged 11 bins/person/day (the best picker got 18 bins/day). 1 bin contains on average 475 kg.
 - Harvesting from the ground, averaged only 3 to 4 bins/person/day.

WA PERTH AREA - CANOPY MANAGEMENT IN A HARSH ENVIRONMENT

Alan Blight, 'Avowest' (Perth & Gingin region, WA)

Refer to PPT [here](#).

Background

- Avowest is north of Perth at Carabooda and Gingin
- Cold, wet winters (500 – 800mm rain) and hot dry summers (>40°C)
- Harvest is July – September / October
- Flowering is usually confined to October
- Mixture of newer trees (< 5 years) and feral orchard (up to 40 years)

Avowest has been attempting canopy management for about 25 years.

First mechanical hedging was tried:

- Attempted to improve shape of old trees.
- Angled cuts (about 15°) on both sides of every second row
- Couldn't make it productive. Better on younger trees perhaps?

Then tried stumping (staghorned) but trees were the same height as they were when cut down by the time they were productive:

- Not enough follow up pruning
- Cincturing regrowth was too variable in producing fruit set

- Pre relatively cheap paclobutrazol (Cultar was expensive in the 90s)

Settled on (large) window pruning*.

Chainsaws for first 15 - 20 years supplemented now with a pruning head on an 8-tonne excavator.

Window pruning*

- Start after harvest (August onwards) sometimes to as late as March
- Aiming to make maximum impact with minimum cuts. Anecdotally fruit set is better if majority of branches are untouched.
- Removing 20 – 30% of the tree is ideal. Sometimes as much as 50%. Rotation of branches over years.
- Sunburn. Try to avoid extreme heat but difficult in WA summer. Use kaolinite for protection but don't have access to rows after pruning.
- Try to follow up pruning to eliminate “bull shoots” (water shoots).
- Mostly happy. Long term yields are 17 tonnes / Ha. Very slow and risks with chainsaws.
- Impossible to prune at the “best time”. Just do it!

Prior to pruning, manager goes through the block & marks with white paint the limb to be removed.



Limbs for removal are marked by the manager



After window pruning. Note this is different to the 'window pruning' described elsewhere which is conducted after mechanical hedging to cut a 1m 'hole' in pruned face of the tree.*

All prunings are mulched in the row, the material then serves as mulch.

Shaping new trees

In newer high density (480 trees/ha) plantings Avowest has attempted to shape younger trees, in order to:

- Avoid feral orchards
- Improve harvest / spraying efficiency
- Productivity?
- Netting.

Tried the open vase shape but:

- Late winter – poor fruit set due to vigorous regrowth and competition for resources by flowering.
- Autumn - theory was exposing buds to sunlight before the “Irreversible commitment to flowering” stage. Didn't work.
- Paclobutrazol not controlling regrowth at 2 – 4 L/Ha
- The inside of the vase filled up with re-growth within 6 months.

** Window pruning described in WA and NZ involves removing a large part of the canopy, it is very different from the window pruning described elsewhere which involves cutting a hole roughly 1m in diameter into the dense sides of a mechanically hedged trees. One delegate suggested that these Perth WA windows should be called 'roller doors'.*

Unhappy with results so will try shape pruning after fruitset next.

Paclobutrazol after pruning is not effective enough (applied through irrigation or as collar drench)

Pruning rules

- Fruit must always win
- Pruning is a long-term project
- Best branches to retain have a high proportion of pendulous branches
- Bull shoots (water shoots) need to be removed, or strongly cut back
- Usually, can't prune one tree in isolation to open windows
- Best after fruit set but before summer (dreaming!)
- Minimum cuts for maximum effect
- The best way to control vigour is to grow fruit.

The future?

- Window pruning* is effective but slow for old, feral orchards
- Tree training is not working.
 - Timing of pruning?
 - More PGR / different timing?
 - Alternatives to vase? Trying some central leaders / low trellis.
- Prefer an ugly avocado tree with fruit to a pretty one without fruit!

Additional comments

- We need to conduct work on the timing of canopy management.
- Growers can try different techniques and timing, but as well as measuring yield, should also measure fruit drop, measure re-growth, record % of tree canopy removed, fruit set etc.
- Carbohydrate levels in the tree need to be monitored through canopy management experimentation to understand this aspect. Potential for carbohydrate levels to be used as another tool to help make decisions. Henk is doing some preliminary measurements of carbohydrate levels, no result yet.

TRISTATE - PRUNING AVOCADOS IN THE TRISTATE

Shane Singh, Consultant, AgriHort Solutions

Shane was unable to attend but submitted his notes prior to the summit.

Irrespective of the region in which you grow avocados, it is important to develop a list of targets you wish to achieve when pruning, down to an individual block level. Some targets may include:

- Skirting for irrigation, mulching and weed management
- Inter-row access
- Height management
- Light interception
- Disease management
- Tree structure, and
- Ease of harvest.

Short-term and long-term productivity is always front of mind. Often decisions about pruning can be left too long due to a focus on production, however Shane believes progressive tree management that starts at planting is the best way to maintain tree viability and long-term productivity.

Consideration of avocado pruning in the Tristate:

Historical canopy management - historically the region has had low levels of canopy management, with many blocks overgrown. The main pruning techniques employed have been hedging or staghorning.

In recent years, there has been a move to higher levels of canopy management that can start within the first year of planting. Many growers have started to improve tree shape, reduce and manage tree height while increasing light penetration and managing bearing timber lower in the tree canopy.

Short timeframe - the short timeframe between harvest and flowering in the Tristate region can make decisions about pruning difficult. Floral development starts while there is still fruit on trees. In some cases, flowering can also occur while fruit is still hanging.

Biannual bearing - the region has a stronger biannual bearing pattern than the northern growing regions. This makes it difficult to decide when to prune, particularly when a heavy prune is needed.

Heat & sunburn - the main timing for pruning is after harvest in September and October. This period is often followed by hot weather that can cause sunburn to structural timber if not managed well.

Re-growth - re-growth after pruning needs to be managed and is often overlooked not just in the Tristate but in all regions. In many cases, nutrition and irrigation need to be adjusted to manage tree growth / re-growth. There may be some opportunities to use plant growth regulators to manage regrowth.

Plant Growth Regulators (PGR) - PGRs are traditionally applied at flowering to improve fruit set by managing canopy vigour.

CANOPY MANAGEMENT IN NEW ZEALAND

Colin Partridge, Technical support to Avoco and consultant, New Zealand

Environment and variety

The NZ climate is classified as cool and most rain falls in winter. Hass is the dominant variety.

Challenges

In this climate (provided root rot is under control) vegetative growth can be luxuriant, especially if a light crop is set.

Wind is a constant enemy in NZ.

Due to the cool climate, orchards very often have previous season's fruit hanging late, overlapping with new flowering and set.

History and lessons learnt in large tree orchards

There now appears to be universal acceptance in NZ that effective light interception on as large a production surface area as possible, is what maximises potential yield. The following techniques were tried with varying success and issues.

Thinning out close planted orchards

Where trees were planted at relatively close planting, the biggest problem was not thinning out alternate trees until too late. Many of these blocks took a very long time to bring back into production. The job needs to be done before tree size is such that insufficient light is reaching the sides of the canopy.

Staghorning

Using staghorning as a method to control tree height. Colin suggests that staghorning should only be considered to help rejuvenate unhealthy trees. In NZ it takes 4 years after staghorning to get back to a productive orchard, in addition, healthy trees develop excessive regrowth with new limbs developing weak attachment points that are prone to breaking during windstorms.

The staghorn 'lollypop'

The 'lollypop' idea where limbs on the tree were thinned out to a few with a big canopy at the end of the limb.

This system involved staghorning a number of the lower limbs of each tree, leaving the most vertically growing ones to continue producing (like a lollypop). The light allowed in was supposed to stimulate regrowth on the lower stumps and when it flowered and set fruit, the tall ones would be removed and *voila*, all the trees would be shorter and with none removed.

The trouble was that, like normal staghorning, the lower regrowth was lanky and took far too long to develop any flower buds, while the fruit at the tops suffered wind and pest damage and were very expensive to pick. Production remained low and this system was slowly abandoned.

Mechanical pruning (using shelter belt trimmers)

Once trees were pruned into whatever shape was desired, the visual result of the trial orchards was impressive, however the commercial result was not impressive. A wall of green shoots sprouted from the pruned area which shaded out the interior of the tree if not thinned by hand. In NZ, these new shoots do not develop flower buds the following spring if the cut is made after mid-November. Also, because the blade cuts indiscriminately, very sharp points on cut twigs and branches are left in the canopy which are dangerous to harvesters. Last, but not least, it can be difficult to make a cut that does not damage any crop hanging at the time.

'Flat topping'

This method started when medium sized trees growing under power lines were 'flat topped' at a set height every year by the power company. These particular trees were not yet overgrown so were exposed to light on all sides and still had quite a lot of internal leaf canopy which was an advantage because sunburn on exposed limbs was minimised, but re-growth had to be managed. However, on large trees with 'hollow' canopies that were 'flat topped', sunburn could be a problem on exposed limbs and watershoot regrowth from the cut limbs resulted in a thicket of watershoots emerging from the cut surface which was a problem for picker access and soon shaded the rest of the tree unless removed.

'Little trees within big trees'

More detail is provided in Colin's paper available on the BPR [here](#).

A system that seems to offer promise for large trees is mainly a combination of extensive window pruning and selective limb removal to develop 'little trees within big trees', also referred to as

'columns'. This is a case of 'parallel evolution' in that Simpson Farms in Central Queensland has arrived at the same approach.

Colin has adapted a poem to describe it:

*"Big trees should have smaller trees,
With windows all around them,
The little trees can bear lots of fruit because
Windows let much more light in."*

The main aim of the approach is to try and create a three-dimensional bearing surface for each main limb (small tree/column) by allowing light right through the canopy. Tree shape is a less important consideration.



NZ example of 'little trees within big trees'

The system was developed to deal with very large trees on wide spacings around 10x10m that were expensive to harvest and difficult to spray. Some were as high as 12m and production was often low.

Colin's article describes the approach in detail but essentially the steps are as follows:

Selectively remove some of the large branches to leave several that are well spaced (to allow easy picking, good light along each and adequate spray penetration) - this will result in a large volume of pruned material to deal with.

Encourage and maintain multiple points of mature productive growth along the length of major limbs. This provides options on length reduction to maintain spacing without a complete loss of production from the limb.

Sunlight filters through the sides of the canopy as well as the top. Well distributed light supports the multiple points of growth mentioned above. Maintain enough light penetration in the canopy to support at least a 2m wide swath of grass between trees. This is a good indicator that the tree has enough space around it and all aspects of the tree are receiving adequate light.

Manage the canopy of the block/orchard rather than tree-by-tree. When making cuts consider things like how it will benefit the neighbouring tree and how the canopy in a block is maximised to capture the available light.

Conduct the main prune in spring, follow up if necessary in autumn to maintain light into the parts of the tree where you want it.

It's important to take a longer-term view of production when pruning. Be aware what will become productive wood this year and what wood will be productive next year and so on.

Canopy management in new higher density, small tree orchards

This mainly applies to trees planted at 6x3m, 5x4m and sometimes up to 8x4m.

Pruning starts at around year 2 and must then be conducted every year.

There are two main canopy management systems used:

a) Annual structural pruning as soon as possible after harvest to limit tree height to around 3-4 meters and improve light penetration into the canopy. No particular tree shape. Main aim is to allow

sufficient light penetration to make the trees capable of setting fruit three-dimensionally through the canopies.

b) V or M -pruning as soon as possible after harvest. The aim is to limit height, but also to create a roughly V or M shaped canopy when viewed down the row in either a North or South direction. This is to replace undesirable canopy height, to a more desirable lower height by the notching of the V, but still maintain bearing surface area.

Both systems require watershoot grooming later in the season to remove unwanted, or to shape new growth.

'Flower pruning'

- The name used for this operation is probably a misnomer, branches with flowers are pruned rather than the flowers themselves.
- A possible reason for its growing popularity in NZ is the high proportion of determinate shoots in some seasons which result in a shortage of shoots able to flower the following season – this leads to severe alternate bearing. Flower pruning of excessively flowering trees is important to manage stress on the tree and produce enough spring leaves for next year's flowering. Flower pruning is therefore carried out, *usually before the set of an expected on-year*, to balance an orchard's fruit carrying branches with vegetative growth.
- Correct timing is important and the best time to carry out flower pruning is in September and October.

More important detail is provided in Colin's report.

The picking debate

There is ongoing debate in NZ about the pros and cons of picking from the ground and using cherry pickers, picking rates, safety factors, the need for skilled labour to operate a cherry picker efficiently and safely, etc.

It is an interesting topic with many interrelated factors. The production of any block will have a large influence on picking costs per bin and because the production/cost situation varies enormously from orchard to orchard, no single situation will suit all. A combination of ground and hydraulic picking is done on many orchards.

Some final points

- Orchardists need to be given different pruning options.
- A spring prune is an invigorating prune.
- A summer prune is a debilitating prune.
- Do a 'flower prune' in an 'on' year.
- Do window pruning in an 'off' year.
- Colin recommends inclusion of pollinizer varieties in orchards in NZ, he discusses his thoughts on how they should be pruned to be most effective.
- Boron – sample and analyse cauliflower stage of flowers – B needs to be 80 ppm.

GRAEME THOMAS

Graeme Thomas, Consultant, GLT Horticulture

Graeme was unable to attend in person but submitted his remarks prior to the summit.

Canopy management is so diverse and variable.

You need to consider:

- Light on branches to develop flowers
- Access for foliar sprays
- Access for pickers
- Alternate bearing.

We can manage nutrition better.

Extension work needs to highlight the need for canopy management for:

- Fruit quality (Premium grade)
- Yield
- Spray penetration (disease).

In the Atherton area in NQ you can get 4m of growth per year.

Need to:

- Manage nitrogen
- Thin out water shoots.
- Conduct cost:benefit studies.

For regions where there is fruit on the tree all year, Graeme proposes the use of cincturing on limbs to be removed after the next harvest. This may be an area for extension work. Is it too labour intensive (need for a cost:benefit study)?

PGR research is needed.

In SW WA PGRs are applied on spring flush (after flowering) and again twice on summer/autumn flush.

At King Avocado in north of NZ North Island, PGRs are applied to soil, but this must be commenced when trees are very young.

Use of NAA in house paint can be applied to pruned stubs to prevent coppicing (also refer to remarks by Francisco Mena who said that it is not useful in Chile because it only acts very locally and is short lived).

Question for the summit – what are the best methods for canopy management extension?

Photos/video taken from **drones** are a good way to demonstrate canopy management.

CANOPY MANAGEMENT OF AVOCADOS IN SOUTH AFRICA

Bram Snijder, Tzaneen, South Africa



Bram is based in Tzaneen in South Africa and is highly regarded horticultural consultant. He has worked as a Scientific Researcher in avocado and coffee for over 20 years for the Agricultural Research Council in South Africa and now runs his own private consultancy business.

This talk mainly applies to orchards at fairly conventional spacings in subtropical regions – [recording available here](#)

Some background on the South African industry

- 58% of industry in Limpopo and Tzaneen areas
- 24% in Kiepersol, Nelspruit & Barberton areas
- 12% in Kwazulu Natal
- 4% in Western Cape
- 2% in East Cape

Harvesting starts at Levubu in Limpopo Province in February, concludes with harvest in W Cape late Jan/early Feb (much the same times as the Australian spread of the harvest season)

380 commercial growers and 165 'emerging/small' growers.

15,500 ha of avocados currently with an additional 800 ha planted each year.

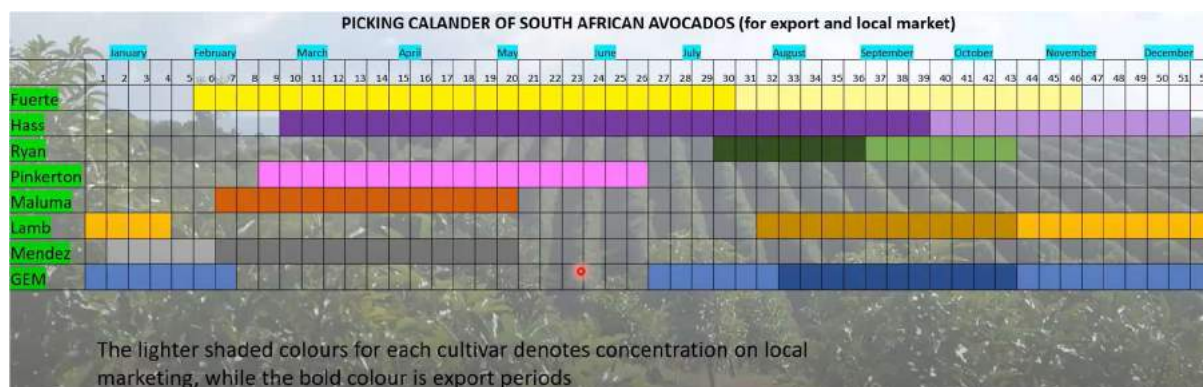
Current production 135,000 t/year (this averages 9t/ha). Employs 12,200 people.

60% exported to EU, 24% consumed locally, 16% processed.

63% black skin varieties, 37% greenskins. Approximate varietal spread:

Hass 51%, Fuerte 22%, Maluma 8%, Pinkerton 7%, Ryan 6%, GEM 3%, Mendez (Carmen®) 2%, Lamb Hass 1%

Varietal harvesting windows:



Lamb is regarded as being hard to work with in nurseries.

Rootstocks used commercially are mainly clonal types:

Duke 7 clonal, Dusa® clonal. Bounty® clonal (on poorer soils where water logging is possible), Edranol seedlings, a few Velvick.

Planting densities range from 12x12m to 6x2.5m. Experimenting with 4x1.5m e.g. with Maluma.

Pruning

Spacing of orchards has an enormous impact on which pruning method is followed.

Generally, start pruning in Year 4 or 5 with wide spacing and Year 3 with close planting.

Phenology is much the same as central Queensland.

Flower initiation takes place mid-Feb to end of Mar (depends on variety).

Up to three leaf flushes per year in warmer areas – spring, summer, autumn. If pruning takes place in Feb/Mar the 3rd (autumn) flush is strong and crop is lost due to lack of flower initiation because the 3rd flush is not mature enough to initiate flowers.

The 'safe' pruning period at this time of year for trees with the three annual flushes is from April till end of July. Whilst in areas where fruit is hung late, major pruning takes place in Sep – Oct.

Purposes of pruning:

1. Tree structure
2. Light penetration
3. Complexity
4. Size maintenance

1. Tree structure

At wide spacings, aim for 3 to 4 well-spaced main limbs

At higher density, aim for 2 to 3 well-spaced main limbs, reduces to 1 to 2 at very high densities

Importance of 'backbone' branches: Bram speaks about the main limbs being the '**backbone**' of the tree and emphasises that although the height of these 'backbone' limbs can be maintained these limbs themselves should not be removed. Often if a 'backbone' limb is removed the light window is too large and stimulates excessive regrowth including unproductive watershoots which require extra work to come back and control within a short period of time which defeats the object. Another benefit of not removing these 'backbone' limbs is that the chances of sunburn are reduced.

Rather than taking out a major limb as we do in Australia with selective limb removal, Bram recommends keeping the selected limbs permanently as the 'back bone' of the tree.

The higher the density the earlier the tree structure must be created.

2. Light penetration

Sunlight is free – use it wisely

Keep the laneways open and the height in check to ensure light gets to the sides of the hedgerow – this where the easy-to-manage fruit should be. It is also of course important for machinery access.

Also make sure light gets INTO the tree to enable buds to develop there for replacement growth for when pruning is conducted.

There should be dappled light on the orchard floor under the trees.

3. Complexity

Potentially the more complexity in the tree, the more fruit the tree can set

Complexity can be enhanced by pruning

Complexity can be achieved by tipping to force lateral buds to break

In Hass the buds inside the tree quickly lose their quality when they are not sufficiently illuminated

4. Size maintenance

As well as light penetration, size is important for spray coverage and economy of harvest.

Maximum tree height in South Africa is about 5m or lower for several reasons.

Importance of follow-up after pruning

Control of regrowth is extremely important – you want re-growth, but it must be managed

Remove all watershoots as they will grow several metres in a season, they won't be productive and they will quickly shade other parts of the tree.

Limbs should be removed flush with the trunk – any stubs should be removed as they coppice (produce multiple shoots)

Summer pruning may be needed to remove unwanted summer flush branches that are preventing light penetrating into the inside of the tree i.e. creating too much shading

Limited nitrogen is applied through summer.

Pruning should be directed towards replacing bearing wood, i.e. where possible, branches are removed so that new productive wood can develop in their place

Managing Hass

Multiple leader system

Cut windows into trees that allows sunlight into the tree (may need to be accompanied by sunburn paint)

Try to maintain a conical shape to the tree (narrower at the top and wider at the base)

This may involve removing 'shoulder' branches, these branches poke towards the laneway and shade the tree below them.

Tree height should be no more than 80% of the distance between tree trunks across the row.

Where mechanical pruning is used it is very important to come back and manage the outside branches this involves tidying them up, removing stubs etc.

Effect of pruning on fruit quality

Maintaining a tree with limited height and good light penetration also results in less insect and disease damage not only because of better spray coverage but also because insects prefer denser foliage and disease is favoured by poor ventilation. Good airflow allows the canopy to dry out quicker after rain. A more open canopy is also likely to produce less wind damage to fruit especially if dead branches are removed as part of the pruning program. Sunburn damage could be higher though.

There is a need to cost out different pruning systems.

Paint appears to be commonly and liberally applied to prevent sunburn in South Africa where pruning is taking place.

Window pruning is important, as is keeping laneways (interrows) open to get light to sides of hedgerow (as well as for machinery access).

It is very important after mechanical pruning to follow up with manual maintenance.

PGRs

Bram feels if pruning is done correctly then regrowth should be reduced and more controlled and therefore there should be less need for PGRs.

He recommends that fertiliser programs and irrigation scheduling should be reduced commensurate with the severity of the pruning. He also recommends easing off nitrogen applications a month before pruning is done.

Also, if possible, only use it on the areas that need it for helping to control regrowth rather than on the whole area.

Bram is wary about PGRs being used to control spring leaf flush since the spring flush is important not only for good fruit retention but there is some suggestion also that it is important for the hormonal balance to maintain the fruitset.

Alternatives need to be found to manage growth as the long-term acceptance of fruit from trees where PGRs is in doubt.

Netting

Netting is being tried for protection from frost, hail and wind rub.

Bram prefers drape nets applied after flowering compared with permanent netting structures as the latter tend to interfere with bees and other pollinator access.

Bram said the jury was still out on the % shade material to use and the colour. However, he said that the black netting appeared to give better sunburn control than white nets.

In warmer areas 15% shade cloth still results in massive vegetative growth and doesn't always have a good effect on fruitset.

The way forward

Better fertiliser management

Deficit irrigation and the use of Vapour Pressure Deficit

Shoot management

Increase flowering to put a brake on vegetative growth

Question time

Q. Questioning the value of drip irrigation in summer rainfall areas where trees are grown on ridges. Denis believes that micro-sprinkler irrigation is more effective in a summer rainfall area. A. Apply fertiliser when rainfall is low, during the wet season (summer) use slow-release fertilisers to gain more control of vegetative growth. More and more drip irrigation is being installed in South Africa.

Q. Investors are planting large areas in Australia with drip irrigation. Massive root systems develop in wet season then they die in the dry season which may be an issue. A. Drip irrigation has only been used for only 4 to 5 years in South Africa so we are still learning. It might become an issue as the trees get older.

Q. What is the status of mechanical hedging in SA? A. It was very popular initially, but with a well-trained team you can conduct canopy management manually more effectively and cheaply (at South Africa's cheaper labour rates).

Q. What about with mechanical selective limb removal? A. Concerned that you might doing long term damage to the tree. Bram wouldn't recommend this as standard practice, mainly because it often involves removing 'backbone' limbs which Bram doesn't like to do.

Discussion by delegates about Bram Snijder's presentation

- The concept of keeping the selected limbs permanently as the 'backbone' of the tree (once trees have already been shaped). The height can be trimmed but these selected limbs not removed.
- Follow-up pruning - "grooming" is important, even in ultra-high-density plantings in Chile.
- The importance of the keeping the inter-row space open – allows light into the sides of the trees.
- Need to standardise our terminology e.g. windows, 'roller doors', grooming.
- Consider short term and long-term gains from mechanical pruning
- Bram said "PGRs should not be needed if you can carry a good crop load to suppress vegetative growth".
- There was a debate about timing and rates of nitrogen. Graeme Thomas' system is to adjust N rates in order to get 18" (45cm) of spring flush over the newly set fruit, this may entail apply no N or a lot of N. The aim is to have enough canopy to generate sufficient carbohydrate to support the new crop AND ensure enough carbohydrate to produce a good flowering and fruitset the next year.
- There was a debate about the merits of netting. A grower reported good benefits at Kumbia (near Kingaroy) partly from increased humidity, but in WA it interfered with bee movement.

PRUNING AVOCADOS – AN ANALYSIS FROM A CHILEAN PERSPECTIVE

Dr Francisco Mena Völker, Gama, Chile



Francisco is based near Santiago in Chile and runs a consultancy company called GAMA Ltda which also conducts research. He consults internationally, regularly present results of research at the World Avocado Congresses and is considered to be a leader in avocado canopy management.

This talk mainly applies to orchards at high density spacings in a cool, non-vigorous Mediterranean climates. [Recording available here](#)

What the ‘Beatles’ and avocado canopy management have in common

A history of pruning avocados, can be summarised by a number of the Beatles albums:

- ‘Let it be’ – not doing anything for a while, but you will soon be begging for . . .
- ‘Help’, and once you start pruning the light will come in and . . .
- ‘Here comes the sun’ but you will be pleading to the trees . . .
- ‘Don’t let me down’, this has got to work and then . . .
- ‘We can work it out’ and finally you will find out that learning how to prune is . . .
- ‘A long and winding road’

The growing environment and avocado industry in Chile

Avocados are grown in Chile from about 30° south to about 34° south however they are looking further south for suitable sites to grow avocados as they are struggling to get enough water in the traditional areas.

Climate changes very little in a north to south direction along the 500 km length of the Chilean coast where avocados are grown but does change significantly east to west between orchards within about 20 km of the coast and those further inland up to 80 km from the coast. Near the coast the cold Humboldt current cools the climate, there is a great risk of low temperatures at flowering, evaporation is lower and humidity and rainfall (400mm) are higher. Inland temperatures are generally warmer although risk of frost is higher, evaporation is higher, and humidity and rainfall (200mm) are lower.

The typical phenology is more like SW WA with peak of flowering in October and with two leaf flushes, two root flushes and two fruit shedding events.

40,000 ha in 2007 but down to 30,000 ha by 2017 due to severe frosts in 2007, drought, shortage of irrigation water and near Santiago and in some valleys, poor quality water (high chloride).

No serious insect pests that can’t be controlled by beneficial insects. Most plantings are on steep hillsides.

Strong increase in planting densities in the last years:

Early 90's	:	277 trees per Hectare.
Mid 90's	:	416 trees per Hectare.
Late 90's	:	555 trees per Hectare
Early 2000's	:	832 trees per Hectare.
Mid 2000'	:	1.111 trees per Hectare.
Early 2010's	:	1.600 trees per Hectare.



Why the Chileans went with higher densities

- Chile has a non-vigorous climate and non-vigorous soils.
- They don't have to spray for insect or disease management and

- **Small Trees more attractive and Safer for Labor.**
- **Faster return of investment.**
- **Higher productions.**
- **Lower Picking costs.**
- **Better Picking Quality (Size picking).**
- **Easier canopy management.**
- **Lower water consumption/Kg.**
- **No option for mechanization on the hills and/or no need for applications/machinery transit in the Orchards**

When you go to higher densities you need to make a serious commitment to canopy management and you need to understand the 'rules of engagement'.

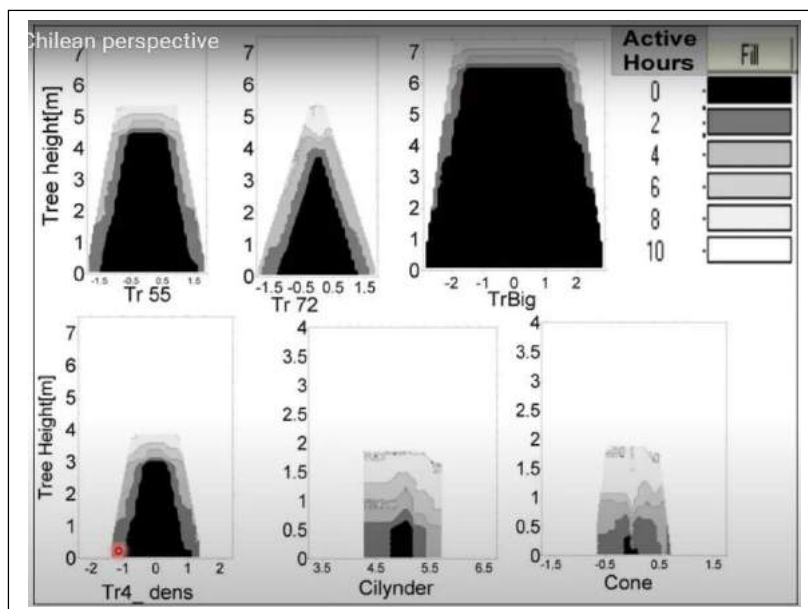
Fruit is essential, not only for economic purposes, but also to suppress vegetative growth.

Development of soil applied PGRs started in 2007 after a low cropping year

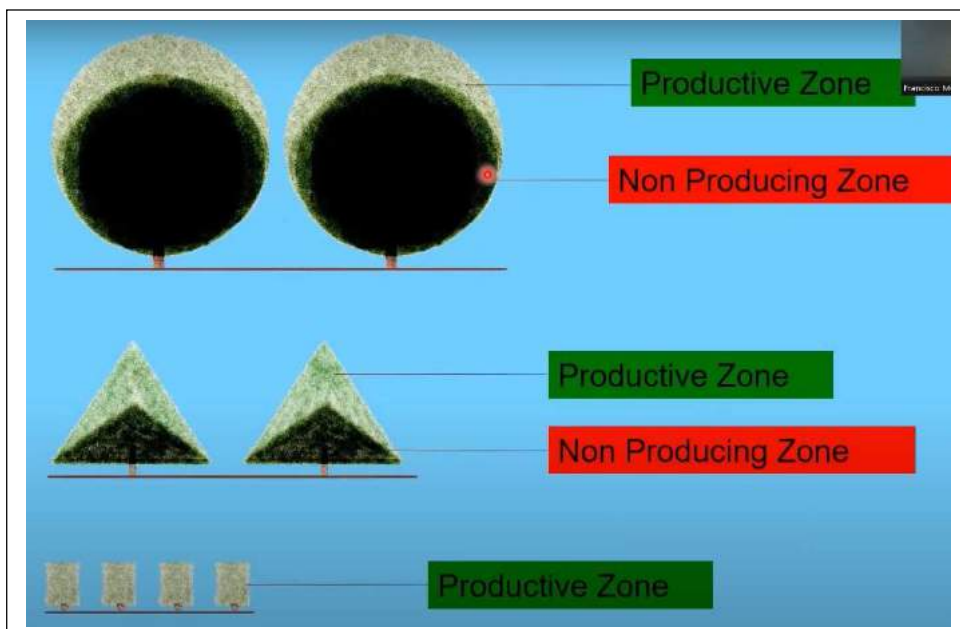
Consequences of shaded orchards:

- Reduction in fruit size
- Lower production
- More prone to lose vigour, not enough carbohydrate for the tree
- More salt damage (in areas with high chloride)
- Greater incidence of branch dieback, stem end rot
- Shaded orchards don't generate enough carbohydrate to feed the roots

Hadari (2004) showed that there is a 60% reduction in light penetration in the outer 50cm of canopy and 80% reduction at 1m. The following diagrams show how much photosynthetically useful light is received for different tree sizes and shapes. The black areas receive no photosynthetically effective light.



Schematic representation of the above graphs:



Some considerations

Avocado is a poorly domesticated crop

The tree response after pruning – the bigger the cut i.e. the closer the cut to the root system the more vigorous the re-growth will be – *correct management of the regrowth is vital to reduce productivity loss because of lack of flowering &/or excess vigour.*

If we prune very hard, we need to manage the regrowth to get it to flower as soon as possible to manage the vigour. If we mess up we will get vigorous vegetative re-growth and a lack of flowers, and we can get the trees into a cycle of more pruning, no flowers, vegetative growth, more pruning and so on.

History of Chilean experience

- Removing trees (thinning) was not the long-term solution
- Stumping trees was expensive to cut, paint etc, plus there was no production for at least two years but very vigorous unproductive re-growth
- PGR trials started in response to trying to control regrowth after staghorning, but results were not consistent
- Then tried girdling in unproductive trees, but this resulted in more flowering in girdled branches but girdling in autumn reduces the carbohydrate reaching root system and they were unhappy with the results
- Tried staghorning alternate rows, but irrigation and nutrition management became very complicated
- Moved to hedgerows, but as trees started to grow into the inter-rows, pruning had to become more aggressive and as a consequence trees became too vegetative
- Mechanical pruning of one side in spring, regrowth in summer, light follow up prune of regrowth in Feb/Mar, then in autumn spray with PGRs to try and get them to flower.
 - To investigate this approach a trial was done with different dates (across Feb and Mar) for the follow up prune and then with or without a PGR (0.5% uniconazole) spray when regrowth was 10 to 15cm long.
 - Results: the longer they left the regrowth before re-pruning, the longer the shoot was (from 1 to 1.3m long), however the shorter the re-growth (from 22cm down to 2cm) after the re-prune.
 - What happened to the number of flowers? With no re-pruning and no PGRs the flower number was the lowest. With no re-pruning but with PGRs the number of flowers was high. With the earliest re-pruning but no PGR the highest number of flowers was achieved. But with all the other treatments the number of flowers was disappointingly low and the flowers were weak and the vegetative shoot could easily out-compete the weak flower.
 - This trial showed that this system was not going to work under Chilean conditions, so it was dropped.
- Concluded that:
 - The influence of climate and eco-physiology is stronger than any PGR
 - PGRs applied to very small shoots do not increase flowering but can decrease it
 - Correct timing and type of pruning are the most important factors
- Tried bringing tree height down and aiming for a vase type tree shape or a single leader shape, came back in winter and re-pruned them to try and maintain their size
 - Single leader: 0, 7 & 25 t/ha = 33 t total (2009 – 2011)
 - Open vase: 19, 23 & 20 t/ha = 63 t total (2009 – 2011)

- Reducing large trees down to less than half their height, the average per year for the three years prior to pruning was 18 t/ha but the average for the 4 years after the height reduction was 19 t/ha and the trees were much smaller and a lot easier to manage. Maintaining this type of tree was quite easy – in winter remove the taller shoots to manage height and then straight after picking remove branches in the laneway and ones that have produced fruit and this is quite easy. Tell staff to only remove very vigorous material from the area where the major prune was originally made. Also remove material that compromises light penetration and remove water shoots. THIS IS THE SYSTEM THAT IS NOW FOLLOWED.



The first step is to take the height of the tree right down.



In winter the water shoot regrowth at the top of the tree is removed and . . .



. . . after harvest removed branches from the sides.



This is an example of the tree they are aiming for.

Pruning high density orchards

Early tree training is conducted to reduce heavy lateral growth. Later on tipping on the sides is done to increase complexity on the sides. It was easy to manage with plenty of flowering. A 3x3m orchard produced 9 t/ha in Year 2 and 18 t/ha in Year 3. The next year there were too many pruning rounds during the year in an attempt to control tree size, and consequently yield went down to 4 t/ha in Year 4. After this, soil applied PGRs were introduced and the number of times pruning was conducted during the year was reduced to once after harvest and if needed once during winter. PGRs are relied upon more than pruning to keep tree size in check. The yield in Year 5 was 40 t/ha, then 19, 31, 17, 43, 18 t/ha after that.



What a high-density orchard looks like in Chile now, you can walk between rows and it nice to manage.

Pruning now consists of removing the higher part of the tree during winter, then right after harvesting they prune excessive lateral growth – this results in weak but very productive lateral branching.

The ‘rules of engagement’

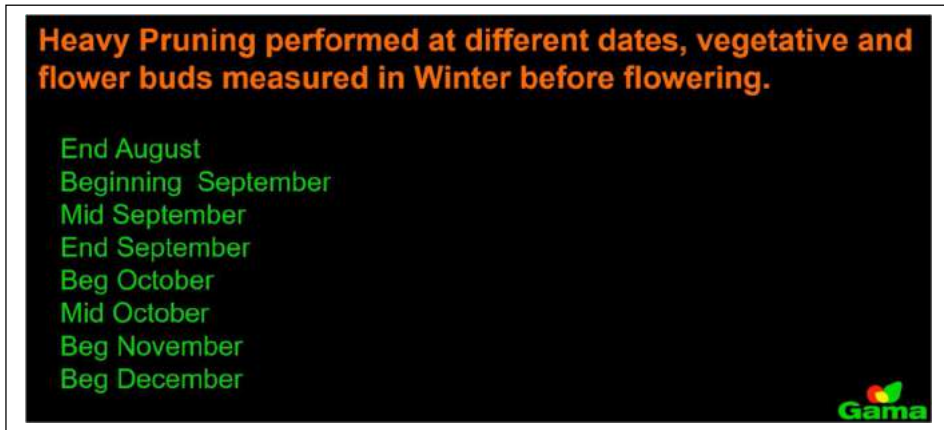
- Pruning intensity.
- Pruning date.
- Flower induction and differentiation (Irreversible commitment to flowering)

Trial to see effect on floral buds of removing developing fruit at different times the previous season

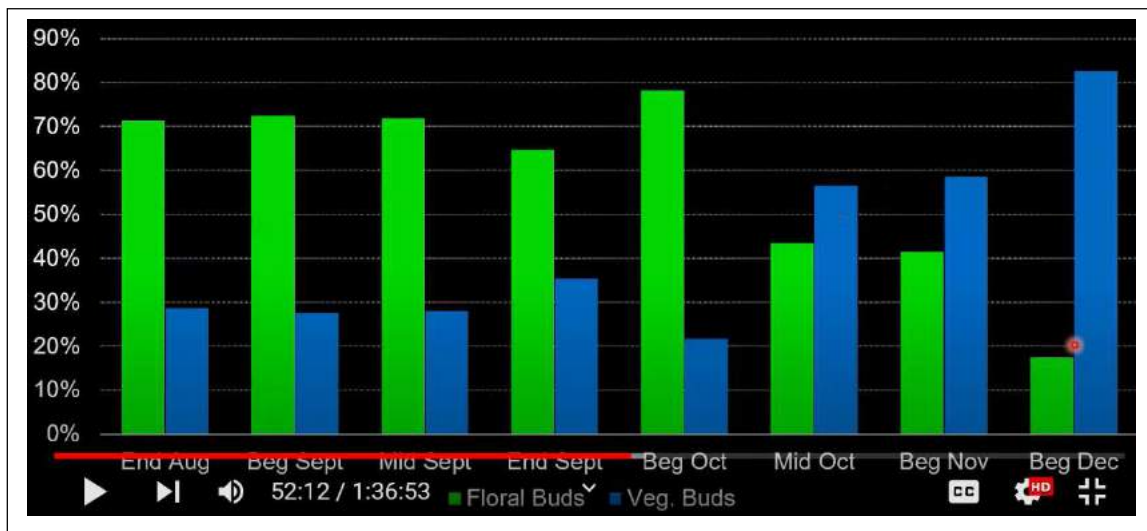
Trees that had fruit removed early (Feb & Mar) had significantly more floral buds than trees that had fruit removed later (Apr, May, Jun, Jul, and normal harvest time i.e. second half of the year). Therefore there was something going on between March and April. There were also more vegetative buds if fruit was removed from April onwards. Also the % of canopy that had flowers on the tree (in October) was much lower when fruit was removed in May or later.

This work was confirmed by José Torres’ Masters degree study that showed that secondary floral meristems started to appear in February (even as early as January). This was more consistent by April and at this point the bud would not revert to a vegetative bud i.e. the development of the floral bud was irreversible. Thus, irreversible flower initiation takes place in Chile in April.

Study of different pruning dates



The effect on buds the following year (see below) clearly shows that the earlier you prune the more floral buds and less vegetative buds you get, and the later you prune the opposite the case.



Timing of pruning follow up (grooming)

Another trial is underway looking at the effect different dates of re-pruning dates (Jan to Aug) to remove water shoots etc (grooming)

Soil applied paclobutrazol (PBZ) trial



Tree on the left was treated with PGRs through the irrigation, tree on the right was not treated.

The trial tested different paclobutrazol rates (from 0 to 6 L/ha) and different wetted diameters (3.5m, to 1m, to drip) in different soil textures (sandy loams and clay loams). In general, the higher rates of PGRs produced higher yields and less alternate bearing.

Also, greater responses were achieved where the root system was concentrated within a smaller volume of soil. In other words, in a higher rainfall area and/or where wide throw sprinklers the PGR will be distributed over a larger area and the result is not expected to be as good.

Higher yields were consistent with heavier flowering intensities.

Effect of soil applied PGRs on shoots, buds and yield



Left: Effect of soil applied PGRs on internode length (upper section of photo).



Right: In spring most of these shortened internodes have flowered.

Below: The flowering stem tends to bend down.

Bottom: Impressive crop set



Production rises with higher PGR rate e.g. 2L/ha vs 4 L/ha

Another trial tested different times to apply uniconazole to the soil. Treatments were applied in the 3rd weeks of Oct, Nov, Dec, Jan and Feb. Trees performed best when the PGR was applied in November, this was followed by October. Fruit size was slightly smaller in the November treatment but this was minimal when compared with the increase in yield (17 t/ha vs 9 t/ha in the December and February application times).

Conclusions

- It's been a long and winding road.
- Illumination criteria is by far the most important one.
- Timing is critical.
- Continuous pruning did not work for us.
- PGR's can play an important role, specially in HD plantings.

1. It has been a 'long and winding' road to find out what works best.
2. Illumination of the tree is by far the most important factor. How far is each part of the canopy from direct sunlight?
3. Timing is critical – you can't prune at just any time of the year – try and avoid the times when the tree is getting ready to commit to flowering (flower initiation) – for this reason in Chile they do not do any pruning in January, February or March. December should also be avoided or at least pruning should not be intensive in December. If heavy pruning is needed, they will try and do it earlier in the season.
4. Continuous pruning did not work for the Chileans. They have found it best to do one pruning after harvest but if more shoot removal is need this is done during winter as a follow up.
5. Under Chilean conditions PGRs play an important role, especially in high density plantings.

Question time

Q. SI - Daily labour rate in Chile? A. About USD40/day

Q. GLT Effect of PGRs on root system? Do they reduce the vigour of your roots? A. We haven't seen any effect yet after 15 years of applying it, and no detectable residues in the soil after about 160 to 180 days. I think PGRs have been blamed for a lot of things that they are not responsible for. Maybe if the trees are lacking in vigour due to some other reason (e.g. a problem with the irrigation system) then it could be more complicated if you are applying PGRs on top of that. But you maintain the vigour and trees are well irrigated but not over irrigated, well fed etc

Q. How much is Phytophthora root an issue for you in Chile? A. Not really a problem in Chile, and we get a quick recovery in the trees after spraying with phosphorous acid. We don't know if it is because we have less aggressive strains of Phytophthora or perhaps due to our inherently higher levels of copper in the soil or water that help (Chile has copper mines). Our main problem is bad irrigation practices and that combined with heavy soil.

Q. The future of PBZ? A. At some point we may lose them. If at some point that happens, and this is something we are working on currently, then may move to girdling in combination with bio-

stimulants to stimulate root growth, and maybe these root stimulants will let us get away with girdling. Our system is such that we need to get the trees to flower heavily every single year (a heavy crop puts the brakes on vegetative growth). Having said that, citrus growers in South Africa are using PGRs more and more. Mango growers are using them too. So even though there is more 'noise' around using PGRs, more and more industries are using them.

Q. The use of GA and cytokinins? A. We did a trial some years ago with GAs at flowering time but we didn't see much result. We have tried 2,4-D to reduce fruit drop. We tried cytokinins to increase fruit size but they weren't successful. So far it is only the anti-gibberellins (paclobutrazol and uniconazole) that have been effective for us. GA has been used in wheat to keep plants short to avoid lodging. Apogee is another type of anti-GA but it wasn't effective in avocados. The chemical companies have another experimental anti-GA that they hope to start testing in the next few years.

Q. What about the use of NAA painting of stumps to reduce shoots? A. Yes we tried it for several years mixed with blue paint (to see where it had been applied) but it only lasted for 3 to 4 months and it was a lot of effort and money to do.

Q. DM What are your recommendations for overgrown trees at low density? How do you bring their size down? A. I would say that if you have big trees you need to find a way to get light into the trees and maybe have a few selected multiple leaders in the tree that still allow the light to penetrate. You need to prune but at the same time leave areas that can flower in the current season. Francisco said you need to bear in mind the reality that any part of the tree further than 1m from direct sunlight is not going to be productive so in effect he was recommending the same system that Colin Partridge described on Day 1, i.e. 'big trees with little trees within them' in other words a few major limbs, each one being separate and well-lit on all sides.

Q. DM What about the use of PGRs on these large trees? A. Yes, when you are doing a lot of pruning and losing a lot of flowers you need a heavy push with PGRs to improve fruitset as much as you can (because fruitset will help you not only economically but put a brake on the vegetative re-growth). In low planting density situations with very high vigour, need much higher PGR rates e.g. 8L/ha to control vigour. We have tried rates as high as 12L/ha as a soil drench after very heavy pruning on large trees that were brought down to 2m in height. If you have very big trees I don't know if it will work. I have seen high rates on big trees in South Africa and they didn't even look like they had been treated, although I have seen them work in New Zealand. I think when you have very deep soils you probably need higher rates. In big trees it is going to be more complicated than in small trees that's for sure.

Q. Soil vs foliar application of PGRs? A. Soil applied PGRs will change the growing habit of the tree – you will get more compact trees and branches that bend down, a weepy growth, they will be completely different. Soil applied PGRs have a longer lasting effect. Soil applied PGRs result in zero fruit residue levels. (Refer to paper by Gardiazabal at WAC in Peru in 2015). And the soil applied PGRs have a much longer effect. They would like to see if there is a change in genetical expression in the tree.



This photo illustrates how the growth habit of the tree changes if treated with soil applied PGRs. Compact foliage, crinkly leaves, branches bend down, not like a regular Hass tree architecture.

Q. SI. Are you seeing any residues in the fruit? A. No have never seen residues in the fruit from soil applied PGRs – it doesn't seem to go to the fruit. Similarly in greenhouse trials with a systemic insecticide applied through the irrigation system for thrips it worked very well but no residues were detected in the fruit.

Q. CP. Have you tested for residues when PGRs are applied as foliar applications? A. Yes you do get residues from foliar applications and this is why there is a 90 day WHP.

Q. CS. Are PGRs transported in the transpiration stream? If so, is it because stomata in the fruit close after about 8 weeks that you are not picking up residues in the fruit? A. We have tried applying PGRs through the soil in nearly every month of the year but have never found residues in the fruit, so some must have been applied whilst stomata are still open in the fruit but we still haven't found any residues.

Q. EC When you apply PGRs are you applying them for their effect on the next year's flowering? A. Yes, and that was always the goal.

Q. GLT. Have you done a costing in very higher density orchards for the pruning? A. The time required to prune by hand with hand shears and small handsaws is relatively low and it doesn't require the high level of skill that hand pruning large trees does. Mostly entails removal of water shoots. So labour is easier to train, so having a system that is easy to manage and easy to explain is really helpful to us. In NZ they are happy for two reasons – it is not more expensive and it is easy to train backpackers to carry it out.

Q. SI. Do PGR rates differ for different densities? PGR rates need to be adjusted for different densities, lower rates are needed for smaller trees. That's not only because trees are small but in the higher density systems we start applying PGRs after the first growing season.

Q. DM. You have been pruning at 2m by hand. Do you think (in SW WA) we could mechanise that in Australia on our flatter orchard areas? If we could mechanise that then come back in the winter to take out the water shoots? Yes maybe that's the way to go, as long as the machinery can handle that.

Final comment by Francisco – I know that some of the things that work for us in Chile may not work for you but that is our experience in our environment, that's why I showed you our phenology etc.

Discussion by delegates about Francisco Mena's presentation

- "Climate and weather have a bigger effect on canopy growth than anything else."
- Judging by the extensive use of PGRs in Chile the cost must be cheaper than in Australia where uniconazole is about \$250/L and paclobutrazol is about \$35/L.
- Universally, light penetrates only about 0.5m into the avocado canopy
- Chile has low vigour soils
- Soil applied PGRs may have a place in Australia
- In experiments with soil applied PGRs in WA there were negative and very long-term effects.
- In Chile when mounds are built, they use excavators (too steep for graders) and these minimise soil compaction
- Older limbs carry a higher load of the endemic pathogens that cause stem end rot
- What is the meaning of "vigour"? A balance is required. For example, a tree with very low vigour is likely to be at a great risk of succumbing to Phytophthora root rot
- On the east coast of Australia the autumn flush is more important for flowers, whilst in WA it is the spring flush that is more important for flowers.
- We need a better understanding of flower induction (research need)

GENERAL DISCUSSION AND THE AS18000 PROJECT

AS18000 - this is a Frontiers Fund project and more of a 'blue sky' project:

- The next stage is an avocado vigour management trial on two different tree heights, looking at labour requirements and WH&S.
- Hass and Maluma are in the trial.
- Two different PGR strategies will be tested – soil drench vs foliar applied
- Colin said there is a lack of genetics in avocado scion and rootstock.
- Denis Roe pointed out that Stefan Köhne in South Africa did a PhD thesis on avocado canopy management – it would be worthwhile studying this and learning from it including the mistakes made.

Other:

- Simon Grabbe asked why are we so interested in tree intensification?
- Stewart Ipsen felt that robotics in avocado is a pipe dream.
- Denis Roe said that avocados are very difficult to manipulate.
- John Tyas felt that seeing that there are no dwarfing rootstocks for avocado, we need to do more work on PGRs and examine the potential of other varieties.
- Eric Carney said it is all about profitability, let's not try and re-invent the wheel. He added that we need to conduct a review of PGR use.
- John Tyas asked if any work has been done linking phenology to genomics.
- Dudley asked what the effect of PGRs is on gene expression.
- Henk has been collecting samples for carbohydrate assessment, results are not compiled or studied yet. He pointed out that there are two main types of carbohydrates – sugars and starch, which one should we measure?
- Denis pointed out that PGRs are used to over-ride the tree's signals.
- Stewart pointed out that if you have a good crop on the tree, picking costs are not that great.
- Henk believes that smaller trees in a smaller area are going to be cheaper to manage, bringing down costs per ha.
- Dudley said that we need to re-examine clonal vs seedling rootstocks.
- Mary Lu Arpaia (UC) has 5 or 6 new rootstocks and scions to release.

WRAP UP - JOHN TYAS

A lot of content and discussion.

Domestic survey – a good representation of what is happening in the industry. Hedging is used very little currently.

International survey a lot of similar issues, we can learn a lot from the different environments for our different environments.

Simon Grabbe presentation – the use of a small number of ‘columns’ as the canopy, importance of access for cherry pickers.

Chris Searle – the need for more windows in the tree

Henk – the use of staggered trees across double rows, importance of getting energy into new roots.

Stewart – the importance of starting a canopy management early in the life of the tree

Alan Blight – made a lot of mistakes early on, removal of ‘bullshoots’, trial under netting, vase approach not working

Colin Partridge – learning from mistakes, the use of ‘little trees’ in big trees

Bram Snijder – the need for consistent terminology, re-visited the need for the interrow space to be kept open, the use of nitrogen

Francisco Mena – The use of ultra-high density and description of their canopy management journey – applying PGRs to the soil, the “rules of engagement”, being aware of the time of flower initiation in relation to timing of pruning, illumination, continuous pruning doesn’t work, the importance of PGRs and no residues if spoil applied

POSSIBLE AREAS FOR RESEARCH

Plant Growth Regulants

- PGR effects on the soil and MRL
- PGR study: one project repeated in different regions
- PGR timing of application and MRL
- PGR literature review first. Compare foliar spray and soil applications and the different types (e.g. GA) – this needs to be followed up with David Oag from DAF who is conducting some trials in CQ as part of AS18000
- Looking at PGRs in greater depth, region and site specific insights.
- Effect of PGRs on gene expression
- Large differences in per hectare costs for Paclobutrazol and Uniconazole. This needs to be factored in with research looking at using these products.

Carbohydrates

- How much structure needs to be left in large overgrown trees to maintain carbohydrate levels to enable production to resume as soon as possible.
- Study of carbohydrate levels throughout the growth cycle
- Do we measure starch or sugars or both?

Pruning techniques

- Early tree training – how to set up the structure after 6 months for a sustainable tree for the life of the orchard
- Cost of hedging verse hand cutting and the result on production
- Cylinder system - have more facts, how was the pruning done, timing, fertiliser regime and the resulting yield
- Pruning techniques to get from a large tree to a small productive tree and managing the tree to still get yield through the process and a year or two after (room for improvement)
- In the lower SW WA the ability to get regrowth post-pruning from previous season to flower, ability to manipulate regrowth to flower?
- Canopy modelling to get understanding of column spacing and maximum heights.

Other

- Linking phenology to genomics
- Re-examine clonal vs seedling rootstocks.
- University of California has 5 or 6 new rootstocks and scions to release.
- Establishing complexity vs. Columns. Yes or no?
- Measuring light penetration.
- Trellising
- Robotics
- Sylleptic vs. proleptic buds (proleptic buds have a period of dormancy)
- Shepard
- Alternative varieties to Hass

SUGGESTIONS FOR EXTENSION

- Field walks are the best – showcasing best and worse experiences
- Visit other regions would be beneficial to see correlations – visual experience enhances learning and understanding
- Regional study groups – return to host farms where a certain approach has been taken a year or two later to see the result and discuss as a group
- Bringing back the farm tours/study groups – best way to learn (use to be part of the Australia/NZ conference)
- Study tours (within region, interstate or international)
- Study group for region – elect a chairperson, they select the topic and organise a site or sites to visit, market the event, then a BBQ (everyone is invited and pays an annual fee to come to cover catering). If you want to be involved you have to host. This would overcome the current of issue finding hosts. Easier to organise outside of levy funds/invitation only – but not easy to organise outside of a project.
- Field walks and study groups, may be difficult to find orchards willing to host.
- YouTube style short videos with practical demonstrations of what has/hasn't worked

REGIONAL APPROACHES

At the end of the summit representatives for each region were asked to identify some guidelines for that region.

North Queensland – Henk and Nicola (Shepard)

- Best approach: Hedging + selective limb removal + window pruning + dead sticking (straight after each other, try and to get everything done in four weeks). Trying to beat the development of flowers and looking after the exposed cuts.
- Taking out crow's feet (cleaning up the profuse regrowth emanating from the hedging cuts whilst conducting the select limb removal operation).
- Open the tree – more cost effective to make the cuts after the hedger has been through.
- One side one year, one side the other year – hedging approach changes every year.
- 1-2.5m of growth every year. Tolga (redder soils) can be up to 2.5m.
- Timing – Shepard at bud development (winter prune).

Central Queensland – Simon, Col, Eric and Dale

- Need to understand the influence of growth, climate, variety, soil, and time and effort going into the program and how much labour you have available to do the job.
- 1m growth is what you're looking for – anything more is unproductive.
- 1.5m wide cylinder/column structures – looking for productivity. Make use of the space but keeping to the productive 1m width of canopy with sufficient light penetration.
- Trimming regrowth – November, December or January.
- Take note of what you are doing so you can learn from what the approach or different approaches resulted in and go from there – it is a constant learning curve.
- Same approach on a different farm may result in a different outcome – something to keep in mind (different fertiliser regimes/general management influences).

South Queensland – Denis Rowe, Tony Dugdell

- State of play assessment before approaching the task – crop load, timing and resources available. This will then determine what the approach will be – select limb, hedging or window pruning

Tristate – Colin Partridge and Chris Searle

- A very different environment!
- Growing the tree is the first challenge given the harsh growing conditions.
- Challenges with mechanical pruning given overhead irrigation for cooling and frost control.
- The canopy is kept close and dense to prevent exposure, unlike other growing conditions (apart from the harsh climate of the Perth region).
- Israeli approach may be a closer match and one this state could learn successful approaches from – Udi Gafni supports the hedgerow approach

NSW – Colin Partridge and Chris Searle

- Conditions and approach are more like New Zealand in southern parts (Comboyne), but the coastal region is different again.

Western Australia – Dudley Mitchell and Stewart Ipsen

- Like most regions there are a large number of practices being used.
- The most common from our observations of small to medium growers is to do nothing for the first 8-10 years (this NOT the best practice).
- Manipulating tree structure from year 2 onwards. Potential for work to be done on looking at this at an earlier stage.
- Selective limb removal, putting cuts into every tree every year.
- Creating columns, the amount per tree depending on row width (3-4 on 8m row width)
- Topping out the columns when they reach max height (row width x 80%)
- Grooming out regrowth both internally and on topped out branches, encouraging weeping regrowth to flower from.
- Applying PGRs in a timely manner.
- The use of hedgers has been used by some larger growers, more so to make it easier to identify limbs that need to be removed and to take some of the bulk out of the job for the hand pruners.

GLOSSARY

Terminology that needs to be defined and standardised

Bowl (see 'vase')

'Chicken feet' / 'Crow's feet' – unproductive coppicing regrowth that sprouts from the cut surfaces made by mechanical hedging.

Determinate and indeterminate flower shoots – flowering shoots that don't have a vegetative bud (determinate) and flowering shoots that do have a vegetative bud (indeterminate). Determinate flowering is more common in cooler climates, indeterminate in warmer climates.

Fill the space – the stage in the growth of a new orchard block when trees in the row have grown together to form a hedgerow but a laneway still exists between rows. This is the stage when measures should be taken to contain the trees to this size.

Flat topping – cutting off the top of the canopy in a horizontal plane (usually resulting in chicken feet coppicing regrowth).

Flower prune – system developed in NZ which is used a month or two prior to flowering when it is evident that there will be a massive flowering, the idea is to remove a proportion of the flowering branches to even out the crop to reduce the potential for alternate bearing.

Flush cut – cutting off a limb flush to the trunk so no stub remains, flush cutting generally reduces the amount of regrowth from the cut area, as opposed to leaving a stub which often results in an excessive number of 'chicken feet' shoots (coppicing).

Grooming – the secondary (follow up) prune often necessary after a major prune, usually involves removing excessive regrowth (e.g. water shoots) stimulated by the major prune, removing other unwanted growth that has become easier to spot as a result of the earlier prune, and generally tidy up.

Shoulders – branches that arise close to the top of the tree and tend to overhang the interrow and shade the lower canopy. Shoulder branches are undesirable giving the tree an upside-down pyramid shape.

Stubs – what you are left with when pruning cuts are not ‘flush cuts’.

Tipping – nipping (often with thumb and forefinger) growing tips in order to create multiple tips in its place, this creates ‘complexity’ in the tree which results in a rounder canopy as opposed to a Christmas tree/pyramid shaped tree with a central leader.

Vase (also referred to as ‘open-vase’ or ‘bowl’) – trees pruned with the intention of having a hollow centre i.e. few if any branches in the centre of the canopy, with intention of getting more light into the centre of the canopy, however the tree usually responds by quickly filling it up with unproductive vegetative growth.

Water shoots/bull shoots – very quick growing, often long vertical, straight vegetative branches that occur after a major prune, and which usually remain unproductive for many years.

Window pruning (a) - holes roughly 1m in diameter cut into the side of the tree to allow light inside the canopy and access for the picker, often needed after mechanical hedging which often results in a dense hedge which results in shading the inside of the canopy.

Window pruning (b) - much larger cuts referred to by one delegate as ‘roller doors’ rather than ‘windows’.

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