

Final Report

Afourer mandarin best practice canopy management

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New South Wales Department of Primary Industries and Regional Development (DPIRD)

Project code:

CT19002

Project:

Afourer mandarin best practice canopy management (CT19002)

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Funding statement:

This project has been funded by Hort Innovation, using the citrus research and development levy and contributions from the Australian Government. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

Publishing details:

Published and distributed by: Hort Innovation

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www.horticulture.com.au

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Public summary

The project CT19002 – Afourer Mandarin Best Management Canopy Manager, commencing in mid-2020, investigated W. Murcott (Afourer) canopy management options to improve long-term yield and reduce alternate bearing. The project aimed to better understand and address the gradual decline in yields and increased propensity to alternate bearing of W. Murcott mandarin trees once they reach the age of 7-10 years.

During the project, research trials, demonstration trials, and overseas study tours were conducted and grower practices were monitored. Project findings are available through the *W. Murcott canopy management guide* and videos published on the NSW DPIRD website (<https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/content/canopy-management>).

When W. Murcott is grown on a medium-vigour rootstock (e.g. trifoliata), it produces a mixture of medium and high vigour shoots (watershoots, single shoots up to 3 m). These trees can be managed with hand pruning to maintain tree structure and a medium size tree. When W. Murcott is grown on a vigorous rootstock (e.g. citrange), it produces many watershoots. On mature trees, the watershoots grow out into the middle of the row and block tractor access. They also shade the lower parts of the canopy, encouraging fruit growth on the top part of the tree that is difficult to harvest and has the most blemishes. The shaded lower parts of the canopy die out. Intensive pruning often encourages more watershoot regrowth, and if all watershoots are removed by hand pruning, very little productive canopy remains to produce next year's crop.

The project identified the management of water shoots is important to successful canopy management. The two main options to manage watershoots are: mechanical hedging and intensive hand pruning. Severely mechanically hedging one side of the tree (e.g. within 1 m of the trunk) is a form of canopy 'reset' and provides a few years of good yield until it needs to be reset again. Alternate sides of the tree are severely hedged as needed. Intensive hand pruning can provide higher long-term yield and profitability than mechanical hedging, but it requires a significant commitment to annual management and an increase in manual labour costs. An important component of intensive hand pruning is managing the regrowth when it is 200 to 400 mm long by thinning out or breaking the regrowth in half to promote side branching and a more compact and complex canopy.

Two additional options can also be considered by growers. Using a one-wire cordon trellis system in an intensive pruning program adds extra cost to orchard establishment, however, there are potential long-term gains in yield and ease of management (e.g. platform pruning and harvesting or robotic harvesting). Using overhead protective netting in an orchard with an intensive pruning management system may have the potential benefit of enhancing profitability because of the faster growth and yield of young trees and the increase in farm gate price from an increase in first-grade pack out (reduced skin wind blemish).

Keywords

W. Murcott, mandarin, pruning, canopy management, economic analysis, productivity.

Introduction

Over the past decade, mandarin production and consumption have been increasing worldwide. China is the largest producer of mandarins (26.9 Mt), followed by the European Union (2.7 Mt) and Türkiye (2.6 Mt). Australia produces about 0.2 Mt of mandarins from 8,800 ha (2023 CAL Citrus Tree Census), with about 50% produced in Queensland. Mandarins in Australia are harvested from March to November, with the season starting in Queensland and moving to the southern states. The span of harvest is because of varieties that mature at different times during the season along with the regional climatic differences between Queensland and the southern states.

There are numerous names for the W. Murcott because of country differences and some are varietal selections or budwood irradiated to exhibit special characteristics such as seedlessness. Some of these varieties are under proprietary ownership (plant variety rights). Some of these other names and variants include Nadorcott, Tango and Afourer. All of these variants have the same canopy management issues discussed in this report. The W. Murcott mandarin is a late-maturing variety that has been increasing in popularity around the world and in Australia. It is popular because the fruit is robust, seedless (seedless in isolation and specially bred seedless variants) and exportable by sea freight. W. Murcott fruit has good consumer demand, and growers like the variety because it yields well throughout the early years of production. Plantings of W. Murcott mandarin in Australia (3,202 ha, 2023 CAL Citrus Tree Census) have now surpassed Imperial mandarin (1,631 ha, 2023 Great Tree Census). Production of W. Murcott is dominated in Sunraysia and the Riverland.

From years 6 to 12, growers are reporting average yields of about 60 t/ha. Once W. Murcott mandarin trees reach 7–10 years of age, they are large, yield gradually declines and they have an increased propensity to alternate bearing. Growers report that average yields from year 13 onwards are about 35 t/ha. The problem is exacerbated by alternate bearing, where trees can yield 100 t/ha in one season and then decrease to 10 t/ha in the following season. Apart from the marketing problems caused by variable volumes of fruit year by year, high yields are often associated with small fruit, while low yields are associated with very large fruit that has reduced flavour and coarse rind. Most growers believe a stable crop load should be 55 t/ha.

The problems with low yield and alternate bearing commencing from years 7 to 13 are attributed to the large canopies (watershoots) shading the lower productive canopy and the terminal-bearing nature of W. Murcott mandarin. Since 2022, growers have also been experiencing declining prices and higher costs. In previous years, prices were \$1,000/t to \$1,300/t. In recent years, prices have declined from \$1,000/t to \$800/t. Harvest costs have also increased from \$200/t to \$285/t. If 15% of annual production (55,000 t) is lost because of a low crop yield or an excessive crop of small fruit, this loss equates to \$8.2 M annually (based on \$1,000/t). Given that production is expected to rise to 85,000 tonnes by 2023, this cost could equate to \$12.7 M annually.

Long-term yield decline and alternate bearing of W. Murcott mandarin are global problems that have prompted researchers and growers to try various practices. Growers who attended overseas tours (e.g. Mildura Fruit Company (MFC) Spain tours pre-2000) report that some overseas growers have had some success in managing the problem. Representatives from an American orchard, Sun Pacific Farming, showed that after many years of trying different canopy management strategies, they are yet to identify a viable solution. Sun Pacific Farming and other growers in the USA are still exploring different strategies, including wide space planting, bending, pruning out centres and trellising (Nutrano, W. Murcott field day, July 2019).

A 2019 study of some Sunraysia and regional W. Murcott growers (Project planning background information report; attached document, Appendix 1) showed that some growers are reporting moderate success in managing yield decline and alternate bearing, while others are still trying various strategies. Some of the canopy management strategies being tried include hedging, light regular pruning (spring and autumn) and chunk pruning. Other non-canopy management strategies include using medium vigour rootstocks, hand thinning and chemical thinning.

This project was based on the principles of participatory research with growers that aimed to:

- a. build the capacity of Australian growers and researchers by collating the best knowledge and experience from Australia and around the world
- b. work collaboratively with growers on existing and new trials
- c. develop best practice W. Murcott canopy management guidelines for the industry.

Methodology

The project aimed to increase the capacity of the Australian citrus industry through study tours and participatory research. The project had two main objectives:

1. **Capacity building:** providing W. Murcott growers and industry development officers with the most up-to-date information (international and domestic) to improve W. Murcott production and canopy management decisions.
2. **Industry research:** monitoring growers' current practices, establishing trials on growers' properties (demonstration and replicated) and economic analysis of production options.

Steven Falivene (NSW DPIRD Citrus Development Officer) led the project and consulted with industry and key W. Murcott growers in 2019 to obtain grower feedback on the problem and gain insights into current practices. This consultation was published in the Project planning background information report (attached document, Appendix 1).

The project engaged with key W. Murcott farms around Australia:

- 3 X Western Australia
- 6 X Sunraysia (NSW & VIC)
- 3 X South Australia

3 X Riverina During the project, growers were visited throughout the season to monitor fruit growth and canopy management. Each orchard provided valuable information about the growth habit of the trees for their specific site circumstances (e.g. climate, soil type, rootstock) and management strategies (canopy management style). Some of these growers conducted canopy management demonstration trials by pruning some trees in different ways.

A Project Reference Group (PRG) was established to provide advice to the project. The PRG provided advice on trials and capacity building activities and provided feedback on project progress. The PRG included 3 growers, a grower/packer, the project team and Citrus Australia.

Replicated trials

Six replicated trials were conducted, four in Sunraysia and two in the Riverina. The trial treatments were based on initial consultation with growers and industry on current practices and feedback.

The Sunraysia replicated trials were conducted on three mature tree blocks and one young tree block, and the Riverina trials were conducted on one mature tree block and one young tree block. The mature tree trials were to investigate canopy management options to improve yields of low yielding blocks. The young tree trials were to explore the effect of pruning young trees to maintain a good canopy structure. The hypothesis was that minor pruning at a young age might prevent trees from becoming too large and having a poor canopy structure.

Canopy management on a perennial crop such as mandarins is a long-term strategy. It can take 3 to 4 years for a change to take full effect. The project was initially established for four years to include three season's harvest. This was to enable canopy management trials to be implemented and the transition of trees into their new canopy management style to be monitored. The project was extended for an additional year, enabling an additional year of harvest data. The extra year provided valuable information and insights to provide enough information to identify canopy management strategy options to improve yields and reduce alternate bearing.

Trials had five replicates with four tree plots and the middle two trees were used for data collection. Fruit size and blemish (1st, 2nd and 3rd grade) were measured by sampling 100 fruit on the tree, and the total weight of fruit per tree was measured.

The Sunraysia mature tree treatments were:

1. Light annual hedging (control): annual light hedging the sides for row access; topping might be done every second year for height control.
2. Half tree hedging: cut one side of the tree hard and let it grow and crop until it hinders row access, then cut the other side.
3. Light hedging annually plus doorway and centre limb hand pruning: A gap is hand pruned between two trees to gain access into the tree and one or two centre limbs are removed. The doorway and limb removal pruning require 45 to 60 seconds per tree.

4. 1 × intensive hand pruning: intensively pruning trees after harvest (spring).
5. 2 × intensive hand pruning: intensively pruning trees after harvest and in autumn.

The Sunraysia young tree replicated trials had three treatments with five replicates. There were four trees in a plot, and the middle two trees were used for data collection. The treatments were:

1. Control: no pruning.
2. 1 × centre limb pruning: removing one or two centre limbs after harvest (spring).
3. 1 × intensive pruning: conducting centre limb pruning and thinning the outside branches when necessary.

The Riverina young tree replicated trials had four treatments and five replicates were applied. There were four trees in a plot and the middle two trees were used for data collection. The treatments were:

1. T1 is light hedge annually (tops & sides),
2. T2 is light hedge annually + chainsaw 2x uprights.
3. T3 is light hedge annually + regrowth management for first 2 years + chainsaw 2x uprights + regrowth management.
4. T4 is intense. Chainsaw 2x uprights+ electrocoupe work+ regrowth management for first 2 years (no hedge)

The Riverina young tree replicated trials had four treatments with five replicates. There were four trees in a plot and the middle two trees were used for data collection. The treatments were:

1. control - no pruning
2. prune every 2 or 3 years 1 or 2 central limbs chainsaw
3. prune - 1 x central limb annually
4. prune- intense annually (central limb + electrocoupe)

Details of the setup of the trials and the results are presented in the May 2025 end-of-project webinar (attached PDF of PowerPoint presentation document, Appendix 1).

Grower observation and demonstration trials

Grower practices were monitored throughout the project by visiting each orchard 2 to 4 times a year. Photographs and notes were taken of canopy growth and tree health. There were two orchards in South Australia, four in Sunraysia and one in the Riverina. These were additional orchard blocks to the five replicated trials in Sunraysia and the Riverina.

Each site provided valuable information on how the trees responded and performed in site-specific situations. The information from one site can be inconsequential, but when it is collated with other grower sites, it becomes a valuable comparative contrast to the performance of W. Murcott canopy management in different situations. This information was included in the *W. Murcott canopy management guide* and presented at farm walks and in webinars. Grower observations and demonstration trials were made into videos with Dean Morris, Ryan Arnold (2×), Richard Eckersley and Andrew Pergoliti (4×).

Spain and South Africa Study tours

Study tours to Spain (2022) and South Africa (2024) provided important international knowledge (Appendix 2 and 3). South Australian W. Murcott grower Ryan Arnold accompanied project leader, Steven Falivene, on both study tours. Ryan made valuable contributions by providing commentary and feedback from a grower's perspective, as well as assisting with the creation of study tour videos. If the grower visited spoke English, they were invited to present to camera, however, some declined, and Ryan or Steven presented the content for the videos. The videos were shot and edited to make them as concise as possible (5 to 10 minutes) while still providing sufficient practical information. The 22 study tour videos and reports are published on the NSW DPIRD website and are listed in the Outputs (Table 1) of this report.

Economic analysis

Economic analysis was undertaken on the favourable canopy management options identified during the project. The analysis provides a way to economically compare the different canopy management options. The results of the economic analysis are reported in the W. Murcott canopy management guide. Post this project, a detailed mandarin production scenario economic analysis will be written that incorporates information from this project. The detailed economic report will complement and be similar in design to the Washington Navel economic analysis: high density, tree dwarfing, trellis, future robotic orchard. Selected scenario spreadsheet budgets will be released so growers can economically analyse production scenarios relevant to their circumstances.

Results and discussion

The replicated trials showed no significant differences in yield, fruit size or rind blemish between treatments. The results are presented in the 2025 webinar (attached document, Appendix 1). However, the trials were very successful in improving our understanding of the realistic, practical challenges to improving W. Murcott yield and reducing alternate bearing. Some grower trials did provide positive results (discussed further) and the replicated trials were able to provide an excellent contrast perspective of non-optimal and optimal pruning techniques for high vigour trees. This information was presented in the W. Murcott canopy management guide available from the NSW DPIRD Citrus Canopy Management web page (<https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/content/canopy-management>).

The replicated trials alone did not generate new tangible, practical knowledge for canopy management.

Some of the grower observations and demonstration trials provided positive yield improvement results. These were at different sites (e.g. climate, rootstock and soil type) and with different canopy management practices. These growers implemented intensive pruning and regrowth management practices on their orchards and maintained good yields. They implemented more intensive regrowth management practices than those used in the replicated trials and at different timings. Demonstration site collaborator, Ryan Arnold learned about these practices from the Spain and South Africa study tour and implemented them on his orchard. At the beginning of the project, Ryan was about to bulldoze his W. Murcott orchard because of low productivity, but the orchard is now profitable and will be maintained. These results were captured in the Western Australia videos of Richard Eckersley and Andrew Pergoliti and the South Australian Ryan Arnold video. Other information came from the study tours of Spain and South Africa, which were captured on 22 videos and in reports. All videos are available on the NSW DPIRD website and individually listed in the Outputs (Table 1) of this report. Some practices did not produce favourable results, and this information is presented in the *W. Murcott canopy management guide*. (<https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/content/canopy-management>).

Combining the replicated trials, positive and negative outcomes from grower observations, demonstration trials, and international study tours, provided a holistic and contextual understanding of the problems. This meant we could provide options in the *W. Murcott canopy management guide* for growers to implement. The options are not definitive solutions because there is no 'one' best solution, but a variety of solutions that might suit a specific circumstance (e.g. farm size, cash flow, labour availability, management skill). The options learnt during the project are presented in further detail in the *W. Murcott canopy management guide* and videos. The key project findings and options were realised towards the end of the project and therefore have not been robustly tested in trials.

The key project findings identified the management of water shoots as important to successful canopy management. The two main options to manage watershoots are:

1. Mechanical hedging and intensive hand pruning. Severely mechanically hedging one side of the tree (e.g. within 1 m of the trunk) is a form of canopy 'reset' and provides a few years of good yield until it needs to be reset again. Alternate sides of the tree are severely hedged as needed.
2. Intensive hand pruning. Intensive hand pruning can provide higher long-term yield and profitability than mechanical hedging, but it requires a significant commitment to annual management and an increase in manual labour costs. An important component of intensive hand pruning is managing the regrowth when it is 200 to 400 mm long by thinning out or breaking the regrowth in half to promote side branching and a more compact and complex canopy.

Two additional options can also be considered by growers:

1. Using a one-wire cordon trellis system in an intensive pruning program adds extra cost to orchard establishment, however, there are potential long-term gains in yield and ease of management (e.g. platform pruning and harvesting or robotic harvesting).
2. Using overhead protective netting in an orchard with an intensive pruning management system may have the potential benefit of enhancing profitability because of the faster growth and yield of young trees and the increase in farm gate price from an increase in first-grade pack out (reduced skin wind blemish).

The economic analysis (presented in the W. Murcott mandarin canopy management guide, Appendix 1 and available on the NSW DPIRD website - (<https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/content/canopy-management>), indicates that intensive pruning management provides the best economic returns followed by mechanical hedging. However intensive pruning requires a high labour input, and this might not be suitable for farms that have limited labour accessibility and the resources to manage large amounts of labour. Interestingly, modelling W. Murcott at a low mature tree yield (35 t/ha) provided higher 20-year cumulative cash flows than standard density navels. This is mainly due the higher fruit price of mandarins as compared to navels. The analysis also indicated that the use of overhead netting and intensive pruning complement each other because the extra yield gained from intensive pruning amplifies the income returned from the higher fruit price. Growing under netting requires a higher and more frequent level of pest and canopy management monitoring and skill. If pests and the canopy are not adequately managed, it can quickly result in downgrading fruit prices or rapidly declining yields that take numerous years to return to regular levels.

Any future work on canopy management of W. Murcott mandarins should consider replicated and on-farm demonstration trials of the options presented in the *W. Murcott canopy management guide*. Any future trials with new canopy management treatments would need another two to three years for the new canopy management treatments to settle into a production cycle.

Some growers are trialling the project's intensive pruning treatment options and there are ideas for variations of mechanical pruning. An opportunity is to also undertake work that focuses on monitoring and extending the results of growers who are trialling new canopy management solutions and establishing simple demonstration trials. The opportunity is discussed in more detail in the recommendations section of this report.

Outputs

Table 1. Output summary

Output	Description	Detail
Milestone reports	Annual reports were prepared to report on the project's progress.	MS102, MS103, MS104, MS105, MS106 and MS107 were submitted to Hort Innovation as per the Research Agreement. These reports aligned with the project monitoring and evaluation plan.
Canopy management guide	NSW DPIRD released a canopy management guide providing practical recommendations and an economic analysis.	<p>A <i>W. Murcott mandarin canopy management guide</i> that includes the data and knowledge gained as well as an economic analysis of the options to help growers make better canopy management decisions has been produced. The guide will be made available on NSW DPIRD's website.</p> <p>An economic analysis of canopy management production systems is provided in the canopy management guide. The information gained in this project will contribute to a future mandarin economic analysis report (inclusion of other mandarin varieties) that will be published along with spreadsheets that growers can use to analyse production scenarios.</p> <p>Since canopy management is a visual and active production practice, 47 videos have been made to support the management guide (videos are listed in the outputs table).</p>

<p>Presentations to the scientific community</p>	<p>Papers accepted for oral presentation.</p>	<p>Conferences, congresses, and symposia.</p> <p><u>International Citrus Congress, Türkiye, 2022</u></p> <p>Oral presentation 'Nadorcott (Afourer) mandarin canopy management and consistent yield challenges: grower pruning practices and experimental treatments' (Appendix 4)</p> <p><u>International Citrus Congress, Korea, 2024 (personal and regional grower organisation funding)</u></p> <p>Oral presentation 'W. Murcott mandarin canopy management: 4-year trials, grower experiences in Australia, South Africa and Spain' Falivene <i>et al.</i> (Appendix 5)</p> <p>2022 Tech Forum poster presentation: Afourer mandarin best practice canopy management (Appendix 6)</p> <p>2025 Citrus Australia Limited Citrus Congress poster presentation: W. Murcott mandarin best practice canopy management (Appendix 7)</p>
<p>Presentations to industry: field days and workshops</p>	<p>Events organised by NSW DPIRD or other industry groups to provide growers with access to field trial sites and industry experts.</p>	<p>Total number of growers and industry members participating at extension events: 579</p> <p>2020, April: Zoom meeting with South African citrus specialist Paul Cronje (Citrus Research International). Detailed meeting notes were published in the 'Project planning background information report' (attached document, Appendix 1): 19 attendees</p> <p>2020, April: Zoom meeting with South African citrus specialist Hans Bester (Citrus Research International). Detailed meeting notes were published in the 'Project planning background information report' (attached document, Appendix 1) : 18 attendees</p> <p>2020, April: Zoom meeting with South African citrus specialist Jackie Standers (Philagro). Detailed meeting notes were published in the 'Project planning background information report' (attached document, Appendix 1) . : 17 attendees</p> <p>2020, Oct: Jakie Stander (Philagro) discussing carbohydrate leaf and root sampling for predicting and managing crop load. : 18 attendees</p> <p>2020, Nov: trial site farm walks inspecting Costa Trentham: 6 attendees.</p> <p>2020, Nov: trial site farm walks inspecting Nutrano Carwarp: 12 attendees</p> <p>2021, April: Loxton NSW DPI citrus roadshows: 45 attendees</p> <p>2021, April: Riverina NSW DPI citrus roadshows: 80 attendees</p> <p>2021, April: Sunraysia NSW DPI citrus roadshows: 95 attendees</p> <p>2021, April: Riverina Dean Morris farm walk: 6 attendees.</p> <p>2021, April: Costa Trentham trial site farm walk: 7 attendees.</p> <p>2022, July: Zoom project update meeting for all Afourer growers to learn about the implementation of pruning trials: 11 attendees</p> <p>2022, July: Tree intensification update and field walk, Dareton. Steven discussed the Afourer project in terms of managing vigorous citrus: 45 attendees.</p> <p>2022, July: Costa Trentham trial site farm walk: 6 attendees.</p> <p>2022, July: Nutrano trial site farm walk: 5 attendees.2023, Aug: Sunraysia Carwarp trial site farm walk: 12 attendees.</p> <p>2023, Aug: Sunraysia Trentham site farm walk: 8 attendees.</p>

		<p>2023, Aug: Riverland demonstration trial site farm walk: 4 attendees.</p> <p>2023, Aug: Riverina trial site farm walk: 6 attendees.</p> <p>2024, June: WA demonstration trial farm walk Harvey: 4 attendees</p> <p>2024, June: WA demonstration trial farm walk Moora: 4 attendees.</p> <p>2024, Aug: SA demonstration trial farm walk: 16 attendees.</p> <p>2024, Aug: Riverina replicated trial site farm walk: 20 attendees.</p> <p>2024, Aug: Sunraysia replicated trial site farm walk at Trentham and Carwarp</p> <p>2024, Oct: QLD Mundubbera Afourer and IPDM farm walk: 25 attendees.</p> <p>2024, Oct: Dareton field day. Steven discussed the W. Murcott project during field sessions. The Dareton field day (2024) report summarises the content and attendees' survey responses (attached document, Appendix 1): 65 attendees.</p> <p>2025, May: final project seminar Zoom meeting with 24 participants. The PowerPoint presentation provided trial results and project outcomes (attached document, Appendix 1): 25 attendees</p>
<p>Industry articles/case studies</p>	<p>Articles accepted for publication in the Australian Citrus News magazine and other publications.</p>	<p>2020, Sep: Project planning background information report. The report presented case studies of growers who outlined their issues and current situation and presented meeting notes from Zoom meetings with three South African W. Murcott experts.</p> <p>2020, Dec: Afourer project update newsletter (attached document, Appendix 1)</p> <p>2021, Sep: Citrus Australia magazine article (Appendix 8)</p> <p>2021, April: Citrus Connect Afourer article (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/citrus-connect/2020-citrusconnect-articles/afourer-project-update)</p> <p>2022: 'Afourer canopy management project update' – article in the <i>Citrus plant protection guide 2021–22</i> – NSW DPIRD (Appendix 9)</p> <p>2022: Spain study tour report, published on the NSW DPIRD website with the associated videos.</p> <p>2024: 'Afourer canopy management' – article in the <i>Citrus plant protection guide 2024</i> – NSW DPIRD (Appendix 10)</p> <p>2024: South Africa study tour report, published on the NSW DPIRD website with the associated study tour videos.</p> <p>2025 – A Citrus Australia magazine article will be written for the spring issue based on the summary of this report.</p>
<p>Videos</p>	<p>Video outputs are edited to give project updates, results and application advice.</p>	<p>47 × videos (Total)</p> <p>11 × case study videos</p> <p>Afourer grower Dean Morris pruning case study https://youtu.be/Xr5I_2HGCpU</p> <p>Afourer mandarin (Nadorcott) pruning PYAP produce intensive pruning case study https://youtu.be/0Ci17V-MpDo</p> <p>Afourer mandarin (Nadorcott) pruning PYAP produce intensive pruning case study https://youtu.be/GSA85B8kiyc</p> <p>QLD mandarin pruning Banpan citrus https://youtu.be/xAFHwEhHOkM</p> <p>QLD mandarin pruning Ironbark citrus https://youtu.be/LdgOqP3g_6w</p>

		<p>QLD mandarin pruning Margram citrus https://youtu.be/px8An_32jMk</p> <p>QLD mandarin pruning Margram citrus extended version https://youtu.be/cochPxi4ryl</p> <p>WA mandarin pruning Richard Eckersley https://youtu.be/Li8chOuk8fk</p> <p>WA mandarin pruning Andrew Pergoliti W. Murcott Cit https://youtu.be/e-W2OGbirSE</p> <p>WA mandarin pruning Andrew Pergoliti W. Murcott Tri https://youtu.be/oz7emVYgjZU</p> <p>WA mandarin pruning Andrew Pergoliti W. Murcott https://youtu.be/2GDEkldlxA</p> <p>18 × Spain study tour videos</p> <p>Web page: https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/content/canopy-management/mandarin-pruning2/afourer-canopy-management-spain-tour-2022</p> <p>Transforming large Afourer trees with intensive pruning https://youtu.be/X5sQqKYIR7k</p> <p>Intensively pruned 4-year-old Tango trees, Seville https://youtu.be/ytmTJwMitok</p> <p>IFAPA research station mechanical pruning and high-density https://youtu.be/3oP-alkqVlk</p> <p>Intensively pruned maturing Tango orchard, Murcia https://youtu.be/vrwuwkNbd80</p> <p>Murcia minimal vs intensive pruned 7-year-old Tango orchard https://youtu.be/mqReJ6UbZl8</p> <p>D'Quart Tango orchard Afourer pruning demonstration https://youtu.be/JW24ysdK2JA</p> <p>Observations of intensively pruned navel trees https://youtu.be/Q3D6ROY80PU</p> <p>7-year-old Tango trees late summer pruning, Angel Mateo orchard https://youtu.be/E5HijpYp59c</p> <p>Murcott pruning, Angel Mateo orchard Murcia, Spain https://youtu.be/LeMVEE356AA</p> <p>Oronules clementine pruning Murcia, Spain https://youtu.be/5vIBDGLA6f8</p> <p>Afourer mandarin growing under nets – autumn watershoot pruning https://youtu.be/x8QOdMLoQjs</p> <p>Automated in-field soil solution analysis iOLAND, Murcia, Spain https://youtu.be/5NA5zgwby8</p> <p>iOLAND Tango pruning trial https://youtu.be/BNB9gTuxU0k</p> <p>iOLAND Afourer plant spacing discussion https://youtu.be/DUnGs5vRDLI</p> <p>Tango mandarin high-density trial https://youtu.be/B-FhnXv4rU</p> <p>Ori mandarin growing principles https://youtu.be/kK6CL2R6cjQ</p> <p>Afourer growing; watershoot layering, Morocco https://youtu.be/JXBc2Hcp7sc</p> <p>Tango watershoot bending and pruning, Eurosemillas</p>
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		<p>https://youtu.be/UaSdbwYqHi8</p> <p>6 × South Africa study tour videos</p> <p>Web page: https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/content/canopy-management/mandarin-pruning2/south-africa-w.murcott-canopy-management-study-tour</p> <p>AGL Farms, Citrusdal https://youtu.be/Kiaq2jppqar0</p> <p>Mouton Citrus, Citrusdal https://youtu.be/GqeLwc0z3Fk</p> <p>Gert de Vries, Suiderland plase, Robertson https://youtu.be/Ax1leEhqGpl</p> <p>Dome Citrus, Robert Brown, Robertson https://youtu.be/1jiWBHeLyDA</p> <p>Indigo Citrus, Danie Grabe, Robertson https://youtu.be/Gcvz87UATIA</p> <p>Growth regulators; Paul Cronje, CRI, Stellenbosch University https://youtu.be/PZfVY2LcJzg</p> <p>12 × W. Murcott pruning styles videos</p> <p>Project Introduction: why is light harvest efficiency and pruning important? https://youtu.be/BEiqH1Okp7Q</p> <p>Replicated trial introduction: an overview of the treatments https://youtu.be/cB296ozev4U</p> <p>Mature tree window layering pruning treatment https://youtu.be/c_47btkeFR8</p> <p>Mature tree window layering pruning treatment https://youtu.be/TOd3YP56E30</p> <p>Light annual hedging pruning treatment https://youtu.be/KRa2nYlrnq4</p> <p>Half tree hedging treatment https://youtu.be/nUDu8G90ETA</p> <p>Centre limb pruning treatment https://youtu.be/XL6e99Zy3yw</p> <p>Young tree window layering pruning https://youtu.be/ynvPhh8Uz0A</p> <p>Young tree window layering pruning https://youtu.be/TOd3YP56E30</p> <p>Young semi-mature tree window layering pruning https://youtu.be/TOd3YP56E30</p> <p>Growing Afourer under nets: challenges of growing Afourer under hail nets https://youtu.be/fANQMgQAco</p> <p>Safe pruning tips: https://youtu.be/OtPA2RxVXKQ</p>
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Outcomes

Table 2. Outcome summary

Outcome	Alignment to fund outcome, strategy and KPI	Description	Evidence
<p>Intermediate outcome: Access to new canopy management information that improves long term yields and reduces alternate bearing</p>	<p>The project was contracted during the Citrus SIP 2017-2021.</p> <p>OUTCOME 3</p> <p>Improved product quality and increased productivity from applying the innovation.</p> <p>Strategy 3.1 – Undertake R&D and extension to develop and extend improvements in productivity and efficiency across the value chain.</p> <p>It is also aligned to the Citrus SIP 2022-2026. Outcome 3. The Australian citrus industry has enhanced adoption of R&D and marketing outcomes through effective communication and extension activities.</p> <p>Strategy 3.1 .Deliver communications and extension programs to create positive change in the areas of biosecurity preparedness, varieties that meet consumer demand, sustainable production, pest and disease management and export protocols and markets.</p>	<p>The project created new information (agronomic and economic) to assist W. Murcott growers in applying the most appropriate canopy management practices to maximise long-term yield and minimise alternate bearing.</p>	<p>The '<i>W. Murcott canopy management guide</i>' provides information (agronomic and economic) to assist W. Murcott growers in applying the most appropriate canopy management practices to maximise long-term yields and minimise alternate bearing. 47 videos were published that support the canopy management guide. 579 growers and industry members participated at extension events.</p>

<p>End of project outcomes: new information available to growers to make improved W. Murcott canopy management decisions.</p>	<p>Project KPIs: Project grower team members are identified and updated</p> <p>Annual field days</p> <p>Three updates published</p> <p>Attended congress</p> <p>Two study tours were conducted and a report and video were published</p> <p>Afourer management best practice canopy management manual published</p>	<p>The main W. Murcott growers of Australia were identified and placed on a communication list</p> <p>17 field days and six Zoom webinars were held</p> <p>Four project updates have been published.</p> <p>Attendance of the 2022 Citrus Congress at Türkiye</p> <p>Conduct a study tour to Spain and South Africa and publish a report and videos</p> <p>Publish W. Murcott canopy management guide</p>	<p>The growers' list was used to circulate information and invite grower participants to extension events.</p> <p>The field days were outlined in milestone reports and the South African Zoom meeting notes were published in the 'Project planning background information report' (attached document, Appendix 1). The end-of-project PowerPoint webinar is provided in the attached documents, Appendix 1.</p> <p>Four project articles were published (one in the CAL magazine and one on the online NSW DPI Citrus Connect newsletter, two in the NSW DPI Plant protection guide). One more article will be submitted to the CAL magazine 2025 spring issue.</p> <p>The 2022 Australian Citrus Congress was attended by Steven Falivene who provided an oral presentation on W. Murcott. Steven also attended the 2024 International Citrus Congress and provided another oral presentation on W. Murcott.</p> <p>Study tour to Spain and South Africa completed and a report and videos are published on the NSW DPIRD website.</p> <p>A W. Murcott canopy management guide has been published and is available on the NSW DPIRD website.</p>
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Monitoring and evaluation

Table 3. Key Evaluation Questions

Key Evaluation Question	Project performance	Continuous improvement opportunities
<p>1. To what extent has the project achieved its expected outcomes?</p> <p><i>To what extent has the project provided growers with</i></p>	<p>Target: The improvement in growers’ knowledge was assessed through surveys conducted at the end of the project (Figure 1).</p> <p>Based on dart board feedback surveys at the 2024 end-of-project farm walks at the Riverina, Sunraysia and the Riverland (50 responses), 100% of growers indicated they obtained significant information to improve how they manage their mandarins and 100% indicated they found the farm walk good value (both questions 100% bull's-eye, Figure 2, Figure 3, Figure 4).</p>	<p>The in-field dart board survey used to capture grower feedback in the field (Figure 1) as it is a monitoring tool that was considered to be and appropriate for the audience and in-field use. Field day participants can provide performance feedback by indicating on a dart</p>

improved knowledge, understanding and skill of Afourer canopy management to yield reasonably even each year and reduce alternate bearing?'



Figure 1. Field day participants providing feedback by indicating which of three options on a dart board they choose. Participants mark their preference with a thick whiteboard marker attached to a piece of string.

board one of three options. Participants mark their preference with a thick whiteboard marker attached to string. The dart board survey asked four questions. This was found to be too many and this was reduced to two key questions. This dart board can be incorporated into the monitoring and evaluation process at the beginning of the project by assessing the best two questions to ask the target audience so as to be able to collect monitoring data relevant to the key M&E evaluation question and KPIs.

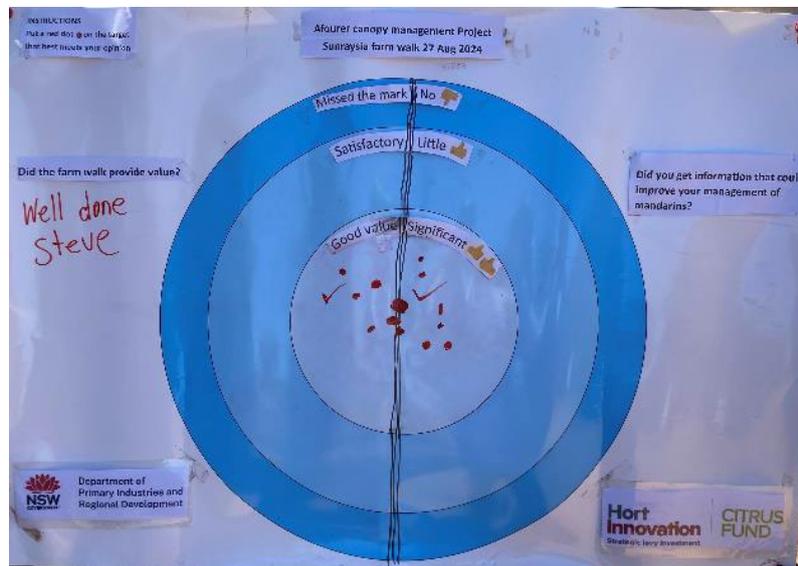


Figure 2. Results from the Sunraysia 2024 end of project farm walk.

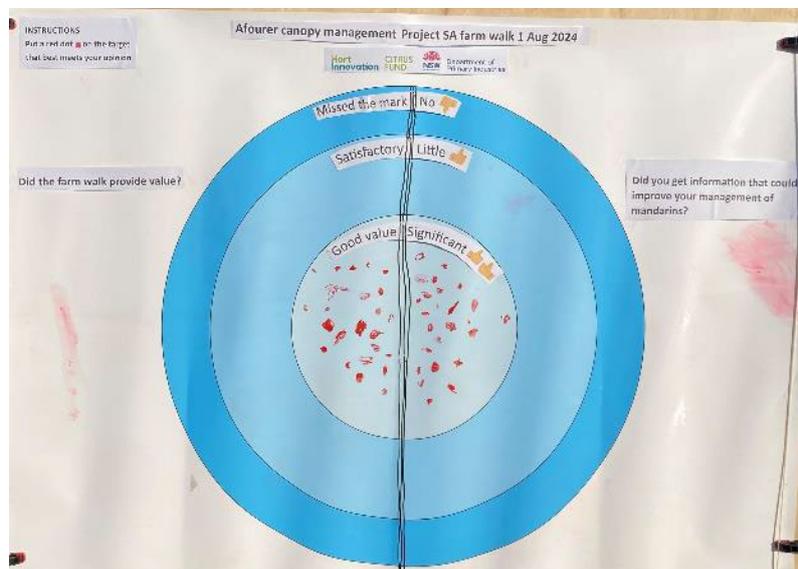


Figure 3. Results from the Riverland 2024 end-of-project farm walk.

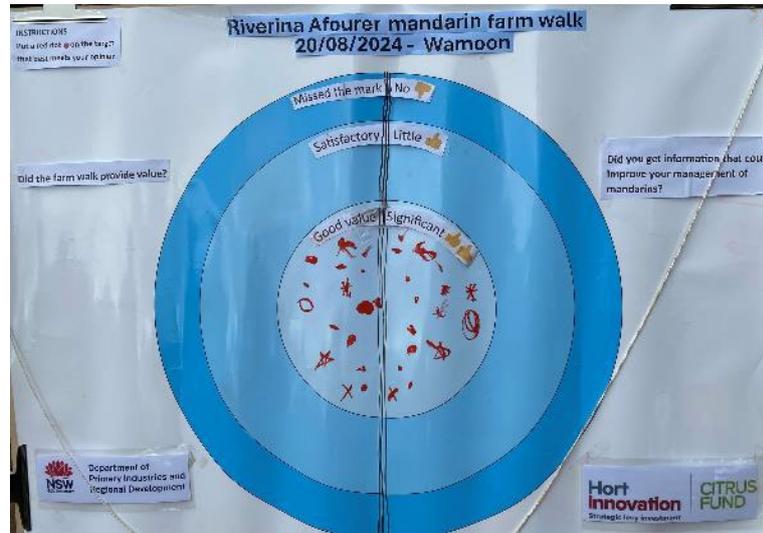


Figure 4. Results from the Riverina 2024 end-of-project farm walk.

An end of project survey was conducted at the end of the 2025 project Zoom webinar. 11 responses were received from the webinar survey and this was followed up by an online survey of the same questions to those not attending the webinar (a further 6 responses). The survey represents 750 ha of W. Murcott production (about 24% of production).

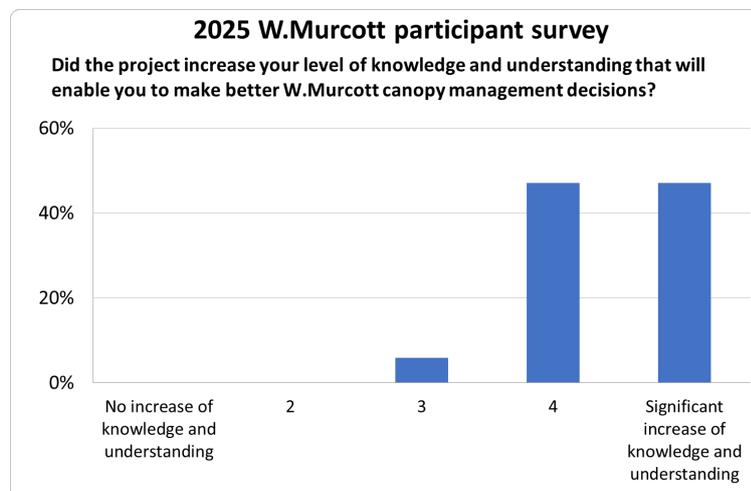


Figure 5. The results of questioning participants if the project helped them make better W. Murcott canopy management decisions

Q1. Did the project increase your level of knowledge and understanding that will enable you to make better W. Murcott canopy management decisions?

100% of participants indicated the project helped them to at least moderately increase their knowledge and understanding to make better W. Murcott canopy management decisions, while 94% indicated they had a good increase in knowledge and understanding (Figure 5).

Q2. Has the project information (e.g. videos) or activities (farm visits) helped you to make some canopy management decisions or changes on your farm?

	<p>This question was accidentally omitted from the post webinar online survey, however for the respondents of the Webinar survey 100% responded yes.</p> <p>Q3. Do you think a second phase of the project will provide value to the industry, e.g. continuing monitor the progress of grower trials (agronomic and economic) and conducting small scale demonstration trials?</p> <p>100% responded yes.</p> <p>Q4. Do you believe there needs to be more citrus on-farm projects that investigate and report the agronomic and economic aspects of alternative on-farm practices (e.g. netting, crop thinning, pruning, deficit irrigation or other).</p> <p>This question was accidentally omitted from the post webinar online survey, however for the respondents of the Webinar survey 100% responded yes.</p> <p>Q5. If you replied yes to the previous question please select as many choices as you wish. If you have more ideas please communicate directly with Steven</p> <p>The questions and results are provided below:</p> <p>88%: Monitor growers orchards, conduct small demonstration trials and communicate results</p> <p>76%: Conduct field days on grower properties to learn from each other (grower experience & demo trials)</p> <p>35%: Install intensive and large replicated trials on a small number of blocks</p> <p>Conducting project activities on grower orchards was highly favoured by participants (about 80%). There is great opportunity to increase engagement with growers by conducting projects that enthuse growers to try different practices (demonstration trials) and extending through farm walk events for growers to observe trials and exchange ideas. This provides practical knowledge and can increase the aspirations to adopt new ideas. Project findings can also be communicated through publications and video report (as done in this project). Videos have been found to be a practical method to extend information that have a strong visual component and supports adoption by those that have a preferred learning style of ‘seeing’.</p>	
<p>2. How relevant was the project to the needs of the intended beneficiaries?</p> <p><i>Did the project provide relevant practical canopy management information to growers (levy payers) to improve yields, minimise alternate</i></p>	<p>Target: The project provided relevant practical canopy management information to growers (levy payers) through publications and field days. This will help growers to improve yields, minimise alternate bearing and remain profitable.</p> <p>The needs of the intended beneficiaries (growers) were identified at the beginning of the project so activities and outputs could be better targeted. This was done by meeting all growers individually to discuss their issues and knowledge gaps. This information was published in the Project planning background information report (attached document).</p> <p>The <i>W. Murcott canopy management guide</i> (attached document, Appendix 1) and the video series (see output section) provide relevant practical canopy management information. Considering that canopy management research takes at least eight years to provide reasonably robust recommendations, the information provided within this limited</p>	<p>The initial survey of growers to understand their issues and knowledge gaps was critical to plan relevant activities to meet grower needs. Upon reflection, a short survey could have been done to enhance monitoring and evaluation targets and assessment. All project ideas should have a process that gives them time and funding to</p>

<p><i>bearing and remain profitable?</i></p>	<p>five-year time frame successfully identified canopy management options and included an economic assessment based on current understanding projections (Figure 6). There is an opportunity to continue work by exploring these options and providing more confident and robust information to the industry (discussed further in the recommendations section).</p> <div data-bbox="395 439 1193 909" data-label="Figure"> </div> <p>Figure 6. One of the economic analysis graphs extracted from the <i>W. Murcott canopy management guide</i> shows the difference in cumulative cash flows from different types of production and canopy management systems.</p>	<p>engage with industry (such as the initial survey in this project) to have a good and technically correct understanding of the issue. Flexibility in project activities will help ensure that they are suitable and are not based on incorrect technical assumptions or adoption assumptions. Another option is to have technical scoping studies that engages with growers and technical experts prior to developing a detailed project.</p>
<p>3. How well have intended beneficiaries been engaged in the project?</p> <p><i>How well have growers and other members of the industry been engaged in the project through project and communication activities?</i></p>	<p>Target: Growers and other members of the industry have been engaged in the project through communication activities such as Zoom meetings, the initial project information survey, personal contact during the project, and at farm walks.</p> <p>Although the Zoom meetings were an opportunity for growers to ask questions, the main purpose of this platform is to deliver information. Having a free-flowing conversation in a Zoom meeting is difficult because participants are unable to read body language and intuitively provide comments in a casual discussion setting.</p> <p>As discussed in key evaluation question 1, the project's initial survey was an excellent way to engage with growers and create rapport. Regardless of the technological advances of phone and online meetings, person-to-person interaction is still a very important part of developing good relationships to foster open interaction.</p> <p>The project monitored grower sites 2 to 3 times per year. Growers were notified when these visits occurred and, if convenient, they met with Steven to discuss ongoing canopy management issues and project updates. The meetings only lasted for 15 to 30 minutes but were an excellent way to get feedback that would otherwise not be discussed in a group environment. Also, having a meeting in the orchard whilst inspecting the canopy prompted discussion and questions that would not occur in an online meeting or at a group session. A good project engagement and extension program has a balanced mix of personal and group activities.</p> <p>The annual farm walks (listed in the output table) provided good group and grower interaction (Figure 7, Figure 8, Figure 9). The first purpose of the farm walks was to update growers on the progress of trials and project outcomes, and the second purpose was to provide a broader industry discussion platform. Group discussion was a very important</p>	<p>Upon reflection, when personal interaction or group activities occur, a few key survey and feedback questions are asked to improve the engagement process. The participants could be asked if there are any ways in which communication can be improved or if they have any ideas on actions or activities that can improve the outcomes of the project.</p>

component of the farm walks and this was facilitated by Steven continually asking growers for their opinions and if they had any similar or contradictory experiences. The project was not just about delivering information to growers; it also involved growers exchanging their learning experiences with other growers.



Figure 7. Sunraysia August 2024 end of project farm walk.



Figure 8. Riverland August 2024 end of project farm walk.



Figure 9. Riverina August 2024 end of project farm walk.

4. To what extent were engagement processes appropriate to the target audience/s of the project?

*Did the project engage with growers through their preferred learning style?
How accessible were extension events to*

Target: The project engaged with growers using various learning styles and provided accessible extension events to growers.

There will always be a mix of preferred learning styles, and it is important to cover all main styles, including reading, viewing, and experiencing. It is recognised that canopy management is a very visual and active subject, and therefore, the project ensured that visual and active engagement extension occurred throughout the project. Visual forms of extension were provided as videos that explained canopy management concepts. A photograph in a report does not provide a three-dimensional perspective to adequately comprehend the message. The best visual extension is providing a personal on-site explanation. However, one-to-one extension to every member of industry not possible because the project has a limited time frame and labour resources. Although a video is presented on a two-dimensional flatscreen, a three-dimensional perspective is provided by the camera moving around at different angles. The video commentator also discusses the canopy providing more engaging communication than a written document. The videos can be accessed at a time suitable to the

As discussed in KEQ 3 (previous row)

<p>growers?</p>	<p>viewer.</p> <p>Active learning by experience is a very important tool that was used in the project. Growers were encouraged to try something different on a small number of trees. About six small demonstration trials (6 to 24 trees) were instigated. It is important to have sufficient demonstration trials because some will be ineffective (e.g. farms sold, tree health decline etc.); success is defined if 50% or more trials remain viable. Two trials provided valuable information on out-of-control canopy growth and the South Australian Ryan Arnold trial and W.A. Richard Eckersley trial provided excellent results on successful intensive canopy management (see Ryan’s and Richard’s videos in the outputs table). The W.A. Andrew Pergoliti videos also demonstrated successful W. Murcott canopy management. It was not part of a project demonstration trial but was a grower monitoring site that provide valuable results (see Andrews’s four videos in the outputs table). Both grower monitoring and demonstration trials provided valuable information. The out-of-control canopy growth trial information was integrated into the <i>W. Murcott canopy management guide</i>.</p>	
<p>5. What efforts did the project make to improve efficiency?</p>	<p>Grower visits and group activities tried to be logistically coordinated so multiple growers and events could occur with one trip.</p>	

Recommendations

This project identified W. Murcott canopy management options (outlined in the *W. Murcott canopy management guide*). However, most of these options were realised towards the end of the project, and consequently, there was insufficient time to test and understand these options fully. The intensive pruning option is being continued by Ryan Arnold in South Australia; Costa South Australia is going to instigate triangular tree pruning in their orchards; Dean Morris will continue to develop one-wire cordon intensive pruning; Nutrano and Costa will continue to use 'half tree mechanical hedging resetting' while other growers continue to use mechanical hedging with hand doorway pruning. The end of project survey obtained a 100% response of participants indicating there would be value in further work, particularly demonstration trials and monitoring of grower trials (Key evaluation question 1).

Pruning is a long-term strategy that can take 3 to 4 years to provide stable results, therefore, pruning is a long-term research program. There is an opportunity to harness the project findings that are being implemented on grower's orchards throughout the growing regions by developing a project that monitors their progress, implements small demonstration trials to investigate variations and extends this information using the same methods as this project (personal interaction, group activity, videos and publications). An intensive replicated trial is not recommended, as this focuses on a few sites and situations, also it did not receive a high response in the survey as a potential high value activity. Replication is achieved by using numerous grower sites throughout the regions of Australia.

The end of project survey obtained 100% responses of participants wanting more “on-farm” projects with preferences for monitoring growers orchards, conducting small demonstration trials and communicating results and conducting field days on grower properties to learn from each other.

A second phase of this project could be an on-farm project with case studies that monitor grower practises and implement demonstration trials. However, this project could also incorporate navel oranges to develop a “Southern citrus extension and development project” that updates the W. Murcott canopy management guide and produces a “Navel export management guide”. The guides will be prescriptive (recommendations) but include grower case studies (demonstration trials) that show where the practice might be suited and not suited. Providing case studies to support recommendations makes the document more relevant and practical.

The concept of a citrus extension and development project could be developed through a well-designed scoping study. The scoping study would survey growers to identify important knowledge gaps and income generating, or cost reduction opportunities, the technical context of new ideas (e.g. strength of technical theory, previous research successes or

failures, or lack of reliable research), on-farm relevance (growers opinions, practical challenges and opportunities) and to provide a short economic impact assessment on the possible benefit and risks of proposed work. The scoping study will provide funding bodies with good technical and on-farm information to assist with informed funding decisions.

Intellectual property

There is no project IP or commercialisation to report.

Acknowledgements

We wish to acknowledge the generous contributions of time and resources by our grower-collaborators and their businesses. Special thanks to Nutrano, Southern Cross, Costas, and Mick Cuzzillo for their collaboration in replicated trials and to Payap Produce, Moricom, Moora Citrus, Ingerson Farms, Yambellup, Pergoliti farms and AgriFresh collaboration in sharing information and conducting demonstration trials.

We wish to acknowledge the work and contribution of project officers Andrew Creek (NSW DPIRD) and Rachelle Johnstone (WA DPIRD), who managed trials and grower consultation in the Riverina and Western Australia citrus production regions (Figure 10).



Figure 10. Andrew Creek (NSW DPIRD) and Rachelle Johnstone (WA DPIRD)

Appendices

Appendix 1: list of attached documents

1. Project planning background information report (available from request to Steven Falivene)
2. May 2025 end-of-project webinar (available from request to Steven Falivene)
3. Dareton NSW DPIRD field day (2024) report (available from request to Steven Falivene)
4. 2020 December Afourer project update newsletter (available from request to Steven Falivene)
5. W. Murcott canopy management guide (available on the NSW DPIRD canopy management website)

Appendix 2 Spain 2022 Study Tour Itinerary

Factsheet and videos available from:

<https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/content/canopy-management/mandarin-pruning2/afourer-canopy-management-spain-tour-2022>

Overseas travel itinerary

Date	Country / Location	Activity
14 November	Alcanar	Orchard : Begoña Amoros Young Tango. Balada Citrus Nadorcott . Ruben Colell Tango. Cooperativa Alcanar Nadorcott/Tango.
15 November	Valencia	Citrus orchard visits: San Alfonso. Nadorcott/Tango "Zero Residue".
16 November	Valencia	Citrus orchard visits: Servalesa and Fitogar - Nadorcott, Tango and some M7.
17 November	Alicante/ Murcia	Orchard visits: Murcia. Masso- Nadocott and Tango.
18 November	Murcia	Orchard visits: Murcia. Angel Mateo.- Nadorcott Tango and varieties from Volcani. Angel Gonzalez- campo Cartagena. Management of salt and nitrates.
19 November	Granada	Transit
20 November	Seville	Sunday (information review)
21 November	Seville /Huelva	Orchard visits: IFAPA institute - High Density plantings and mulching. Francisco Arenas. Citrus Nostrum Paco Guanter: Nadorcott, Tango and other varieties.
22 November	Seville	Orchard visit: Golden citrus, Martinavarro, Bollo, Sintesis, Rio Tinto fruits (organic farms)
23 November	Seville to Agadir, Morocco	Orchard visit: Eurosemillas Rafa Cano Farms Tango and Daisy SL. Fitogar. Late direct flight Seville to Agadir, Morocco Ryan Air
24 November	Agadir	Orchard visits: Nadorcott special designated areas with no cross pollination.
25 November	Agadir/Marrakesh	Orchard visits: Agadir and other citrus areas around Marrakesh: Nadorcott and other varieties.

Appendix 3. South Africa 2024 Tour Itinerary.

Factsheet and video are available from:

<https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/content/canopy-management/mandarin-pruning2/south-africa-w.murcott-canopy-management-study-tour>

Overseas travel itinerary

Date	Country / Location	Activity
22/4/24 Mon	Citrusdal	Dept. Horticulture Univ Stellenbosch Farm visits <ul style="list-style-type: none"> • ALG Estates (www.algestates.com) • Mouton Citrus (www.moutoncitrus.co.za) Overnight Piekenierskloof hotel
23/4/24 Tue	Citrusdal / Robertson	Farm visits <ul style="list-style-type: none"> • Suiderland Plase (www.suiderlandplase.co.za) • Dome Citrus Overnight Excelsior guest house
24/4/24 Wed	Robertson	Farm visits <ul style="list-style-type: none"> • Zandvliet farm (www.indigofruit.co.za) • Unipack (www.unipack.co.za/) Overnight Excelsior guest house
25/4/24 Thu	Patensie	Drive to Patensie 580 km, 6.5 hours Overnight Jeffery's Bay
26/4/24 Fri	Patensie	Farm visits <ul style="list-style-type: none"> • Meet with citrus advisory officer Andre Combrink (Citrus Research International, CRI). • Visit Quacha Farms and AIN citrus Overnight Port Elisabeth
27/4/24 Sat	Port Elisabeth	Drive to Port Elisabeth and report review Overnight Port Elisabeth
28/4/24 Sun	Port Elisabeth	Rest Overnight Port Elisabeth
29/4/24 Mon	Port Elisabeth	River Valley farm visits <ul style="list-style-type: none"> • Habata • Sitrusrand Overnight Port Elisabeth
30/4/24 Tue	Port Elisabeth	River Valley farm visits <ul style="list-style-type: none"> • Sunriver Citrus Overnight Port Elisabeth

Appendix 4

Turkey Citrus Congress abstract 2022

S03O17

Nadorcott (Afourer) mandarin canopy management and consistent yield challenges: grower pruning practices and experimental treatments

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The Nadorcott (Afourer) mandarin is popular because the fruit is robust, seedless, and exportable by sea freight. Afourer fruit has good consumer acceptance and growers like the variety because it yields well throughout the early years of production with good financial returns. However, once Afourer mandarin trees reach 7–10 years of age, the trees are large, lower parts of the canopy are shaded, tractor access is inhibited, and growers are reporting low long-term yields and alternate bearing. Alternate bearing leads to marketing problems and fruit size is reduced in years of low and high yields. Pruning is a key strategy to regulate canopy size, however, Afourer trees are highly vigorous and produce many watershoots, making pruning a challenge. In some cases, extensive pruning can induce more growth than was originally removed. Australian Afourer growers are trying different hand and mechanical pruning strategies to manage vigour and crop load. Each of these grower strategies provides opportunities to learn while recognising site-specific influences, management circumstances and regional differences. Most growers are targeting a consistent crop load of 55 tonnes per hectare.

These grower experiences have identified a number of canopy management options: intensive hand pruning, autumn watershoot pruning, centre tree pruning, half tree heavy hedging and mechanical pruning. A project has started to compare these strategies, and financial projections have been developed to explore opportunities and limitations. The project welcomes input and engagement from citrus technologists worldwide for their experiences and ideas.

Appendix 5**Korea Citrus Congress abstract 2024****W. Murcott mandarin canopy management: 3-year trials, grower experiences in Australia, South Africa and Spain****Falivene S.,¹ Creek A.,¹ Johnstone R.² Monks D.,¹**

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The W. Murcott mandarin is popular with growers worldwide because it yields well in the early years, the fruit is robust, seedless, and exportable by sea freight. When W. Murcott reaches 7–10 years of age, the trees are large, lower parts of the canopy are shaded, tractor access is inhibited, and growers report low yields and alternate bearing. Inconsistent yields make marketing difficult, exacerbated by inconsistent average fruit size. Pruning is a key strategy to regulate canopy size, however, W. Murcott trees are highly vigorous and produce many water shoots, making pruning challenging. The project conducted five replicated pruning experiments, numerous demonstration pruning trials and study tours to Spain and South Africa. Five levels of pruning treatments, from intensive manual pruning to mechanical hedging, were implemented in the experiments. There was no statistical difference in yield and fruit size in the first three years. The lack of response is probably because of the time needed for a tree to re-establish its canopy from a large to a small tree and the difficulty of managing highly vigorous regrowth. This regrowth was predominately long water shoots which were removed in the following seasons' pruning. The study tours to Spain and South Africa showed that regrowth (of 200–300 mm shoots) management was key to success where excessive regrowth was rubbed off and the remaining shoots were broken to encourage side shoots. Regrowth management could occur up to three times per season, depending on the vigour response. Rootstock had a major effect on the vigour of W. Murcott; citrange produced highly vigorous trees, while trifoliata rootstock grew less vigorous trees that were easier to manage.

Appendix 6: Citrus Australia 2022 technical forum poster presentation



Afourer mandarin best practice canopy management

Horticulture Innovation CT19002

Project overview

Afourer mandarin plantings in Australia have now surpassed Imperial mandarin. Once Afourer mandarin trees reach 7–10 years, they are prone to alternate bearing (100 t/ha then 20 t/ha the next season). Apart from the marketing problems caused by variable volumes of fruit, high yields are often associated with smaller fruit, while low yields are associated with very large fruit with a coarse rind.

Growers are also reporting a gradual decline in long-term average yield. This could be attributed to the large canopies shading the lower productive canopy and the terminal bearing nature of Afourer mandarin.

This treatment establishment phase of the project are three seasons of harvest from 2021 to 2023. This Horticulture Innovation levy funded project with NSW DPI in-kind input is:

1. building the knowledge and skills of Australian growers and researchers by collating the best knowledge and experience
2. working collaboratively with growers on existing and new replicated and demonstrative pruning trials
3. developing best practice Afourer pruning guidelines for the industry

Replicated trials

Six replicated trials have been established, 4 on mature trees and 2 on young trees. Four are in Sunraysia and 2 in the Riverina. Yield, fruit size, fruit blemish and watershoot growth are measured. The treatments at the Sunraysia sites are:

1. light annual hedging
2. half tree heavy hedging
3. traditional one-minute annual pruning
4. intensive annual spring pruning
5. intensive annual spring pruning and regrowth management in autumn.

Demonstration trials

Demonstration trials have been implemented on growers' properties in Sunraysia and Western Australia. The treatments are selected variations of treatments from the replicated trials.

Figure 1: Half tree pruned demonstration trial at Ellerslie, NSW.



Outputs to date

A report outlining current grower practices and feedback from researchers and agronomists from South Africa has been published.



Figure 2: Excerpt from the grower practice and South Africa feedback report.

Videos

A series of videos will soon be released demonstrating the pruning techniques used for each pruning treatment and the results to date. Videos will be available on the NSW DPI website.



Figure 3: Excerpt from one of the six videos outlining the replicated trial pruning treatments.

Field days

Field days are held in autumn for growers to inspect experimental sites and observe canopy growth and fruit set.



Figure 4: Farm walk participants inspecting replicated trial trees at Costa Orchards, Gool Gool, NSW.



Figure 5: An intensively pruned Afourer mandarin tree in the replicated trial.

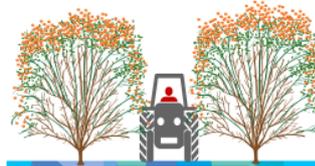


Figure 6: Large mature Afourer trees that are growing most of the fruit on the outer canopy shell.



Figure 7: The intensive pruning treatment aims to develop a tree structure that produces fruit throughout the tree rather than only on the outer shell.



Figure 8: Overgrown mature Afourer mandarin causing row access and lower canopy shading problems.

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This project has been funded by Hort Innovation using the citrus research and development levy, funds from the Australian Government, NSW DPI in-kind and participating citrus growers in-kind. For more information on the Hort Innovation fund and strategic levy investment, visit horticulture.com.au.

Appendix 7. 2025 Citrus Australia Congress Riverina poster presentation

W. Murcott mandarin canopy management: 4 year trials, grower experiences in Australia, South Africa and Spain

Steven Falivene¹, Andrew Creek², Dave Monks¹ and Rachelle Johnstone²
 1 NSW Department of Primary Industries and Regional Development
 2 WA Department of Primary Industries and Regional Development

BACKGROUND: The W. Murcott mandarin is popular with growers worldwide because it yields well in the early years, the fruit is robust, seedless (with isolation), and exportable by sea freight. When W. Murcott reach 12–15 years of age, the trees are large, lower parts of the canopy are shaded, tractor access is inhibited, and growers report low yields and alternate bearing. Inconsistent yields and fruit size makes marketing difficult and erodes profitability.

AIM

Develop best practice canopy management techniques that will improve long term yields and minimise alternate bearing in W.Murcott mandarins.

STRATEGY

Pruning is a key strategy to regulate canopy size, however, W. Murcott trees are highly vigorous and produce many long water shoots, making pruning challenging. The project conducted five replicated pruning experiments, demonstration pruning trials and study tours to Spain and South Africa. Five levels of pruning treatments from intensive manual pruning to mechanical hedging were implemented in the experiments.

RESULTS

There was no statistical difference in yield and fruit size in the four years of experimental trials. The lack of response was probably because of the time needed for a tree to re-establish its canopy from a large to a small tree and the difficulty of managing highly vigorous regrowth. Regrowth was predominately long water shoots which were removed in the flowing seasons' pruning.

The study tours to Spain and South Africa showed that regrowth management was important. Regrowth management in South Africa removed excessive regrowth in spring to summer and the remaining shoots were broken in half to encourage side shoots. Regrowth management could occur up to three times per season depending on the vigour response. A demonstration trial conducted by Ryan Arnold (Pyap Produce, S.A.) showed that trees could be managed by intensive pruning and spring regrowth management, but they needed a total of about 6-8 min per tree (~\$4000 ha⁻¹). However, this extra pruning and regrowth management could yield an extra 10-20 tons ha⁻¹ or \$8000-\$16,000 ha⁻¹.

Rootstock had a significant effect on the vigour of W. Murrcott; citrange produced highly vigorous trees, whilst trifoliata rootstock grew less vigorous trees that were easier to manage. There were also differences of growth habit between the regions. Pruning strategies need to be adapted to tree growth habit and site conditions.

PROJECT LEARNINGS

- Different pruning strategies for different vigour of trees
- Minimise use of vigorous rootstock (mix of rootstocks)
- Hedging is a viable option, need to accept disadvantages (alternate bearing, yield loss, harvest etc)
- Intensive pruning
 - ~ 6-8 min tree, easier and efficient picking
 - Vase vs triangular tree shape
 - Vigorous trees need extra regrowth management

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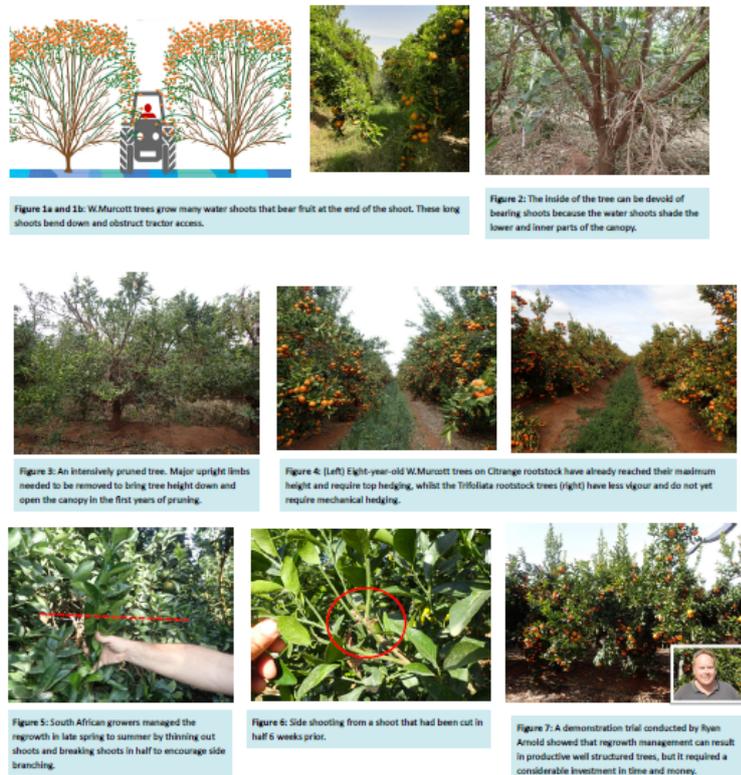


Figure 1a and 1b: W.Murcott trees grow many water shoots that bear fruit at the end of the shoot. These long shoots bend down and obstruct tractor access.

Figure 2: The inside of the tree can be devoid of bearing shoots because the water shoots shade the lower and inner parts of the canopy.

Figure 3: An intensively pruned tree. Major upright limbs needed to be removed to bring tree height down and open the canopy in the first years of pruning.

Figure 4: (Left) Eight-year-old W.Murcott trees on Citrange rootstock have already reached their maximum height and require top hedging, whilst the Trifoliata rootstock trees (right) have less vigour and do not yet require mechanical hedging.

Figure 5: South African growers managed the regrowth in late spring to summer by thinning out shoots and breaking shoots in half to encourage side branching.

Figure 6: Side shooting from a shoot that had been cut in half 6 weeks prior.

Figure 7: A demonstration trial conducted by Ryan Arnold showed that regrowth management can result in productive well structured trees, but it required a considerable investment in time and money.

VIDEO OUTPUTS

Over 35 videos are available on the NSW DPIRD website showcasing various aspects of W.Murcott canopy management.

Afourer canopy management Spain tour 2022

Introduction

An Afourer mandarin (Afourer) tour was conducted in November 2022, visiting many orchards in Spain and over 100 hectares. The focus of the study tour was to learn about canopy management strategies to maximise productivity. There are 12 videos available each for provided and video range from 2 to 13 minutes. A report available that summarises the tour and their observations from each orchard (see link below).

The videos are:

1. Project introduction: why is Afourer the best alternative to W. Murcott? (5m 20s)
2. Background: the production objectives of the treatments (1m 15s)
3. Mature tree without leucostic cutting treatment (10m)
4. Mature tree without leucostic cutting treatment (30m extended version)
5. Light annual leucostic cutting treatments (1m 30s)
6. Light annual leucostic cutting treatments (5m 30s)
7. Citrange top pruning treatment (10m)
8. Vase tree without leucostic cutting (12m)
9. Vase tree without leucostic cutting (23m extended version)
10. Vase tree with mature tree without leucostic cutting (6m 45s)
11. Spacing Afourer under nets: challenges of spacing Afourer under net (9m 30s)
12. Side shooting (5m 30s)

An overview of the project is available from the Horticulture Innovation Afourer project description web page.

The videos are:

1. QLD mandarin pruning (Murrcott mandarin, 7m) [Watch video](#)
2. QLD mandarin pruning (Imperial mandarin, 5m) [Watch video](#)
3. QLD mandarin pruning (Imperial mandarin, 6m) [Watch video](#)
4. QLD mandarin pruning (Imperial mandarin, 15m) [Watch video](#)



Appendix 8 2021, Sep: Citrus Australia magazine article



Afourer trial aims to improve long-term yields

A new project to develop best practice canopy management techniques in Afourers aims to improve long-term yields and minimise alternate bearing.

Afourer mandarins are recognised for producing high yields (60-90 tons per hectare) during the early years of production, sometimes peaking over 100 tons per hectare.

However as the trees grow large the yield begins to decline and alternate bearing becomes more prominent. Some growers of mature trees have reported average yields of 35 to 40 tons per hectare.

Excessive vigour and unmanaged watershoot growth are thought to contribute to yield decline in Afourer trees by shading the lower canopy.

Alternate bearing contributes to yield decline because the low crop load in 'off' years reduces long-term average yields.

In the short-term alternate bearing produces low-value small fruit in high crop load years, and in low crop load years leads to oversized fruit.

The project will investigate pruning strategies through replicated trials and demonstrations to minimise vigour and water shoots with the aim of improving long term yields and reducing alternate bearing.

Most of the trials are on grower properties in Sunraysia and the Riverina.

Project lead, Steven Falivene, NSW DPI, said the project has two objectives.

"Firstly, to develop best practice canopy management techniques to improve long-term yields and minimise alternate bearing in Afourer mandarins.

"Secondly, to develop capacity of Afourer growers in Australia by collating information locally and overseas, case studying growers, implementing on-farm trials and linking growers."

Growers from all states are participating in the project with Andrew Creek (NSW DPI) managing the Riverina and Rachelle Johnstone (WA DPIRD) managing Western Australia.

Key points

- ❖ Pruning strategies explored
- ❖ Trials on grower properties
- ❖ Mechanical hedging reviewed

"Already zoom meetings with South African researchers have been conducted and case study and background information report has been presented to the group," Mr Falivene said.

Case studies will be conducted on most grower properties to explore the numerous management options currently being trialled by growers including hand thinning, chunk pruning, limb bending, annual limb

removal, autumn water shoot removal and mechanical hedging.

The trial treatments will investigate multiple regrowth management events aligned with best management practices currently used by some Australian Afourer growers and recommended by South African researchers.

The management of the canopy and water shoots is not limited to hand pruning and includes mechanical hedging treatments.

"It is thought that developing a good limb structure and managing regrowth in autumn are important practices.

"The case study and background information report also concluded that that water shoots dominating the canopy is a common theme amongst growers that have problems with productivity." ●



Steven Falivene and growers in the trial.

Appendix 9. 2021-22 Plant Protection Guide



Afourer canopy management project update

Steven Falivene, NSW DPI

A Hort Innovation Australia funded project led by New South Wales Department of Primary Industries (NSW DPI) aims to develop best practice canopy management techniques. The project will improve long-term yields and minimise alternate bearing in Afourer mandarins.

Afourer mandarins are recognised for producing high yields (60–90 tonnes per hectare) during the early years of production, sometimes peaking over 100 t/ha. However, as the trees grow larger, their yield declines and alternate bearing becomes more prominent. Some growers of mature trees have reported average yields of 35 to 40 t/ha in 'off' years.

Excessive vigour and unmanaged water-shoot growth are thought to contribute to yield decline in Afourer trees by shading the lower canopy. Alternate bearing contributes to yield decline because the low crop load in 'off' years reduces long-term average yields. In the short-term, alternate bearing produces low-value small fruit in high crop load years, and in low crop load years leads to oversized fruit.

The project will investigate pruning strategies through replicated trials and demonstrations

to minimise vigour and water-shoots and to improve long-term yields and reduce alternate bearing. Most of the trials are on growers' properties in Sunraysia and the Riverina.

This project has two main objectives:

1. to develop best practice canopy management techniques to improve long-term yields and minimise alternate bearing in Afourer mandarins
2. to enhance Afourer production in Australia by collating information locally and overseas, case studying growers, implementing on-farm trials and linking growers.

Demonstration trials

Demonstration trials have been established on growers' properties around Australia. Treatments include:

1. heavy topping (~1.5 m) every second row (Figure 2)
2. half tree hand pruning (Figure 3)
3. north-west window pruning and intensive pruning.



Figure 2. David Stevens standing in front of a tree (25 November 2020) that was heavily pruned.



Figure 3. Half tree hand pruning treatment at the Southern Cross managed farm at Eilerslie.

Appendix 9. 2021-22 Plant Protection Guide - Continued

Replicated trials

Seven replicated trials have been established: four on mature tree blocks and three on young tree blocks, each has four or five replicates. Five replicated trials are in Sunraysia and two are in the Riverina.

Sunraysia mature tree replicated trial treatments:

1. Light hedging annually (LH): annual light hedging sides for row access, topping might be done every second year for height control.
2. Half tree hedging (HH): cut one side of the tree hard and let it grow and crop until it causes row access issues then cut the alternate side.
3. 1M pruning after harvest: traditional one-minute pruning, open a door into the tree and remove some centre limbs (Figure 4).
4. 1× intensive pruning: intensive side window pruning after harvest and no regrowth management during summer.
5. 2× intensive pruning and regrowth management: intensive side window pruning after harvest and regrowth management during summer.

Riverina mature tree replicated trial treatments:

1. Light hedging annually (LH): annual light hedging sides for row access, topping might be done every second year for height control.
2. 1M centre limb pruning: annual light hedging sides for row access and traditional one or two centre limbs removed.
3. Centre limb pruning + regrowth management: annual light hedging sides for row access, traditional one or two centre limbs removed and regrowth management in summer and autumn.
4. 3× pruning and regrowth management; intensive side window pruning after harvest and regrowth management in December and autumn (Figure 5).

Young tree pruning

Three replicated young tree trials were implemented; Nutrano (Vic, Sunraysia), KW Orchards (NSW Sunraysia, formerly Belah Heights) and Mick Cuzzillo (Riverina). The treatments include no pruning, centre limb pruning (Figure 6) and intensive pruning and are replicated five times. The intensive pruning treatment removes centre or side branches that are expected to be problem limbs and providing adequate space between the limbs. The aim is to prevent the

trees from growing 'wild' by the time they reach maturity.



Figure 4. An intensively pruned tree in the Sunraysia replicated trial (few days after pruning). Pruning aimed to form a structure of well-spaced limbs. This treatment will have a yield reduction in the first year and pruning next season is expected to be easier and quicker.



Figure 5. Young mature trees pruned intensively in spring in the Riverina have grown a good number of new shoots. Andrew Creek, trial coordinator and pruner, said that the trees look bare, similar to the photo of the Sunraysia intensively pruned trees.



Figure 6. Young tree pruning replicated trial at Nutrano; centre pruning treatment.

Appendix 10. 2021-22 Plant Protection Guide- Continued

Field days

November 2020 Sunraysia farm walks

Two farm walks occurred in Sunraysia to inspect pruning trial sites, overview grower Afourer practices and general discussion. A follow-up visit will occur in late summer or early autumn.

A farm walk was held on 24 November at KW Orchards (formerly Belah Heights; Figure 7), which is managed by Lyn Tonsin and Toby Hederix. Toby discussed that his trees have been growing and producing well for the first 10 years, however they have reached maximum size and need to be pruned for row access. The trees have been pruned similarly to the one-minute pruning treatment in the replicated trial.

A farm walk occurred on 25 November at Nutrano SunWest that is managed by Tom Braybrook along with consultancy from David Stevens. The farm has one of the oldest Afourer trees in the region and Tom and David discussed the challenges of managing the highly vigorous trees (Figure 8). Managing their trees is mostly by mechanical pruning and some hand pruning where relevant. Tom indicated that the trees yielded very well during the early years and then as the trees matured and needed annual pruning for row access, average yields started to decline. Tom and David, with the help of Rachael McKenzie (field technical officer), are actively running numerous trials to help understand the best option for their circumstances (reported in project demonstration trials).



Figure 7. Farm walk participants inspecting replicated trial trees at KW Orchards. Steven Falivene is holding an electric chainsaw that was used to implement pruning trials.



Figure 8. Farm walk participants inspecting replicated trial trees at Nutrano.

South Africa Zoom meetings: pruning and carbohydrate sampling

Four Zoom meetings occurred with South African citrus specialists Paul Cronje (Citrus Research International), Hans Bester (Citrus Research International) and Jackie Standers (Philagro). Notes from the zoom meeting are available upon request.

Acknowledgements

- NSW DPI
- Hort Innovation, using the citrus research and development levy and contributions from the Australian Government. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.
- Afourer grower project members providing their time and trial blocks in-kind.
- The contributions of the growers and funding bodies are kindly appreciated. Special thank you to Nutrano, Southern Cross, KW Orchards and Mick Cuzzillo for your collaboration in replicated trials.



Appendix 11. 2024 Plant Protection Guide



Afourer canopy management

Steven Falivene, NSW DPIRD

This Hort Innovation Australia-funded project led by NSW DPIRD aims to develop best-practice canopy management techniques in Afourer mandarins.

The intended outcomes of the project are to improve long-term yields and minimise alternate bearing (the tendency to produce a greater than average crop one year, and a lower than average crop the following year) in Afourer mandarins. These are known for producing high yields (60–90 t/ha) in the first 8–10 years, but as the trees mature, their yield declines and alternate bearing becomes more prominent. Some growers with mature trees have reported average yields of 35–40 t/ha in 'off' years. Using different pruning strategies in replicated trials and demonstrations, we aim to find the ideal pruning regime to minimise vigour and water shoots, improve long-term yields, and reduce alternate bearing.

In November 2022, a tour group visited many orchards in Spain and an orchard in Morocco. The focus was to learn about canopy management strategies to maintain consistent production. The tour participants were Steven Falivene and Mahmud Kare (NSW DPIRD), Ryan Arnold (citrus grower) and John Chavarria (packing house consultant).

The key points learned from the tour include:

- intensive pruning is a common practice in most Afourer orchards
- key reasons to prune include:
 - tree height needs to be maintained below 3 m as pickers are not allowed to use tall ladders in Spain (Figure 3 and Figure 4)
 - trees with an open structure dry quicker, reducing fungal infections
 - if the trees are not pruned, yields decline
- pruning takes about 5 to 10 minutes per tree depending on tree size (\$4–\$10 AUD/tree); labour cost is about \$18/h Australian equivalent
- an orchard in Morocco was trying to manage trees by allowing water shoots to grow. However, yields have started to decline in their mature orchards, and they need to change their strategy
- Spain has been in drought for a couple of seasons, with some growers receiving as low as 50% of their water allocation, and in Murcia, they also have high salinity water (3–5 dS/m). The growers recognise the value of good irrigation monitoring and practices.

Eighteen videos of the study tour (one for each farm visited) are available from the [NSW DPIRD citrus website](https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus) (<https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus>); videos range from 2 to 10 minutes. A companion three-page summary from each farm visit is also available.

Acknowledgements

This project is funded by Hort Innovation, using the citrus research and development levy and contributions from the Australian Government and co-investment from NSW Department of Primary Industries and Regional Development.

Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.



We thank Afourer grower project members for providing their time and trial blocks in-kind. Special thank you to Nutrano, Southern Cross, KW Orchards, Costas Orchards and Mick Cuzzillo for collaborating in replicated trials.

Appendix 11. 2024 Plant Protection Guide - Continued

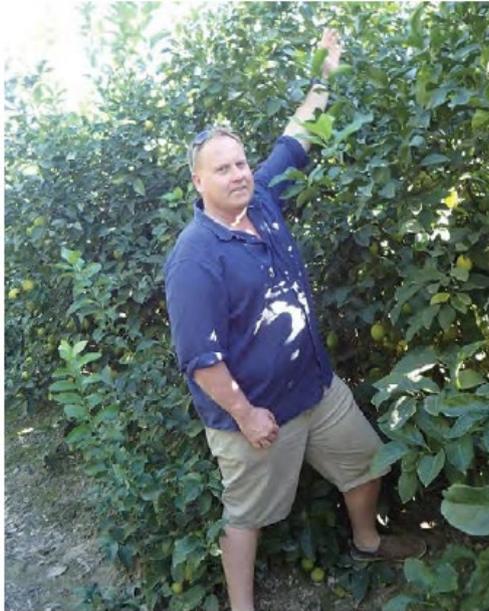


Figure 3. Ryan Arnold (citrus grower, PYAP Produce) showing that most trees are pruned to about 2 m so fruit can be harvested from the ground.



Figure 4. Spanish citrus grower Rafael Cano (Eurosemillas) demonstrates how managing young trees through pruning and limb bending is very important to set the trees up for long-term productivity.

Project updates

