Final Report

Experimental summerfruit orchard – phase II (SF17006)

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Delivery partner:

Department of Jobs, Precincts and Regions (DJPR)

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Content

Public summary

The Australian Summerfruit industry produces peach, nectarine, plum and apricot for domestic and export markets and is valued at $339 million. The industry is focused on export opportunities in Asia.

This project provided reliable, scientificy-based, local information on key orchard management factors to improve fruit quality for the Summerfruit industry. Orchard factors investigated included crop load, rootstocks, canopy design and deficit irrigation. The experimental Summerfruit orchard at Tatura SmartFarm provided data for best management production protocols for these orchard factors for peach, nectarine, plum and apricot.

The experimental orchard presented a go to demonstration site for growers, the horticultural industry, and other stakeholders such as education (University, secondary, primary), government (federal, state, local), catchment management and water authorities, and agricultural (corporate, consultants, nutrition, ag chemical, international agencies) sectors. The orchard provided the platform for improved horticultural networks and cross-industry collaboration.

The project identified crop load management is of critical importance for high fruit quality. Dwarfing rootstocks provided vegetative vigour control and good yield and fruit size outcomes. Regulated deficit irrigation (RDI) maintained yield and fruit quality and reduced irrigation by up to 40%. Vase canopy systems produced greater vegetative growth and tree vigour (pruning biomass, trunk growth, leader growth) compared to Vertical Leader and Tatura Trellis canopy systems. The supporting structure (i.e., posts and wires) in both the Vertical Leader and Tatura Trellis systems provided the capacity for higher fruit number per tree in the early years of tree establishment and consequently greater cumulative yields.

The project results were disseminated though field tours, roadshows, industry workshops, grower magazine articles, conference presentations, science-based best management practice protocols, scientific publications and a suite of online resources and information including newsletters, webinars, virtual orchard tours, YouTube videos, annual production and fruit quality reports and time-series photos of orchard and crop management factors.

Technical summary

The Australian Summerfruit industry is valued at $339 million, producing peach, nectarine, plum and apricot for domestic and export markets. The industry has become focused on export prospects, with Asia representing a major growth opportunity. The industry has the potential to grow fruit to market specification, taking advantage of new and existing free trade agreements, driving up export volumes, creating new niche markets for premium products on the domestic market and receiving a premium price.

However, sales growth of Summerfruit is impeded by low consumer satisfaction with fruit quality, leading to low prices and static consumption, which is threatening the survival of many producers. Agriculture Victoria Research (AVR), with the support of the Australian Summerfruit industry and Hort Innovation, undertook to investigate and develop management practices that will increase productivity and grower returns through improved eating quality and consumer satisfaction. High quality fruit meets consumer expectations by achieving criteria for fruit size, maturity, firmness, sweetness and acidity, blemish and skin colour.

The project focused on agronomic management to improve fruit quality, by manipulating the vegetative to fruit (source-sink) ratio and assimilate partitioning to fruit (yield, quality). The project examined the effects of modifying sink size (crop load) via fruit thinning management and modifying source strength via tree size and vegetative vigour (dwarfing rootstocks, canopy design) and water stress (deficit irrigation) with a focus on yield, fruit size and sweetness outcomes.

The project increased horticultural knowledge of rootstocks, deficit irrigation, canopy design and crop load for stone fruit under Australian conditions. Overall, key findings on tree growth, vegetative vigour and production responses under different orchard management factors were:

- Cornerstone rootstock produced large, sweet fruit and high yield. Krymsk® 86 showed semi-dwarfing traits and outperformed Elberta rootstock in terms of fruit size, red skin colouration and packout yield but had lower fruit sweetness. Krymsk® 1 trees had low yield and excessive suckering but showed dwarfing traits (low light interception, small main branch size, reduced pruning biomass).
- High crop load regimes produced high yields, low fruit weight, reduced sweetness (°Brix), delayed maturity, increased firmness and lowered packout percentage. Low crop load produced larger fruit and advanced maturity. In the early production years, high crop load increased suckering.

- Tatura Trellis out yielded vase trees in establishment years due to having larger tree size (light interception) and capacity to carry more fruit number. Tatura Trellis resulted in more uniform fruit weight and maturity compared to vase canopy systems. Greater annual vegetative growth (pruning biomass, trunk growth) occurred on vase tree despite having lower tree size (light interception).
- Similar production (yield, fruit quality) outcomes were observed between Vertical Leader and Tatura Trellis canopy systems. Greater and more uniform light distribution occurred under Tatura Trellis canopies despite taller trees under Vertical Leader trees. These light regimes responses reflect the canopy design and architecture of each training system (i.e., V shape 3-D Tatura Trellis canopy versus vertical 2-D hedgerow trellis canopy).
- Regulated deficit irrigation (RDI) maintained yield and fruit quality and reduced irrigation by up to 40%. Deficit irrigation during fruit growth stage I (cell division) and stage III (cell expansion) penalised yield and fruit size.
- Full irrigation in the subsequent season following long-term severe deficit irrigation practices (i.e., deficit irrigation at O, 20 and 40 % of crop water requirement) failed to recover production (fruit size, number) and tree health (vigour).

The project communicated with industry and extended key findings using extension approaches that catered for different learning styles. The project results were disseminated though field tours, industry roadshows, industry workshops, grower magazine articles, conference presentations, science-based best management practice protocols, scientific publications and a suite of online resources including newsletters, webinars, virtual orchard tours, YouTube videos, annual production and fruit quality reports and time-series photos of orchard crop management factors. Furthermore, a diverse range of extension mechanisms helped to counter challenges around COVID-19 pandemic and lockdowns, including hybrid, virtual and online approaches.

The project outcomes include sustainable orchard management practices to optimise orchard systems and labour efficiencies for high and uniform fruit quality. The study provided orchard management knowledge to maintain and enhance domestic and international market access (uniform high-quality fruit), increase potential exports and strategies for climate resilience. A recent industry survey indicated that 80 % of the industry were aware of this research and at least 60 % were implementing some sort of change to improve business or orchard practices.

Future work is needed on the application of sensing technologies to provide spatial data on canopy, trunk, flower and fruit metrics so that orchard-specific crop load targets (and thinning requirements) can be determined. Such data will also identify areas within an orchard that require different management (e.g., summer pruning or spray requirements) to increase crop uniformity. Accelerated adoption of sensor technologies offer production efficiencies, labour (safety, workforce, efficiency) advantages and sustainability benefits.

Keywords

Peach, nectarine, apricot, plum, fruit quality, yield, orchard field experiments, deficit irrigation, dwarfing rootstocks, canopy management, crop load management, production protocols, demonstration blocks, agronomy, field tours, roadshows, industry workshops, conference presentations, science-based best management practices, on-line information and resources, virtual orchard tours, YouTube videos.

Introduction

The Australian Summerfruit industry is valued at $339 million, producing peach, nectarine, plum and apricot for domestic and export markets. Victoria accounts for the majority of the Summerfruit production. The industry has become focused on export prospects, with Asia representing a major growth opportunity. The industry has the potential to grow fruit to market specification, taking advantage of new and existing free trade agreements, driving up export volumes, creating new niche markets for premium products on the domestic market and receiving a premium price.

Uniformity in fruit quality is key to maintaining and enhancing domestic and international market access and to increase potential exports. Previous stone fruit research showed fruit quality variability is high both within and between trees, and that fruit quality can be manipulated via innovative orchard management (Lopresti et al. 2014). Furthermore, smart deficit irrigation management practices offer climate resilience under drought and low water allocation conditions (Goodwin and O’Connell 2017); however, the impact of water deficits on fruit quality is largely unknown.

An experimental Summerfruit orchard at Tatura SmartFarm was established under project SF12003 and directed through an industry advisory committee to examine the effects of rootstocks, deficit irrigation, canopy design and crop load management on fruit quality and yield. The high-density orchard of peach, nectarine, plum and apricot was designed using a diverse range of cultivars, rootstocks, canopy designs, crop load and irrigation management practices. The intensive orchard research program provided datasets, orchard systems knowledge and an ongoing resource for industry to underpin new production technologies (e.g., sensors and robotics) that will address high production costs.

The objectives of the project were to:

1. Reduce the variability and improve consistency in fruit quality of Summerfruit (peach, nectarine, apricot and plum) by examining the effect of agronomic management practices (crop load, rootstock, irrigation management, canopy architecture).
2. Develop production protocols to provide fruit that meet consumer expectations on domestic and export markets.
3. Provide a Summerfruit resource for grower training and education.
4. Deliver structured regional and national roadshows to key growing regions to extend project learnings to growers.

Methodology

Project SF17006 utilised the experimental Summerfruit orchard (3 ha) at Tatura SmartFarm established under project SF12003. The project was conducted over 6 years incorporating growing seasons 2018/19, 2019/20, 2020/21, 2021/22 and 2022/23.

The research examined rootstocks, deficit irrigation, canopy design and crop load management factors on fruit quality and yield. The orchard consisted of peach, nectarine, plum and apricot crops and incorporated a diverse range of cultivars, rootstocks, canopy designs, crop load, irrigation management practices and tree densities.

These key orchard management factors (e.g., rootstocks, canopy design, crop load, deficit irrigation) were informed from previous orchard systems research (e.g., Lopresti et al. 2014; Goodwin and O'Connell 2017) and industry expert guidance and advice (project SF12003 reference group).

Each field experiment was statistically designed (e.g., randomized, replicated, measurement units, buffer zones) to study specific treatment factors (e.g., fruit number, deficit irrigation, rootstock vigour), detailed in research preschedule (SF12003 Milestone report 103) and summarised below:

Experiment	Species cultivar	Factor	Canopy	Replication
1a	Peach September Sun	Rootstock x Crop load	Vase	5
1b	Nectarine Rose Bright	Rootstock x Crop load	Vase	5
2a	Peach August Flame	Canopy x Crop load	Vertical leader	8
2b	Peach August Flame	Canopy x Crop load	Tatura Trellis	8
2c	Nectarine Autumn Bright	Canopy x Crop load	Vertical leader	8
2d	Nectarine Autumn Bright	Canopy x Crop load	Tatura Trellis	8
3a	Apricot Golden May	Canopy x Crop load	Vase	8
3b	Apricot Golden May	Canopy x Crop load	Tatura Trellis	8
3c	Plum Angeleno	Canopy x Crop load	Vase	8
3d	Plum Angeleno	Canopy x Crop load	Tatura Trellis	8
4	Nectarine September Bright	Irrigation level x timing	Open Tatura	6

Further details on orchard experiments, agronomic treatments (crop load, deficit irrigation, rootstocks, canopy design), crops and cultivars, and orchard demonstration (cultivar, tree training systems) blocks and associated new technology (e.g., precision irrigation system, mobile sensing platform, trunk dendrometers, fruit gauges) are available in industry magazine articles (Appendix 3), scientific presentations (Appendix 6), scientific publications (Appendix 7) and on the Horticulture Industry Network (HIN) website: http://www.hin.com.au/networks/profitable-stonefruit-research#experiments (Appendix 1).

The project delivered updates and research findings via field tours, roadshows, industry workshops, grower magazine articles, conference presentations, science-based best management practice protocols, scientific publications and a suite online resources and information including web resources pages, newsletters, webinars, virtual orchard tours, YouTube videos, annual production and fruit quality reports and time-series photos of orchard and crop management factors (Appendices 1 – 7).

The project established an advisory committee (project reference group, PRG). The PRG comprised grower, industry and Hort Innovation representatives, project and senior AVR staff. The committee was fundamental in navigating industry engagement through COVID-19 restrictions and steered decisions on experimental factors: agronomic management practices (canopy architecture, irrigation strategies, crop load management, dwarfing rootstocks) and tree management (nutrition, tree training, and pest, disease and weed management). PRG meetings were held annually to update on project progress, discuss communication directions, seek feedback on findings from the field research program and explore future research opportunities. Appendix 8 provides minutes of PRG meetings held during the 2018 – 2023 period.

Results and discussion

The research on rootstocks, deficit irrigation, canopy design and crop load management factors on fruit quality and yield for peach, nectarine, apricot and plum has been published in scientific journals (Appendix 7), summarised in industry magazine articles (Appendix 3), grower production protocols (Appendix 2), production (yield, fruit quality) reports (Appendix 5), presentations at industry and scientific forums (Appendix 6) and communicated to industry by roadshows, webinars, orchard tours, newsletters and via the Horticulture Industry Network (HIN) website: http://www.hin.com.au/networks/profitable-stonefruit-research#experiments (Appendix 1).

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Outputs

Output	Description	Detail
Profitable Stonefruit Website	Website showcasing project experiments, events, results, recommendations on rootstocks, canopy and crop load and deficit irrigation and new orchard technology.	HIN website incorporates project updates, events, production protocols, annual production and fruit quality reports and new orchard Agtech: http://www.hin.com.au/networks/profitable-stonefruit-research > 19,100 hits. See Appendix 1 Table 1 for experiments and topics on rootstocks, crop load, canopy and deficit irrigation
Technical videos	Thirty-nine YouTube videos of orchard experiments on rootstocks, canopy and crop load and deficit irrigation, demonstration blocks, new technology and project webinars.	Videos available on the HIN website. http://www.hin.com.au/networks/profitable-stonefruit-research > 21,900 views. See Appendix 1 Table 2 for list of videos on rootstocks, crop load, canopy, deficit irrigation and new technology.
Virtual orchard 360° tours	Five virtual orchard tours on orchard experiments on rootstocks, canopy and crop load and deficit irrigation, demonstration tree architecture (palmette, cordon) blocks.	Virtual orchard 360° tours available on HIN website: 1. Rootstock experiment: Peach 'September Sun' https://www.hin.com.au/networks/profitable-stonefruit-research/stonefruit-rootstock-trials#Field 2. Irrigation experiment: flowering of nectarine 'September Bright' https://www.hin.com.au/networks/profitable-stonefruit-research/stonefruit-irrigation-trials#virtualtour 3. Canopy crop load experiment: Peach 'August Flame' - vertical trellis versus Tatura Trellis

		https://www.hin.com.au/networks/profitable-stonefruit-research/stonefruit-canopy-crop-load-trials#virtualtour 4. Canopy crop load experiment: Plum 'Angeleno' - Tatura Trellis versus vase https://www.hin.com.au/networks/profitable-stonefruit-research/stonefruit-canopy-crop-load-trials#virtualtour 5. Palmette and cordon tree structures https://www.hin.com.au/networks/profitable-stonefruit-research/stonefruit-novel-canopy-systems-for-mechanisation/palmette-and-cordon-virtual-orchard-tours ≈ 4,000 views. See Appendix 1 Table 3 for details of rootstocks, crop load, canopy and deficit irrigation experiment virtual tour.
Industry newsletters	Twenty-four Profitable Stonefruit Network newsletters highlighting project updates, roadshows, workshops and research findings.	Newsletters emailed to growers and industry stakeholders on project updates and events (roadshows, workshops, webinars, publications), production protocols, annual production and fruit quality reports. 32 – 64 % opened. See Appendix 1 Table 4 for detailed list of newsletters.
Production protocols	Four grower orchard production protocols describing: canopy options, deficit irrigation, dwarfing rootstocks and crop load management.	Protocols available on HIN website: 1. Canopy design options for stone fruit http://www.hin.com.au/networks/profitable-stonefruit-research/stonefruit-canopy-crop-load-trials#protocol1 2. Irrigation scheduling for regulated deficit irrigation (RDI) in stone fruit http://www.hin.com.au/networks/profitable-stonefruit-research/stonefruit-irrigation-trials#protocols 3. Rootstock performance in stone fruit http://www.hin.com.au/networks/profitable-stonefruit-research/stonefruit-rootstock-trials#Protocols 4. Crop load management in stone fruit http://www.hin.com.au/networks/profitable-stonefruit-research/stonefruit-canopy-crop-load-trials#protocol2 See Appendix 2 for hard copies of each protocol.
Grower magazine articles	Four industry grower magazine articles describing: deficit irrigation, canopy rootstocks and crop load management factors.	1. O'Connell M. (2020). Irrigation management for stone fruit. Australian Tree Crop, Feb/Mar, 34–35. 2. O'Connell M, Hincksman, M. (2020). Tatura trellis outperforms vase. Australian Tree Crop, July, 38–39. 3. O'Connell M (2021). 'Rose Bright' nectarine rootstocks and crop load. Australian Tree Crop, July, 30–33. 4. O'Connell M (2022). Orchard factors to lift fruit quality and yield. Australian Tree Crop, April/May, 40–41. See Appendix 3 for hard copies of each article.
Industry roadshows, workshops	Nineteen stone fruit roadshow, workshop and webinar	1. Workshop: Rootstocks, deficit irrigation, canopy and crop load management, 19 July 2018, Tatura, Summerfruit workshop 2. Workshop: Experimental stone fruit orchard: dwarfing rootstocks,

and webinars	presentations on deficit irrigation, rootstocks, canopy and crop load management and new technology.	deficit irrigation, canopy and crop load management, 6 August 2018, Bologna 3. Roadshow: Irrigation management and fruit quality, 13 August 2019, Renmark 4. Roadshow: Irrigation management and fruit quality, 14 August 2019, Swan Hill 5.Roadshow: Irrigation management and fruit quality, 15 August 2019, Cobram 6. Workshop: Transforming your orchard irrigation with sensors and monitoring, APAL Grower R&D Update, 13 November 2019, Melbourne 7. Webinar: Sensors for Summerfruit, 16 March 2021 8. Webinar: Agtech for horticulture, 16 August 2021, Food for thought symposium, Melbourne 9. Webinar: Rootstocks on peach and nectarine, 25 August 2021 10. Webinar: Overview of Agtech research projects, 25 August 2021 11. Webinar: Experimental stone fruit orchard, 31 March 2022, Summerfruit Australia AGM 12. Workshop: Experimental stone fruit orchard, 16 May 2022, Summerfruit Australia Export Information Session, Woorinen 13. Workshop: Experimental stone fruit orchard, 17 May 2022, Summerfruit Australia Export Information Session, Cobram 14. Workshop: Experimental stone fruit orchard, 18 May 2022, Summerfruit Australia Export Information Session, Mooroopna 15. Workshop: Experimental stone fruit orchard, 25 May 2022, Fruit Tech 2022, Shepparton 16. Webinar: Experimental stone fruit orchard, 20 June 2022, Fruit Growers Tasmania 17. Workshop: Experimental stone fruit orchard, 28 July 2022, Summerfruit Industry R&D update, Tatura 18. Workshop: Recovery responses to deficit irrigation in nectarine, 16 May 2023, Summerfruit Australia 2023 workshop, Moama 19. Workshop: Project SF17006 and HIN website resources, 16 May 2023, Summerfruit Australia 2023 workshop, Moama See Appendix 1 Tables 6, 7 and 9 for more details on each presentation.
Orchard tours and field walks	One hundred and sixteen orchard tours and field walks of experimental Summerfruit orchard at Tatura SmartFarm showcasing agronomic management practices (rootstocks, deficit irrigation, canopy, crop load) for improved yield and fruit quality, novel orchard design (tree architecture: palmette,	See Appendix 4 for list of visiting groups to the experimental Summerfruit orchard.

	cordon) and new technology.	
Production updates	Seven production (yield, fruit quality) reports describing orchard management factors of rootstocks, canopy, crop load and deficit irrigation.	1. Yield and fruit quality results from rootstock – crop load study on peach 'September Sun' http://www.hin.com.au/__data/assets/pdf_file/0008/181637/Peach-SEPTEMBER-SUN-2022.pdf 2. Yield and fruit quality results from rootstock – crop load study on nectarine 'Rose Bright' http://www.hin.com.au/__data/assets/pdf_file/0009/181638/Nectarine-Rose-Bright-2022.pdf 3. Yield and fruit quality results from canopy – crop load study on peach 'August Flame' http://www.hin.com.au/__data/assets/pdf_file/0016/183202/Table-2-Peach-August-Flame.pdf 4. Yield and fruit quality results from canopy – crop load study on nectarine 'Autumn Bright' http://www.hin.com.au/__data/assets/pdf_file/0005/183191/Table-1-Nectarine-Autumn-Bright-2022.pdf 5. Yield and fruit quality results from canopy – crop load study on apricot 'Golden May' http://www.hin.com.au/__data/assets/pdf_file/0006/183192/Table-3-Apricot-Golden-May-2022.pdf 6. Yield and fruit quality results from canopy – crop load study on plum 'Angeleno' http://www.hin.com.au/__data/assets/pdf_file/0007/183193/Table-4-Plum-Angeleno-2022.pdf 7. Yield and fruit quality results from deficit irrigation study on nectarine 'September Bright' http://www.hin.com.au/__data/assets/pdf_file/0004/181651/Regulated-Deficit-Irrigation-Nectarine-September-Bright.pdf See Appendix 5 for hard copies of each report. Production reports available on HIN website.
Scientific presentations	Ten presentations at scientific forums on orchard management factors (rootstocks, canopy, crop load, deficit irrigation) and new technology.	1. Continuous detection of new plant water status indicators in stage I of nectarine fruit growth. XXX International Horticultural Congress IHC2018: International Symposium on Water and Nutrient Relations and Management of Horticultural Crops, Istanbul, Turkey, August 2018. 2. Effects of rootstock and crop load management on yield and fruit quality of early-season nectarine 'Rose Bright' and late-season peach 'September Sun'. XXX International Horticultural Congress IHC2018: International Symposium on Cultivars, Rootstocks and Management Systems of Deciduous Fruit and Fruit Tree Behaviour in Dynamic Environments, Istanbul, Turkey, August 2018. 3. Effect of crop load management and canopy architecture on yield and fruit quality of late-season plum 'Angeleno'. XXX International Horticultural Congress IHC2018: International Symposium on Cultivars, Rootstocks and Management Systems of Deciduous Fruit and Fruit Tree Behaviour in Dynamic Environments, Istanbul, Turkey, August 2018.

		4. Diurnal irrigation timing affects fruit growth of late-ripening nectarines. International Symposium on Precision Management of Orchards and Vineyards, Palermo, Italy, October 2019. 5. Field non-destructive determination of nectarine quality under deficit irrigation. International Symposium on Precision Management of Orchards and Vineyards, Palermo, Italy, October 2019. 6. Sensing fruit and tree performance under deficit irrigation in 'September Bright' nectarine. International Symposium on Precision Management of Orchards and Vineyards, Palermo, Italy, October 2019. 7. Crop load and canopy architecture affect yield and fruit quality of 'Golden May' apricot. XII International Symposium on Integrating Canopy, Rootstock and Environmental Physiology in Orchard Systems, Wenatchee, Washington, USA, July 2021. 8. Evaluation of a portable impact probe for rapid assessments of flesh firmness in peaches and nectarines. XII International Symposium on Integrating Canopy, Rootstock and Environmental Physiology in Orchard Systems, Wenatchee, Washington, USA, July 2021. 9. A ground-based mobile platform to measure and map canopy thermal indices in a nectarine orchard. XXXI International Horticultural Congress (IHC2022): Water a worldwide challenge for horticulture, Angers, France, August 2022. 10. Carry-over effects of long-term water deficit in nectarine, II International Symposium on Precision Management of Orchards and Vineyards, Tatura, Australia, December 2023. See Appendix 6 for hard copies of each presentation.
Scientific publications	Sixteen scientific publications on orchard management factors (rootstocks, canopy, crop load, deficit irrigation), crop physiology and new technology.	1. O'Connell M.G., Scalisi, A. (2023). Carry-over effects of long-term water deficit in nectarine. Acta Horticulturae (draft) 2. Scalisi, A., O'Connell M.G., Whitfield D.M., Underwood J., Goodwin I. (2023). A ground-based mobile platform to measure and map canopy thermal indices in a nectarine orchard. Acta Horticulturae (in press). 3. O'Connell, M.G (2022). Crop load and canopy architecture affect yield and fruit quality of 'Golden May' apricot. Acta Horticulturae 1346, 287-294. https://doi.org/10.17660/ActaHortic.2022.1346.36 4. Scalisi, A.; O'Connell, M.G. McGlone, A, Langdon-Arms, S (2022). Evaluation of a portable impact probe for rapid assessments of flesh firmness in peaches and nectarines. Acta Horticulturae 1346, 837-844. https://doi.org/10.17660/ActaHortic.2022.1346.107 5. Park, S.; Ryu, D.; Fuentes, S.; Chung, H.; O'Connell, M.; Kim, J. (2021) Dependence of CWSI-based plant water stress estimation with diurnal acquisition times in a nectarine orchard. Remote Sensing 13, 2775. https://doi.org/10.3390/rs13142775 6. O'Connell, M., Scalisi, A. (2021) Sensing fruit and tree performance under deficit irrigation in 'September Bright' nectarine. Acta Horticulturae 1314, 9-16. https://doi.org/10.17660/ActaHortic.2021.1314.2 7. Scalisi, A.; O'Connell, M.G. (2021). Relationships between soluble solids and dry matter in the flesh of stone fruit at harvest. Analytica 2, 14-24. https://doi.org/10.3390/analytica2010002 8. Scalisi, A., O'Connell, M. Turpin, S, Lo Bianco, R. (2021) Diurnal irrigation timing affects fruit growth of late-ripening nectarines. Acta

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Visiting scientists and students	Hosted eight visiting scientists and students to study orchard management, fruit quality and crop physiology of stone fruit	1. Alessio Scalisi, 2017-2018, University of Palermo, Italy. 2. Kate (Suyoung) Park, 2017-2019, The University of Melbourne, Australia. 3. Prof. Luca Corelli Grappadelli, 2018-2019, University of Bologna, Italy. 4. Fabio Graziani, 2019-2020, University of Bologna, Italy. 5. Thomas Fahey, 2021-2023, RMIT, Australia. 6. Lorenzo Bonzi, 2022-2023, University of Pisa, Italy. 7. Maidul Islam, 2022-2023, RMIT, Australia. 8. Prof. Pablo J. Zarco-Tejada, 2023, The University of Melbourne, Australia.
Project reference group	Meeting minutes of PRG	PRG meetings held at Tatura on: 1. 18 Oct 2018 2. 30 Apr 2019

		3. 19 Aug 2021 4. 3 Mar 2022 5. 22 Aug 2022 See Appendix 8 for hard copies of each PRG meeting minutes.
Media article	Roadshow 2019 press coverage	See Appendix 9 for hard copy of press article.

Outcomes

Outcome	Alignment to fund outcome, strategy and KPI	Description	Evidence
Improved consistency in Summerfruit quality.	Outcome 2: The value of fruit sold on the domestic market is increased to restore grower margins. Strategy 2.3: Conduct supply chain efficiency R&D to improve both the eating experience and packout rates.	Scientific results from orchard field experiments on peach, nectarine, apricot & plum at Tatura SmartFarm have shown that agronomic management practices (crop load, rootstock, deficit irrigation, canopy architecture) can increase consistency in fruit quality.	Scientific publications and conference presentations (see Outputs table above for list of scientific communications).
Ability to manipulate Summerfruit yield and quality to meet domestic and export market quality specifications	Outcome 2: The value of fruit sold on the domestic market is increased to restore grower margins. Strategy 2.3: Conduct supply chain efficiency R&D to improve both the eating experience and packout rates.	Scientific results from orchard field experiments on peach, nectarine, apricot & plum at Tatura SmartFarm showed that high-density orchard systems combined with agronomic management practices (crop load, rootstock, deficit irrigation) can be modified to manipulate yield and quality.	Scientific publications and conference presentations (see Outputs table above for list of scientific communications).
A Summerfruit resource for grower training and education	Outcome 4: An industry culture of continuous improvement has been embedded to support long-term economic sustainability	The Summerfruit experimental orchard at Tatura SmartFarm and HIN website resources provided growers a platform for field tours, workshops and training.	High level of grower and stakeholder engagement and accessibility in project resources (experimental orchard tours), agronomic information (roadshows, industry workshops, protocols, industry magazine articles) and online resources (HIN website, YouTube videos, virtual orchard tours). National and international exposure of

			project findings in conjunction with a world class experimental orchard and state-of-the-art fruit analytics and laboratory facilities at Tatura SmartFarm led to unintended project outcomes during the 2018 – 2023 period. These unintended project outcomes included research collaborations and subsequent scientific presentations and publications with academic research groups: 1. University of Melbourne (Prof. D Ryu, Prof. S Fuentes, Ms S Park, PhD student) on UAV sensing crop water stress of peach and nectarine 2. University of Bologna (A/Prof. Brunella Morandi, Mr Fabio Graziani, Masters student) on vascular flows of plum 3. University of Palermo (A/Prof. Riccardo Lo Bianco, Mr A Scalisi, PhD student) on fruit quality and water stress physiology of nectarine 4. University of Pisa (Mr Lorenzo Bonzi, Masters student) on Agtech and crop water status 5. University of Melbourne (Prof. Pablo J. Zarco-Tejada, Mr Tomas Poblete Cisterna, Ms Na Wang) on remote sensing evapotranspiration and water status of peach, plum, apricot and nectarine 6. RMIT (Dr Matthew Marino, Mr Maidul Islam, Masters student) on remote sensing vegetation indices 7. RMIT (Prof. Roberto Sabatini, Prof. Alessandro Gardi, Mr Thomas Fahey, PhD student) on remote sensing fruit maturity.
Growers are better integrated with the supply chain and responsive to consumer and market demand in domestic and export markets.	Outcome 1: Industry has developed a diversified export market portfolio to absorb growing production volumes. Strategy 1.3: Continue to invest in export readiness and capability focusing on high-priority markets.	Scientific results were communicated to the Summerfruit Industry via an extension program throughout the project that enabled adoption of best management practices for domestic and export quality fruit.	Delivery of project findings to the industry involved a suite of extension approaches to communicate to growers, such as roadshows, field tours, magazine articles, industry presentations, production protocols and web content (e.g., newsletters, YouTube videos, data sets, virtual orchard tours, time series photos) to guide growers to become sustainable based on research data of tree growth, vegetative vigour and production (yield, fruit quality) responses under

			different orchard management factors. A recent industry survey indicated that 80 % of the industry were aware of this research and at least 60 % were implementing some sort of change to improve business or orchard practices (see Appendix 1).

Monitoring and evaluation

Key Evaluation Question	Project performance	Continuous improvement opportunities
To what extent has the project achieved its expected outcomes?	The project engaged with key industry personnel and grower organisations in key growing regions. The Summerfruit experimental orchard enabled the development of rigorous scientific evaluation of high-density orchard production systems and management practices capable of manipulating fruit yield and quality.	Continued liaison with the PRG and Australian Summerfruit industry peak body (Summerfruit Australia LTD).
How relevant was the project to the needs of intended beneficiaries?	The project has provided levy payers with local knowledge and best practice recommendations (production protocols) to improve production outcomes.	New R&D needs to be undertaken to test and adapt Agtech for Summerfruit particularly with respect to crop load management. Results from this project on dwarfing rootstock for Summerfruit crops should be used to examine narrow row pedestrian orchards.
To what extent were engagement processes appropriate to the target audience of the project?	The project engaged the entire Summerfruit industry through roadshows, workshops, orchard tours, newsletters, webinars, industry magazine articles and extensive provision of web-based information and technical material (videos, protocols, virtual orchard tours, production reports).	Continued liaison with the PRG, Australian Summerfruit industry peak body (Summerfruit Australia LTD) and local grower groups.
What efforts did the project make to improve efficiency?	The project adhered to project plans (M&E, experimental pre-schedule) and conducted regular PRG meetings. The project remained agile in the targeted engagement and communication to industry. Key findings were extended through a diverse range of extension mechanisms to counter challenges around COVID-19 pandemic and lockdowns by face-to-face, hybrid, virtual and online approaches. Improved efficiency occurred from advice of the PRG and feedback following industry roadshows, industry workshops, orchard tours, presentations (industry, scientific),	Continued liaison with the PRG, Australian Summerfruit industry peak body (Summerfruit Australia LTD) and local grower groups. Feedback surveys and questionnaire forms to gauge project outcomes and inform KEQs.

	publications (grower articles, scientific journal papers), milestone reports, and web-based metrics and statistics of the online content material. Valuable scientific input and advice is acknowledged from hosting of visiting scientists and university students who utilised the experimental orchard and research facilities at Tatura SmartFarm.	

Recommendations

The following agronomic recommendation for Summerfruit growers can be made as a result of the research that was undertaken in this project:

- Use Cornerstone rootstock for high tree vigour to produce large, sweet fruit and high yield.
- Avoid planting dwarfing Krymsk® 1 rootstock due to low yield and excessive suckering.
- Krymsk® 86 rootstock provides semi-dwarfing vigour traits, good fruit size, red skin colouration and packout yield; however, may reduce fruit sweetness.
- Avoid high crop load regimes as they produce excessive suckering, low fruit weight, reduced sweetness, delayed maturity, increased firmness and lower packout percentage.
- Tatura Trellis out yields vase trees in establishment years and produces more uniform fruit weight and maturity due to having larger tree size (light interception) and capacity to carry more fruit and provide good light distribution.
- Regulated deficit irrigation (RDI) should be adopted as standard practice as there is no impact on yield and fruit quality and offers water savings of 40 % compared to full irrigation.
- Only implement severe deficit irrigation if there is a need to park trees under drought conditions (i.e., low irrigation allocation) as recovery takes more than 1 year.

It is recommended that the experimental Summerfruit orchard at the Tatura SmartFarm continues to be supported for the following reasons:

- A world-class research facility to test many aspects of whole-of-supply chain RD&E for the Summerfruit industry including crop physiology, agronomy, traceability, IPDM, sensing, mechanisation and robotics.
- An educational resource for training students, orchard workers and service providers on the best management systems for Summerfruit crops. This includes face-to-face training as well as online short technical videos and webinars. The orchard would also continue to provide promotion of sustainable farming practices to government.
- Accelerated adoption of sensor technologies for capturing accurate and precise data (e.g., fruit quality characteristics, flower number and distribution in a tree, canopy geometry, soil parameters and weather conditions).
- Contributes valuable data to new novel orchard designs, such as narrow row (pedestrian) orchards that incorporate 2D canopies, dwarfing rootstocks and cordon tree training systems to increase production efficiencies, labour advantages and sustainability benefits.
- Showcase the orchard at the forthcoming 2nd International Symposium on Precision Management of Orchards and Vineyards (https://ccem.eventsair.com/pmov2023) being held at the Tatura SmartFarm as well as other local and international events (e.g., 11th International Symposium on Irrigation of Horticultural Crops).

Recommendations for further research include:

- Advanced crop load management in orchards. This research will explore orchard-specific relationships between crop load, tree size and fruit quality (size and colour) using artificial intelligence and sensing data collected in the experimental Summerfruit, Sundial and Narrow (i.e., AS22002) orchards at the Tatura SmartFarm and commercial orchards.

- Precision spatial management systems using Agtech and sensing technologies to provide data on canopy, trunk, flower and fruit metrics for thinning, irrigation and pruning management (resource use efficiency) to increase crop uniformity and dovetail into 'next generation' precision orchard management (Agriculture 4.0).
- The economics of implementing spatial management in Summerfruit orchards based on Agtech and sensors.

Refereed scientific publications

O'Connell M.G., Scalisi, A. (2023). Carry-over effects of long-term water deficit in nectarine. *Acta Horticulturae* (draft)

Scalisi, A., O'Connell M.G., Whitfield D.M., Underwood J., Goodwin I. (2023). A ground-based mobile platform to measure and map canopy thermal indices in a nectarine orchard. *Acta Horticulturae* (in press)

O'Connell, M.G. (2022). Crop load and canopy architecture affect yield and fruit quality of 'Golden May' apricot. *Acta Horticulturae* 1346, 287-294. DOI:10.17660/ActaHortic.2022.1346.36

Scalisi, A.; O'Connell, M.G. McGlone, A, Langdon-Arms, S (2022). Evaluation of a portable impact probe for rapid assessments of flesh firmness in peaches and nectarines. *Acta Horticulturae* 1346, 837-844. DOI:10.17660/ActaHortic.2022.1346.107.

Park, S.; Ryu, D.; Fuentes, S.; Chung, H.; O'Connell, M.; Kim, J. (2021) Dependence of CWSI-based plant water stress estimation with diurnal acquisition times in a nectarine orchard. *Remote Sensing* 13, 2775. DOI:10.3390/rs13142775

O'Connell, M., Scalisi, A. (2021) Sensing fruit and tree performance under deficit irrigation in 'September Bright' nectarine. Acta Horticulturae 1314, 9-16. DOI:10.17660/ActaHortic.2021.1314.2

Scalisi, A.; O'Connell, M.G. (2021). Relationships between soluble solids and dry matter in the flesh of stone fruit at harvest. *Analytica* 2, 14-24. DOI: 10.3390/analytica2010002

Scalisi, A., O'Connell, M. Turpin, S, Lo Bianco, R. (2021) Diurnal irrigation timing affects fruit growth of late-ripening nectarines. *Acta Horticulturae* 1314, 61-68. DOI:10.17660/ActaHortic.2021.1314.9

Scalisi, A., O'Connell, M.G., Lo Bianco, R. (2021). Field non-destructive determination of nectarine quality under deficit irrigation. *Acta Horticulturae* 1314, 91-98. DOI:10.17660/ActaHortic.2021.1314.13

Park, S.; Ryu, D.; Fuentes, S.; Chung, H.; O'Connell, M.; Kim, J. (2021). Mapping very-high-resolution evapotranspiration from unmanned aerial vehicle (UAV) imagery. *ISPRS International Journal of Geo-Information* 10, 211. DOI:10.3390/ijgi10040211

O'Connell, M., Stefanelli, D. (2020). Effects of rootstock and crop load management on yield and fruit quality of early-season nectarine 'Rose Bright' and late-season peach 'September Sun'. *Acta Horticulturae* 1281, 121-130. DOI: 10.17660/ActaHortic.2020.1281.18

O'Connell, M., Stefanelli, D. (2020). Effect of crop load management and canopy architecture on yield and fruit quality of late-season plum 'Angeleno'. *Acta Horticulturae* 1281, 227-234. DOI:10.17660/ActaHortic.2020.1281.31

Scalisi, A.; Pelliccia, D.; O'Connell, M.G. (2020). Maturity prediction in yellow peach (Prunus persica L.) cultivars using a fluorescence spectrometer. *Sensors* 20, 6555. DOI:10.3390/s20226555

Scalisi, A.; O'Connell, M.G. (2020). Application of visible/NIR spectroscopy for the estimation of soluble solids, dry matter and flesh firmness in stone fruits. *Journal of the Science of Food and Agriculture* 101, 2100-2107. DOI: 10.1002/jsfa.10832

Scalisi, A., O'Connell, M., Lo Bianco, R., Stefanelli, D. (2019). Continuous detection of new plant water status indicators in stage I of nectarine fruit growth. *Acta Horticulturae* 1253, 9-16. DOI:10.17660/ActaHortic.2019.1253.2

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Goodwin, I., and O'Connell, M.G. (2017). Drought water management: an Australian perspective. *Acta Horticulturae* 1150, 219–232. DOI:10.17660/ActaHortic.2017.1150.31

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Intellectual property, commercialisation and confidentiality

No project IP, project outputs, commercialisation or confidentiality issues to report.

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Appendices

SF17006 Summerfruit Orchard Phase II

Final Report

Biosecurity and Agriculture Services-
Horticulture Services

June 2023

AGRICULTURE VICTORIA

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CONTENTS

EXECUTIVE SUMMARY

Transformational research by Agriculture Victoria Research (AVR) has resulted in the Australian summerfruit industry gaining valuable insight into future production systems that improve fruit quality and productivity, as well as supporting industry longevity and resilience.

The SF17006 Summerfruit Orchard Phase II project was led by Agriculture Victoria in consultation with industry members of Summerfruit Australia Limited and Hort Innovation. The project aim was to increase the quality of fruit to increase value and profitability of the Australian summerfruit industry and increase domestic and export sales by improving consistency in fruit quality of summerfruit (peach, nectarine, apricot & plum) through the effect of enhanced agronomic management practices (crop load, rootstock, irrigation management, canopy architecture). This is achieved through high-density orchard production systems and management practices capable of manipulating fruit yield and quality to meet domestic and export market quality specifications.

The Agriculture Victoria Horticulture Services team (HS) were responsible for engagement and practice change within the summerfruit industry. The objective was to use the learnings from this research to develop educational materials, tools, and resources to support quality improvements and profitability across the industry.

AVR research disseminated to the summerfruit industry included in the online repository (www.HIN.com.au website):

- Stonefruit production research
    - Rootstock experiments
    - Irrigation experiments
    - Canopy experiments
    - Crop load experiments
- Stonefruit harvest research
    - Maturity and fruit quality

Over the length of this project, the total website page hits focusing on stonefruit production research were 19,135. Thirty-nine videos were published with views totalling 21,906. Five virtual orchard tours that contain 360-degree panoramic photos of the research orchard experiments, had a total of 4,014 views. 24 newsletters were sent to 93 growers who had signed up to the Profitable Stonefruit network, with newsletters also sent to producers through the Summerfruit Australia Ltd industry newsletter, with 3,723 views in total.

The engagement and extension program was challenged by the restrictions of COVID-19 and required a flexible and agile approach to showcasing the project. With the inability to approach growers face-to-face (due to COVID restrictions), the program targeted the Profitable Stonefruit Network which is an existing Agriculture Victoria virtual network of ninety-three growers/exporters. The program also worked with the Summerfruit Australia network via the CEO newsletter, and connections to the Summerfruit Export Development Association (SEDA) group and Summerfruit Australia members more broadly.

A mixture of digital extension and traditional and virtual industry forums were delivered. The digital extension focused on development of website pages and videos to capture research information, providing a passive way for industry to find information using google searches. This extension also included e-newsletters, sent through emails to disseminate information to actively target an existing network of producers (with an export focus) containing links to the webpages on specific topics. A suite of interactive online resources was developed that included web pages containing research results, grower protocols, virtual orchard tours, and videos of interviews with scientists explaining the research and results, and time series photos of plant and fruit development over 5 years. Information placed on the Horticulture Industry Network (HIN) platform provided dissemination and awareness of the project and its advancements. Profitable Stonefruit Network growers/exporters, SEDA and the general summerfruit industry were directed to these resources through regular e-newsletters. Awareness of these topics were measured through video views, webpage hits, and the number of newsletters opened.

Traditional and virtual industry forums were used to disseminate information through face-to-face group information sessions called the Stonefruit Research Roadshows. Online meetings and webinars replaced these group information sessions in instances where COVID-19 restrictions were in place from 2020 to 2022. These events focused on production research and included post event webinar recordings as a way of disseminating awareness of these topics. Although attendance at the online events in 2020-22 were less than similar face-to-face events held in regional locations in 2019, the recordings provided greater flexibility for people to look at these presentations at a time that suited them and has resulted in a greater number of viewings.

The challenges and disruptions from the COVID-19 pandemic significantly impacted the summerfruit industry’s ability to uptake change or technology to support the optimal harvest quality as growers were not able to get pickers to pick at optimal times; harvest costs increased; airfreight/shipping costs increased; and growers/exporters were in survival mode. These externalities have also significantly clouded the ability to measure the impacts of the SF17006 project and the associated predicted increases in crop quality, value and volume. Despite this, results from a 2023 industry survey have indicated that, of the 27 respondents, 90% of them were aware of this summerfruit research, and 60% had implemented a change with their business decisions and orchard management practices because of one or more of the grower protocols.

BACKGROUND

The Summerfruit Orchard Phase 2 project (May 2018-July 2023) was led by Agriculture Victoria Research with the support of BAS Horticulture Services and Summerfruit Australia Ltd. The project aim was to increase the value and profitability of Australian horticulture by improving consistency in fruit quality of summerfruit (peach, nectarine, apricot & plum).

The Agriculture Victoria Horticulture Services team (HS) were responsible for engagement and extension within the summerfruit industry.

The objective of the program was to use the learnings from the research to develop systems, tools and resources to drive quality improvements and profitability across the horticulture industry.

SUMMERFRUIT EXTENSION

The HS contributions to the project in Victoria were subject to COVID-19 restrictions and stay at home orders. Flexible and agile extension approaches were required to disseminate information from Summerfruit Orchard Phase 2 research to targeted audiences. The recent COVID-19 pandemic required multiple approaches to showcasing innovation and practice change brought about through the research. These approaches included webpages, videos, newsletters to targeted networks, and virtual approaches such as webinars in place of the traditional face-to-face industry forums.

Digital extension involved both passive and active dissemination of information. It focused on the development of website pages and videos to capture research information on the existing Horticulture Industry Network (HIN) platform, providing a passive way for industry to find information using google searches. This extension also included e-newsletters, sent through emails to actively disseminate information to an existing targeted network of producers containing links to the webpages on specific topics.

Traditional and virtual industry forums were used to disseminate information through face-to-face group sessions that formed part of an annual cycle of Stonefruit Research Roadshows. Online meetings and webinars replaced these group sessions in instances where COVID-19 restrictions were in place.

The program targeted the existing Profitable Stonefruit Network which was an existing Agriculture Victoria virtual network of ninety-three growers and exporters who are Summerfruit Australia members, and via the CEO of Summerfruit Australia to include Summerfruit Australia members as well as the Summerfruit Export Development Association (SEDA) group.

ACTIVITIES & DELIVERABLES

1. Digital extension

Website landing pages were developed and published for Summerfruit Orchard Phase 2 project on the Horticulture Industry Network (HIN) website. This website contains research information for stone fruit (Summerfruit) producers across Australia.

The Profitable Stonefruit Network on this website is a well-established platform for research information focusing on production research, orchard management, harvest / post-harvest research, and market research. The Summerfruit Orchard Phase 2 project was able to take advantage of this network by developing information for the production focus. Information was then sent via the existing industry Profitable Stonefruit Network e-newsletter that growers had signed up to. The network e-newsletter contained descriptors with weblinks which directed members to new or updated research information on the HIN website. Summerfruit Australia (SAL) was also able to send this information via newsletters to a wider audience, providing an opportunity for producers around Australia to see the research.

Information on this website contains articles about the research developed by the key AVR researchers. This includes video interviews of these scientists providing insights into the research, and 'how to' videos.

Written, visual and auditory applications such as photos, diagrams, virtual tours and videos support a number of learning styles. This information supports those wanting to revisit information or to understand more about the research, and is especially useful after a face-to-face event or webinar where a topic is initially introduced.

1.1 The HIN website content

1.1.1 Summerfruit extension

Research focus	Summary data	
Stonefruit production research	**Total web hits**	19,135
- Rootstock experiments	**Videos published**	39
- Irrigation experiments	**Videos - total views**	21,906
- Canopy experiments	**Virtual tours published**	5
- Crop load experiments	**Virtual tours - total views**	4,014
Stonefruit harvest research	**Newsletters sent**	24
- Maturity and fruit quality	**Newsletters - total views**	3,723

Specific information (landing) pages for Summerfruit Orchard Phase 2 were developed under the Production research focus (tab) of the Profitable Stonefruit Network (http://www.hin.com.au/networks/profitable-stonefruit-research#tab__177176).

The following pages were developed as an online industry manual enabling them to be updated as research results became available:

- Stonefruit: rootstock experiments
- Stonefruit: irrigation experiments
- Stonefruit: canopy and crop load experiments

These pages contain an introduction to the research, research results and key grower protocols for rootstock, irrigation, canopy and crop load practices.

1.1.2 Protocol extension

Grower protocols from the research were developed and extended on the network pages:

- Grower protocols - rootstock performance in stonefruit http://www.hin.com.au/networks/profitable-stonefruit-research/stonefruit-rootstock-trials#Protocols
- Irrigation protocols - current recommendations and guidelines http://www.hin.com.au/networks/profitable-stonefruit-research/stonefruit-irrigation-trials#protocols

- Protocols for canopy design options for stonefruit http://www.hin.com.au/networks/profitable-stonefruit-research/stonefruit-canopy-crop-load-trials#protocol1
- Protocols for crop load management in stonefruit http://www.hin.com.au/networks/profitable-stonefruit-research/stonefruit-canopy-crop-load-trials#protocol2

1.1.3 Google Analytics for Summerfruit Orchard Phase 2 research pages on the website

Table 1 provides statistical data from Google Analytics on the number of page hits since the start of the Summerfruit Orchard Phase 2 project.

Table 1: Number of webpage hits since development (Date range: 1 Jul 2019 – 29 May 2023)

Topics	Hits	Link
Profitable Stonefruit research (all pages)	19135	http://www.hin.com.au/networks/profitable-stonefruit-research#tab__177176
Stonefruit rootstock experiments	1016	http://www.hin.com.au/networks/profitable-stonefruit-research/stonefruit-rootstock-trials
Topics: • Introduction • Grower Protocols - Current recommendations and guidelines • Results • Field and fruit quality results from Rootstock – Crop load study • Nectarine and peach rootstock and crop load results • Virtual orchard tour - 360-degree photography of the orchard • Time series photos		
Stone fruit canopy and crop load experiments	1442	http://www.hin.com.au/networks/profitable-stonefruit-research/stonefruit-canopy-crop-load-trials
Topics: • Protocols - Current recommendations and guidelines • Protocols for canopy design options for stonefruit • Protocols for crop load management in stonefruit • Results and Observations for 2022 • Virtual Orchard tours • Time series photos • Crop load and fruit position influence variability in nectarine quality • The effects of canopy architecture and crop load on non-structural carbohydrate in young stone fruit trees • Results and observations 2017-2021 (pages) • 2021 Results from the Canopy - Crop load study • 2020 Plum 'Angeleno' Science paper and Apricot 'Golden May' quality and yield results • 2019 Plum, Apricot, Peach and Nectarine findings (includes videos)		
Stonefruit irrigation experiments	973	http://www.hin.com.au/networks/profitable-stonefruit-research/stonefruit-irrigation-trials
Topics: • Stonefruit nectarine drought recovery response to deficit irrigation • Introduction to the research • Irrigation Protocols - Current recommendations and guidelines • Results • 2016-22 Yield and fruit results • 2021 Sensing fruit and tree performance under deficit irrigation in ‘September Bright’ nectarine • 2018 Plant water status trial • Irrigation management: Water supply, delivery, application and strategies • 2019 Virtual orchard tour • Time series photos 2015-2020		

1.2 Videos

Videos were developed as extension tools to support the research. Videos provide a visual and auditory approach to explaining research. Videos were embedded into their respective topical webpages and used to summarize research by providing an overview of the science and results from the research. See the list of videos developed for this research in table 2 which also includes longer videos that provide a detailed explanation about research topics, such as webinar recordings and lectures.

Table 2: Number of views – YouTube statistics. Note, all YouTube videos are embedded into the relevant website pages.

Videos	Views (to 30 May 2023)	Date Published	Link
Stonefruit drought recovery study on deficit irrigated nectarine trees	206	Mar 6, 2023	https://youtu.be/2bhpPxdMR_k
Summerfruit research orchard update at the Summerfruit Australia Export information sessions	163	May 26, 2022	https://youtu.be/3SRVmnmn1A4
Summerfruit research overview 2022	433	May 4, 2022	https://youtu.be/cy1udaFy5x8
Stonefruit Orchard experiments - aerial view	801	Dec 14, 2021	https://youtu.be/Peovri0u084
Stonefruit canopy research overview October 2021	1658	Dec 13, 2021	https://youtu.be/1cSN3EGhRTs
Stonefruit cropload research overview October 2021	472	Dec 13, 2021	https://youtu.be/25vONN0BSiY
Stonefruit Irrigation research overview October 2021	337	Dec 13, 2021	https://youtu.be/Oymp1vZEMfw
Stonefruit rootstock research overview October 2021	549	Dec 13, 2021	https://youtu.be/FHo29JLmdLU
Agriculture Victoria Research on Stonefruit	102	Oct 31, 2021	https://youtu.be/_wu3T8Qj6V8
Summerfruit Webinar August 2021 - Rootstock research on peach and nectarine.	185	Aug 30, 2021	https://youtu.be/DjwIW73O9dU
Summerfruit Webinar 1 Production and Ag Tech Research 25 Aug 2021	138	Aug 26, 2021	https://youtu.be/SCiSW7QG_Ag
Demo 6. Nectarine Autumn Bright Palmette Demonstration 2015-2020	386	Apr 14, 2020	https://youtu.be/zSyfjPVZV2k
Demo 5. Peach Snow Flame 25 Palmette Demonstration 2015-2020	213	Apr 14, 2020	https://youtu.be/lXiwKJQ8lxg
Demo 4. Peach Snow Flame 23 Palmette Demonstration 2015-2020	364	Apr 14, 2020	https://youtu.be/zT5py5HDRWs
Demo 3. Peach O'Henry Cordon Demonstration 2015-2020	5263	Apr 14, 2020	https://youtu.be/5h490ps0oPo
Demo 2. Peach O'Henry Palmette Demonstration 2015-2020	417	Apr 14, 2020	https://youtu.be/Ynl0-mzD-0s
T. Irrigation Experiment - Nectarine September Bright on Open Tatura trellis 2015-2020	405	Apr 14, 2020	https://youtu.be/-CzUBB17Bag
10. Plum Angeleno Vase canopy experiment 2015-2020	528	Apr 9, 2020	https://youtu.be/-UI024URfDU
9. Plum Angeleno Tatura Trellis canopy experiment 2015-2020	407	Apr 9, 2020	https://youtu.be/rQanOw5IOB0
8. Apricot Golden May Vase Canopy experiment 2015-2020	310	Apr 8, 2020	https://youtu.be/nKfaZ1TgCAo
7. Apricot Golden May Tatura trellis canopy experiment 2015-2020	1672	Apr 8, 2020	https://youtu.be/mTS0oc5lYtw
6. Nectarine Autumn Bright Vertical Leader canopy experiment 2015-2020	209	Apr 8, 2020	https://youtu.be/rkMReFMO2tg

Videos	Views (to 30 May 2023)	Date Published	Link
5. Nectarine Autumn Bright on Tatura Trellis Canopy Experiment 2015-2020	189	Apr 8, 2020	https://youtu.be/O6jOy1kCH4Y
4. Peach August Flame on Tatura Trellis Canopy Experiment 2015-2020	221	Apr 7, 2020	https://youtu.be/LXi9TiMPHlk
3. Peach August Flame Vertical Leader Canopy experiment 2015-2020	162	Apr 7, 2020	https://youtu.be/slANy8XowOg
Demo 1. Nectarine Ice Princess Vase demonstration 2015-2020	120	Apr 7, 2020	https://youtu.be/kt1iKdJdKW0
2 J. Nectarine Rose Bright Vase Krymsk86 Rootstock Experiment 2015-2020	91	Apr 6, 2020	https://youtu.be/HKJ5LBhQxMg
2 I. Nectarine Rose Bright Vase Krymsk1 Rootstock Experiment 2015-2020	35	Apr 6, 2020	https://youtu.be/FzugTEYK-hU
2 H. Nectarine Rose Bright Vase Elberta Rootstock Experiment 2015-2020	26	Apr 6, 2020	https://youtu.be/HRFRlyquXtw
2 G. Nectarine Rose Bright Vase Cornerstone Rootstock Experiment 2015-2020	63	Apr 6, 2020	https://youtu.be/WY8o1B5OZw4
2 F. Nectarine Rose Bright Vase Nemarguard Rootstock Experiment 2015-2020	112	Apr 6, 2020	https://youtu.be/1hGsP1xbODI
1 E. Peach September Sun Vase Cornerstone Rootstock Experiment 2015-2020	18	Apr 6, 2020	https://youtu.be/k6uxtQrc7Yc
1 D. Peach September Sun Vase Cadaman Rootstock Experiment 2015-2020	139	Apr 6, 2020	https://youtu.be/2cfv8hhUMNY
1 C. Peach September Sun Vase Krymsk86 Rootstock Experiment 2018-2020	53	Apr 6, 2020	https://youtu.be/L7_Gmt-aKSQ
1 B. Peach September Sun Vase Elberta rootstock experiment 2016-2020	58	Apr 6, 2020	https://youtu.be/Z-sMH26IZxY
Regulated Deficit Irrigation for stonefruit quality	332	Sept 9, 2019	https://youtu.be/poEZGyJS4sM
Stonefruit Cropload Experiments Plum Angeleno	4831	Sept 9, 2019	https://youtu.be/Wr2SSIuW0XA
Stonefruit Cropload experiments Apricot Golden May	164	Sept 9, 2019	https://youtu.be/L_HpOhRNRqA
Stonefruit research roadshow 2019	74	Aug 27, 2019	https://youtu.be/jlOD499mUXU
Number of videos published: 39 Total Views:	21906		

1.3 Virtual Orchard Tours with 360-degree photos

Many growers and producers were not able to visit the research orchard during the peak growing season as they were too busy in their own businesses. So, virtual tours were developed on the HIN website to show industry members a view of the orchard during blossom and fruit development prior to harvest, allowing producers to look at the experiments at a time that suited them. Virtual tours were made of 360-degree photos sequenced one after the other to simulate growers walking through the orchard. Virtual tours were developed for the irrigation experiment, rootstock experiments and the canopy and crop load experiments comparing canopy design. Five tours were developed from July 2019. Table 3 provides some examples of these tours.

Table 3: example of virtual tours in the stonefruit research orchard

Virtual Tours	Views	Link
Rootstock experiment: fruit on Peach September sun 2020#	883	http://www.hin.com.au/networks/profitable-stonefruit-research/stonefruit-rootstock-trials#Field
Irrigation experiment: flowering of nectarine September bright 2019#	546	http://www.hin.com.au/networks/profitable-stonefruit-research/stonefruit-irrigation-trials#virtualtour
Canopy crop load experiment: Peach August Flame - vertical trellis versus Tatura trellis 2020#	916	http://www.hin.com.au/networks/profitable-stonefruit-research/stonefruit-canopy-crop-load-trials#virtualtour
Canopy crop load experiment: plum Angeleno - Tatura trellis versus vase 2020#	888	http://www.hin.com.au/networks/profitable-stonefruit-research/stonefruit-canopy-crop-load-trials#virtualtour
Palmette and cordon tree structures 2019*	763	http://www.hin.com.au/networks/profitable-stonefruit-research/stonefruit-novel-canopy-systems-for-mechanisation/palmette-and-cordon-virtual-orchard-tours
Total views:	4014	

Orbix360 software analytics

*Roundme.com software analytics – note: As of February 2023, the Roundme service was discontinued, therefore the tours are no longer visible.

1.4 Newsletters containing Summerfruit Orchard Phase 2 information.

To update producers about the latest research on the website, several newsletters were developed and sent through the Profitable Stonefruit Network. The network currently has 93 members across Australia, most of whom signed up to receive the newsletter at meetings held in major growing regions such as Swan Hill, Cobram, and Renmark. Information from these newsletters was also passed on to other networks by Summerfruit Australia, through their industry newsletter called 'the Drupe'.

Examples of newsletters containing Summerfruit Orchard Phase 2 information with links to online newsletters:

30 May 2022

- NATIONAL ROADSHOW video recording of presentation on the stonefruit orchard research results
- Big data: Mobile sensing in orchards

11 March 2022

Production research results

- Results from the experiments for the 2021-2022 season from the Stonefruit research orchard, Tatura SmartFarm

14 December 2021

Summerfruit production research results

Videos - results of:

- canopy research
- rootstock research
- crop load research
- irrigation research

9 September 2021

Webinars recorded from summerfruit industry events

- August - webinar 1: Production research, Ag Tech research
- September - webinar 2: Supply chain research

17 June 2021

Grower Protocols - Current recommendations and guidelines

- Rootstock performance
- Irrigation protocols
- Canopy design options
- Crop load management

12 April 2021

- Canopy - Crop load study
- Rootstock - Crop load study
- Deficit irrigation study

Table 4 contains statistics from Campaign Monitor for 93 newsletter recipients. The percentage of participants opening the emails varied from 32 to 64% according to Campaign Monitor. However, the total number of openings were often much higher indicating that the newsletter had been passed on to other industry members that were not on the Campaign Monitor email list, and therefore were not recorded as '% Recipients opened'.

Table 4: Newsletter topics and statistics

Newsletter date	Topics	Total Opens	% Recipients opened	Link
7 March 2023	• Drought recovery responses of a nectarine orchard by using full irrigation following long-term deficit water management. • Can we reduce the risk of storage disorders in nectarine and peach after sea freight? • When to harvest stonefruit	68	45	https://victoriandepartmentofeconomicdevelopmentjobstr.createsend.com/campaigns/reports/viewCampaign.aspx?d=j&c=69D83EA8D6DCF37F&ID=FE2F15DDAA0A6F9F2540EF23F30FEDED&temp=False&tx=0&source=Report
11 Oct 2022	• Stonefruit research overview for the Australian Summerfruit industry	152	54	https://victoriandepartmentofeconomicdevelopmentjobstr.createsend.com/campaigns/reports/viewCampaign.aspx?d=j&c=69D83EA8D6DCF37F&ID=64832A9B586606CB2540EF23F30FEDED&temp=False&tx=0&source=Report
22 Jul 2022	• Research & development showcase and SAL Annual General meeting 28 July - Tatura, Victoria.	232	49	https://victoriandepartmentofeconomicdevelopmentjobstr.createsend.com/campaigns/reports/viewCampaign.aspx?d=j&c=69D83EA8D6DCF37F&ID=6A430B42E9A14B0E2540EF23F30FEDED&temp=False&tx=0&source=Report
30 May 2022	• NATIONAL ROADSHOW video recording of presentation on the stonefruit orchard research results • Big data: Mobile sensing in orchards	147	52	https://victoriandepartmentofeconomicdevelopmentjobstr.createsend.com/campaigns/reports/viewCampaign.aspx?d=j&c=69D83EA8D6DCF37F&ID=191C76426C3EE0282540EF23F30FEDED&temp=False&tx=0&source=Report
3 May 2022	• Research overview for the Australian Summerfruit industry • Dr Mark O'Connell to present research results at the SAL 2022/23 export season Export Information Sessions: SF17006 Summerfruit Orchard Phase II - Key findings, protocols and where to find more information • Summerfruit industry research and development forum and showcase	117	56	https://victoriandepartmentofeconomicdevelopmentjobstr.createsend.com/campaigns/reports/viewCampaign.aspx?d=j&c=69D83EA8D6DCF37F&ID=8BFF9076242ABAA72540EF23F30FEDED&temp=False&tx=0&source=Report
11 March 2022	Production research results • Results from the experiments for the 2021-2022 season from the Stonefruit research orchard, Tatura SmartFarm	76	55	https://victoriandepartmentofeconomicdevelopmentjobstr.createsend.com/campaigns/reports/viewCampaign.aspx?d=j&c=69D83EA8D6DCF37F&ID=6C7BE8D5442F6F122540EF23F30FEDED&temp=False&tx=0&source=Report
15 February 2022	• Sensors for Summerfruit (farm walk)	177	64	https://victoriandepartmentofeconomicdevelopmentjobstr.createsend.com/campaigns/reports/viewCampaign.aspx?d=j&c=69D83EA8D6DCF37F&ID=358

Newsletter date	Topics	Total Opens	% Recipients opened	Link
				D5CFA26A8C9FE2540EF23F30FEDED&temp=False&tx=0&source=Report
14 December 2021	Summerfruit production research results Videos - results of: • canopy research • rootstock research • crop load research • irrigation research	178	54	https://victoriandepartmentofeconomicdevelopmentjobstr.createsend.com/campaigns/reports/viewCampaign.aspx?d=j&c=69D83EA8D6DCF37F&ID=DA49832C1CA2FDD22540EF23F30FEDED&temp=False&tx=0&source=Report
9 September 2021	Webinars recorded from recent summerfruit industry events • August - webinar 1: Production research, Ag Tech research • September - webinar 2: Supply chain research	92	42	https://victoriandepartmentofeconomicdevelopmentjobstr.createsend.com/campaigns/reports/viewCampaign.aspx?d=j&c=69D83EA8D6DCF37F&ID=E4502243C8B3A8522540EF23F30FEDED&temp=False&tx=0&source=Report
30 August 2021	Reminder • *Video - Webinar 1 Production and Ag Tech research	56	32	https://victoriandepartmentofeconomicdevelopmentjobstr.createsend.com/campaigns/reports/viewCampaign.aspx?d=j&c=69D83EA8D6DCF37F&ID=347C088FD2F869072540EF23F30FEDED&temp=False&tx=0&source=Report
25 August 2021	Today's webinar • Webinar 1. Production research, Ag Tech research • 4 - 5 pm Vic, NSW, Qld; 3.30 - 4.30pm SA; 2 - 3pm WA • Ask questions live online! • Due to the current challenges with Covid-19, these industry events replace the 2021 Stonefruit Research Roadshows	100	37	https://victoriandepartmentofeconomicdevelopmentjobstr.createsend.com/campaigns/reports/viewCampaign.aspx?d=j&c=69D83EA8D6DCF37F&ID=3F2249027445C4132540EF23F30FEDED&temp=False&tx=0&source=Report
23 August 2021	Reminder • Webinar 1. Production research, Ag Tech research - 25th August • Webinar 2. Supply chain research - 1st September • Ask questions live online! • Due to the current challenges with Covid-19, these industry events replace the 2021 Stonefruit Research Roadshows	151	49	https://victoriandepartmentofeconomicdevelopmentjobstr.createsend.com/campaigns/reports/viewCampaign.aspx?d=j&c=69D83EA8D6DCF37F&ID=365BB2E1996CB9CD2540EF23F30FEDED&temp=False&tx=0&source=Report
4 August 2021	Webinars - Research results • Webinar 1. Production research, Ag Tech research • Webinar 2. Supply chain research	334	45	https://victoriandepartmentofeconomicdevelopmentjobstr.createsend.com/campaigns/reports/viewCampaign.aspx?d=j&c=69D83EA8D6DCF37F&ID=B305D9B4995A48C82540EF23F30FEDED&temp=False&tx=0&source=Report
17 June 2021	Grower Protocols - Current recommendations and guidelines • Rootstock performance • Irrigation protocols	259	42	https://victoriandepartmentofeconomicdevelopmentjobstr.createsend.com/campaigns/reports/viewCampaign.aspx?d=j&c=69D83EA8D6DCF37F&ID=4E4

Newsletter date	Topics	Total Opens	% Recipients opened	Link
	• Canopy design options • Crop load management			2771797F2395F2540EF23F30FEDED&temp=False&tx=0&source=Report
12 April 2021	• Canopy - Crop load study • Rootstock - Crop load study • Deficit irrigation study	95	40	https://victoriandepartmentofeconomicdevelopmentjobstr.createsend.com/campaigns/reports/viewCampaign.aspx?d=j&c=69D83EA8D6DCF37F&ID=FE93C273851624BF2540EF23F30FEDED&temp=False&tx=0&source=CampaignSent
25 September 2020	• Grower Protocols, and results of field and fruit quality 2016-2020, for: 1. Stonefruit canopy & crop load experiments 2. Stonefruit rootstock experiments 3. Irrigation experiments	103	42	https://victoriandepartmentofeconomicdevelopmentjobstr.createsend.com/campaigns/reports/viewCampaign.aspx?d=j&c=69D83EA8D6DCF37F&ID=BC0D0E9DA64B0C212540EF23F30FEDED&temp=False&tx=0&source=Report
2 September 2020	• Results: canopy-crop load experiments for Plum	86	37	https://victoriandepartmentofeconomicdevelopmentjobstr.createsend.com/campaigns/reports/viewCampaign.aspx?d=j&c=69D83EA8D6DCF37F&ID=7FE8B06CAF744C702540EF23F30FEDED&temp=False&tx=0&source=Report
26 August 2020	• Results for rootstock experiment	72	45	https://victoriandepartmentofeconomicdevelopmentjobstr.createsend.com/campaigns/reports/viewCampaign.aspx?d=j&c=69D83EA8D6DCF37F&ID=BDD909E8AB2ABF412540EF23F30FEDED&temp=False&tx=0&source=Report
5 August 2020	• Results: Stonefruit canopy crop-load experiments (4 seasons)	120	50	https://victoriandepartmentofeconomicdevelopmentjobstr.createsend.com/campaigns/reports/viewCampaign.aspx?d=j&c=69D83EA8D6DCF37F&ID=6268AEA820FA6BFB2540EF23F30FEDED&temp=False&tx=0&source=Report
16 April 2020	• Videos of orchard photos spanning 2015 to 2020 for: 1. Rootstock experiments 2. Canopy crop load experiments 3. Irrigation experiments 4. Palmette & Cordon demonstrations • Virtual orchard tours (360 photos): Rootstock and Canopy crop load experiments	170	58	https://victoriandepartmentofeconomicdevelopmentjobstr.createsend.com/campaigns/reports/viewCampaign.aspx?d=j&c=69D83EA8D6DCF37F&ID=EB5B1895E2437B6D2540EF23F30FEDED&temp=False&tx=0&source=Report
1 November 2019	• Irrigated scheduling for RDI • Introduction to orchard technology	164	48	https://victoriandepartmentofeconomicdevelopmentjobstr.createsend.com/campaigns/reports/viewCampaign.aspx?d=j&c=69D83EA8D6DCF37F&ID=FE16F4AC9213BB572540EF23F30FEDED&temp=False&tx=0&source=Report
3 October 2019	• Update on the canopy crop-load experiments - Plum Angeleno: Tatura trellis versus vase - Apricot Golden May: Tatura trellis versus vase • Virtual Orchard Tour - A look at tree structures of Palmette and Cordon	96	47	https://victoriandepartmentofeconomicdevelopmentjobstr.createsend.com/campaigns/reports/viewCampaign.aspx?d=j&c=69D83EA8D6DCF37F&ID=A82

Newsletter date	Topics	Total Opens	% Recipients opened	Link
	• In case you missed the Stonefruit Research Roadshow 2019			587B19065A49E2540EF23F30FEDED&temp=False&tx=0&source=Report
9 September 2019	• Regulated Deficit Irrigation during water scarcity	410	55	https://victoriandepartmentofeconomicdevelopmentjobstr.createsend.com/campaigns/reports/viewCampaign.aspx?d=j&c=69D83EA8D6DCF37F&ID=F7B7E5C1C61A278C2540EF23F30FEDED&temp=False&tx=0&source=Report
31 July 2019	Stonefruit Research Roadshow 13 - 15 August 2019 Renmark - Swan Hill – Cobram • Irrigation management impacts fruit quality	268	46	https://victoriandepartmentofeconomicdevelopmentjobstr.createsend.com/campaigns/reports/viewCampaign.aspx?d=j&c=69D83EA8D6DCF37F&ID=6386A37C4B97F9AE2540EF23F30FEDED&temp=False&tx=0&source=Report
Newsletters: 24	**Total opens:**	**3723**		

2. Traditional and virtual industry forums extension

The Stonefruit Orchard Phase 2 project information was also disseminated through webinars and group sessions called the Stonefruit Research Roadshows. Horticulture Services organised and facilitated these roadshows at major growing regions located in Victoria and South Australia. When traditional face-to-face events could not be conducted due to the COVID-19 pandemic restrictions, virtual technologies were adopted such as webinars. These webinars were recorded and made available for those unable to attend the online events.

2.1 Summerfruit Orchard Phase 2 Project inclusion at industry forums

2.1.1 Stonefruit Research Roadshows

The Stonefruit Research Roadshows were initially developed in 2016 to showcase the science being conducted at Agriculture Victoria’s stonefruit research orchard in Tatura.

The 2019 Stonefruit Research Roadshow event, held in August 2019 at Renmark, Swan Hill and Cobram growing regions, exposed the industry to science from the Summerfruit Research Orchard Phase 2 project, including harvest and post-harvest research from a supply chain innovation project (Serviced Supply Chains).

Topics covered by researchers:

- Harvest maturity impacting fruit quality.
- Irrigation management impacts fruit quality.
- Observations from monitoring export fruit: sea freight and airfreight
- Stonefruit cultivar performance during export and predicting shelf life
- New fruit quality monitoring technology
- Industry Updates

Table 5 lists the number of attendees at the stonefruit roadshow across Renmark, Swan Hill and Cobram.

Table 5. attendance at three major grower locations

Attendance	Growers	Ag Vic	Service Providers	Total
Renmark	11	5	2	18
Swan Hill	17	6	4	27
Cobram	11	5	2	18
			Total attendance	60

Comments captured from attendees at these events:

- All presentations were relevant and appreciated. It is rare that R&D programs are as well-focused upon industry needs. So thanks to you all for your excellent work and coming to Cobram. Well done!
- All topics and updates were fantastic.
- Good information relating to: optimal irrigation with limited water; monitoring fruit maturity; choosing optimal harvest point
- All topics relevant as we don't have many avenues in the stonefruit industry for local research knowledge.
- Experiments occurring at Tatura - I will follow up on irrigation requirement
- Glad to hear about the HIN website
- Industry updates very useful
- Some of the research seems to confirm the obvious
- New technology info good but don't want data logged. Need to be able to use it for immediate results in paddock.
- Industry update is a good addition
- Harvest maturity related to DA meter (Good)
- Confirmed irrigation practices
- Interesting report on export temperature.
- Good information on monitoring technology

Is there anything you would like more on?

- Increasing shelf life of fruit
- Fruit handling at retail distribution / store for domestic sales
- Different types of nutrition and how they alter fruit quality - synthetic - organic
- Data on temp from field and how long @ each temp
- Think presentation was good - worthwhile
- Ruben technology
- Export temp monitoring
- Orchard mechanisation
- Early ethylene production - chemical/cultural manipulation
- Irrigation
- Will continue to monitor the advances on the different areas
- Need to look at the data SIM logger in the coming season for air freight
- Transition to mechanised harvesting
- New handheld fluorescence
- DA meter
- New fruit quality monitoring technology
- Fruit quality meter using fluorescence
- Stonefruit that doesn't go soft

2.1.2 Webinar Series & industry forums – an alternative to the roadshow during the Covid 19 pandemic

2021 - Summerfruit Industry Webinars: Production research, Ag Tech research and supply chain innovation research - August / September 2021.

As an alternative to a face-to-face roadshow, the project team trialled using webinars. Table 6 lists the research topics, that were presented to attendees. Table 7 captures the number of registrations and actual attendees to the webinar event, and Table 8 highlights how useful the topics were from data captured through a poll. 93% indicated that they thought it was useful information for their business, and 85% would like to see more of these presentations and learn more about these topics.

A comment from one of Australia's largest producers based in Swan Hill, said "Good way to present it (information as a webinar) given that face-to-face events were not possible."

Table 6: Webinar for 2021 focused on research from the SF17006 project.

• 1st Webinar – 25 August
Production and Ag Tech research • Rootstocks on peach and nectarine. Results from SF17006 project, Experimental Stonefruit Orchard with Dr Mark O'Connell, Agriculture Victoria • Overview of the Ag Tech research projects, Dr Mark O'Connell, Agriculture Victoria • Hand held sensor: measuring fruit quality and maturity, Dr Daniel Pelliccia, Rubens technologies • Mobile platform to map fruit number, size, colour and canopy size, Dr Steve Scheding, Green Atlas
Webinar video on 'Stonefruit grower events' page http://www.hin.com.au/networks/profitable-stonefruit-research/stonefruit-grower-events or on YouTube: https://www.youtube.com/watch?v=SCiSW7QG_Ag (135 views since publication)

Table 7. Number of registrations and attendees to the webinar event.

Date	Webinar Event Name	No. Registered	No. Attendees	Poll:
				Number that answered poll questions
19/08/2021	Production and Ag Tech research	49	34	14

Table 8. Poll numbers totalled for whole webinar series.

No. Registered	No. Attendees	Poll:	Which of the following best describes you?				How useful was this information for your business?			Would you like to see more of these presentations?		Would you use this information in your business			Would you like to learn more about this topic?	
Total for series:		#no. answered	Grower	Exporter	Both	Service provider*	Useful	Not useful	unsure	Yes	No	Yes	No	Not sure	Yes	No
		14	2	0	2	3	13	0	1	12	2	12	1	1	12	2

*Note: There was some confusion using the generic term 'Service provider' as it was interpreted by some attendees as exporters/packhouses, not just agriculture service businesses, and government researchers

2022 - National roadshow strategy for SF17006: stonefruit experimental orchard research

Discussions with the stonefruit experimental orchard advisory committee (March 2022) about the national roadshow, with consideration of the COVID-19 pandemic risks[1], and inclusion of future consultation with regional grower groups and organisations, resulted in the following strategy to deliver information to Summerfruit producers around Australia and will most likely consist of:

- Hybrid virtual presentations to grower groups in Western Australian, Tasmania, New South Wales and Queensland.
- Hybrid[2] or face-to-face[3] presentations to regional areas in Victoria. These include Cobram region, Swan Hill region, and possibly Mildura region to include growers just across the border in South Australia as well.

Extension of this research was delivered to grower groups at one of their existing pre-planned events, unless requested by grower groups for a single focused event on this research.

In the case of COVID-19 variant causing more shutdowns or increasing risks to the health of staff and recipients, a virtual online event was run, and a recording made for those who couldn't attend that one off event. Evidence from the 2021 Summerfruit research webinar series suggests that recording the event and making it available to growers to view at their leisure via newsletters is a practical approach, with 135 views since its publication in August 2021 in its entirety, and with videos split into topics such as rootstock research on peach and nectarine viewed 172 times.

[1] Current risks: https://www.health.gov.au/health-alerts/covid-19/case-numbers-and-statistics#cases-by-state-and-territory

[2] Hybrid virtual presentations are online live presentations given to regional grower events, as part of a pre-existing event organised by industry. They require regional organisers to access Wi-Fi and connect a laptop and data projector or large television screen with a sound system for the online presentation with capability to operate virtual platforms such as Zoom.

[3] COVID-19 risks must still be considered before any face-to-face meetings occur, and that risk is assessed by Agriculture Victoria and the individual. Therefore, face-to-face meetings will be only considered in regions close to the Tatura research centre, and the willingness of Dr Mark O'Connell to attend these events.

Table 9 highlights approaches around Covid-19 to present grower protocols to industry nationwide. Dr Mark O'Connell attended both virtual and regional events within Victoria, with risks considered for each event.

Table 9: National and regional discussions for alternatives to travelling to grower regions around Australia, with events listed and attended by Dr Mark O'Connell.

Region	Comment / request
Queensland: Andrew Finlay (Chair SAL Board)	Due to Covid risk, Andrew suggested presenting information at online AGM. Mark O'Connell presented at AGM 31st March 2022 (11 producers attended – large production: Vic, NSW and Qld members, plus SAL CEO & VFF)
Cobram: CDFGA – Karen Abberfield (IDO)	May 17th – Cobram Executive board + growers: event cancelled as export event was occurring same night. Mark O'Connell attended Cobram Export information session
Swan Hill: SFDA – Dean Morpeth (President)	From discussions, Mark O'Connell attended Swan Hill Export information session
Industry wide - Trevor Ranford (CEO SAL)	Trevor provided opportunity for Mark O'Connell to attend and present grower protocols at the Export Information Sessions - 6.30pm – 8.00pm - Swan Hill Region, Cobram Region & Shepparton Region • Monday 16 May 2022, 4.30pm-6.30pm – Swan Hill: Woorinen Football and Netball Club. Reserve Road, Woorinen VIC 3589 (approx. 50 participants) • Tuesday 17 May 2022, 4.30 pm-6.30 pm – Cobram: Cobram & District Fruit Growers Association Office. 30A Bank Street, Cobram VIC 3644 (approx. 30 participants) • Wednesday 18 May 2022, 4.30pm-6.30pm – Shepparton: Mooroopna Pizzeria and Wine Bar. 88 McLennan St, Mooroopna VIC 3629 (Attendance – approx. 30)
Goulburn Murray Region: Fruit Growers Victoria - 2 hour event – Mark O'Connell at stand.	25 May 2022 - Fruit Tech 2022. Local to Mark O'Connell's office and region.
Tasmania: Fruit Growers TAS **Lawrence Cowley, Industry Development Officer - Fruit Growers Tasmania Inc.** **262 Argyle Street, Hobart. TAS 7000**	Hosted online event on Monday 20th June 3.15pm Attendance: 3 businesses – Large apricot producers
Industry wide: Trevor Ranford, Mark O'Connell, Ian Goodwin	Summerfruit Industry Technical R & D update 28th July 2022, Tatura SmartFarm AgVic 1. Summerfruit Aust AGM 2. Lunch 3. R&D update 4. Tatura SmartFarm tour and AgTech showcase Attendance: 40
Western Australia: **Shay Crouch WA Perth NRM – Sustainable Ag Manager**	Discussed opportunity to present online to grower group plus options for other topics 26 May 2022. Unfortunately, it did not go ahead.
South Australia:	Industry numbers reduced: members selling farm or changing business away from summerfruit production. Considered online national AGM to be best bet.

2023- Summerfruit Australia industry event, 16th May, Moama

At a Summerfruit Australia Ltd grower event held in May 2023, Dr Mark O'Connell spoke about recovery responses of deficit irrigated nectarine trees, followed by Mark Hincksman, from Horticulture Services highlighting the Horticulture Industry Network website (hin.com.au) industry resources showcasing research findings and information. Mark then provided participants with a survey on the SF17006 project.

INDUSTRY LEARNINGS & ADOPTION

The challenges and disruptions from the COVID-19 pandemic significantly impacted the summerfruit industry's ability to uptake change or technology to support the optimal harvest quality as growers were not able to get pickers to pick at optimal times; harvest costs increased; airfreight/shipping costs increased; and growers/exporters were in survival mode.

Externalities over the past three years have significantly clouded the ability to measure the impacts of the SF17006 project and the associated predicted increases in crop quality, value, and volume. COVID-19 impacted the export of Australian summerfruit during both the 2020 & 2021 seasons. The 2020 season's exports were impacted by snap port closures and delays in markets. The 2021 season was even more challenging with labour shortages disrupting optimal harvest times, reduced availability and increased costs of air freight, and reduced availability of shipping containers and increased costs of shipping. During the 2020-21 season, the summerfruit industry exported 22,000 tonnes, an increase of 1% from the previous season but below what was anticipated. Despite the drop in export tonnage, the tonnage was still greater than three years ago as summerfruit exports have shown a steady increase over the previous three seasons.

Snapshot of the industry's awareness and uptake of the research

Participants at the SAL 2023 industry face-to-face Moama event, as well as industry members of SAL and CDFGA were provided with a survey and asked questions relating to the SF17006- 'Summerfruit orchard phase 2' project. This provided a snapshot of the industry's awareness and uptake of the research. It indicated that 90% of the industry are aware of this summerfruit research, and that 60% had implemented a change with their business decisions and orchard management practices because of one or more of the grower protocols.

From the result of the survey (Table 10), the first question asked industry participants about awareness of the research on orchard management practices to improve yield and fruit quality in peach, nectarine, plum and apricot production. 83% were aware of research on strategic deficit irrigation management practices, 74% on research into canopy design options, 61% on rootstock research, 52% on research into optimising crop loads, and 4% said they were not aware of this research. These figures indicate that the multiple approaches to extending this information, such as face to face and online events, supported by web information and newsletters, has been successful.

The second question asked what information helped with business decisions and orchard management practices. 43% had implemented changes to irrigation and rootstock management, 35% had implemented changes around canopy, 39% on crop load management, and 39% had not implemented anything from the research, however comments were captured around producers looking to do this in the future, such as 'not yet implemented orchard management practices from research' and 'if I was aware of the research, I would have used it and it may have been useful. Found it in today's presentations. Will look at HIN website to integrate practices. The presentations from Agriculture Victoria were great.'

When asked how this research has helped with productivity in orchard management and fruit quality, some participants provided comments such as, 'better informed decisions behind rootstock choices', 'Irrigation savings on water. Rootstock in keeping trees smaller - happy workers', 'helped to improve efficiencies around canopy structure in orchards', 'better quality', and 'better fruit for consumers.' Participants also provided comments relating specifically to the HIN website as an information resource such as, 'HIN has been extremely valuable as an extension on in person events, hosting content to extend to the audience' and, 'I source information from many sources, mostly from overseas. HIN is part of a suite of sources.' One participant who did not believe that the research helped with their business decisions provided further comment which indicated they were concerned about the increased cost of production with no increase in returns and being 'super worried about the future'.

Tables 10 and 11 indicate that more than 90% of the industry are aware of this summerfruit research, and that 60% had implemented a change with their business decisions and orchard management practices from one or more of the grower protocols.

Table 10: Result of the industry survey from face-to-face industry event, Moama May 2023

Project SF17006 – 'Summerfruit Orchard Phase 2' survey		
Total surveys completed		23
1. Are you aware of the following research on orchard management practices to improve yield and fruit quality (peach, nectarine, plum and apricot)?		
	Total	%
Irrigation: strategic deficit irrigation management practices.	19	83
Rootstock: dwarfing, semi-dwarfing, and high vigour rootstocks.	14	61
Canopy: canopy design options.	17	74
Crop load: optimising crop load.	12	52
No	1	4

2. What information helped you with business decisions and orchard management practices?		
	Total	%
Irrigation	10	43
Rootstock	10	43
Canopy	8	35
Crop load	9	39
None of the above	9	39

Table 11: Online industry survey sent through profitable stonefruit industry newsletter, 28 May 2023.

Project SF17006 – 'Summerfruit Orchard Phase 2' survey		
Total surveys completed	4	
1. Are you aware of the following research on orchard management practices to improve yield and fruit quality (peach, nectarine, plum and apricot)?		
	Total	%
Irrigation: strategic deficit irrigation management practices.	4	100
Rootstock: dwarfing, semi-dwarfing, and high vigour rootstocks.	4	100
Canopy: canopy design options.	4	100
Crop load: optimising crop load.	4	100
No	0	0
2. What information helped you with business decisions and orchard management practices?		
	Total	%
Irrigation	1	25
Rootstock	2	50
Canopy	2	50
Crop load	3	75
None of the above	1	25

Despite challenges across the Australian Summerfruit industry, the SF17006 project continues to support progress towards increasing the value and profitability of summerfruit producers by supporting improvements in business decisions and orchard management that provide improved production and consistency in fruit quality of summerfruit (peach, nectarine, apricot & plums), achieved through high-density orchard production systems and management practices capable of manipulating fruit yield and quality to meet domestic and export market quality specifications.

Canopy design options for stonefruit

Mark O'Connell, Agriculture Victoria, Tatura

Canopy architecture and design are important orchard business decisions made before crop establishment.

Canopy type and design influences tree density, tree size and shape and governs orchard management (irrigation, nutrient, pest & disease), labour inputs, infrastructure (posts, wire, soil anchors) costs, tree light interception, vegetative growth and development, fruit quality and production potential.

Open Vase free standing canopy design is very common and represents the current industry standard for peach and nectarine in Australia.

Canopy systems range from low density free standing (vase) trees to modern high-density 2-dimensional (hedgerow) vertical trellis and 3-dimensional V-trellis systems.

Research into canopy design on peach, nectarine, plum and apricot at Tatura using vase and trellis systems found canopy selection effects tree growth and vigour and impacts yield and fruit quality.

Canopy types

Open Vase canopy design is very common in most stonefruit regions of the world and represents the current industry standard for peach and nectarine in Australia.

The agronomic performance of several canopy designs was compared at the Tatura Stonefruit experimental orchard on peach, nectarine, plum and apricot (Table 1).

The orchard study examines canopy designs and training systems for future orchards. The experimental orchard was established in 2013 on Shepparton fine sandy loam. Orchard layout includes tree spacing of 4.5 m x 2 m (1,111 trees per hectare) and 4.5 m x 1 m (2,222 trees per hectare), drip irrigation under vase, Vertical Leader, Tatura Trellis and Open Tatura canopy systems.

Tree vigour and production performance

The experimental orchard study affords the unique and direct comparison between canopy designs in terms of vegetative growth, yield and fruit quality. To understand the impact of canopy design such an analysis requires the same crop-cultivar mix, tree age, tree density and orchard management (rootstock, irrigation, nutrient, pest and disease) to be consistent between the canopy systems.

Table 1. Crop, cultivar, and canopy combinations at Tatura Stonefruit Orchard

Crop and Cultivar	Canopy design
Nectarine 'Rose Bright'	Vase
Nectarine 'Autumn Bright'	Vertical Leader
Nectarine 'Autumn Bright'	Tatura Trellis
Nectarine 'September Bright'	Open Tatura
Peach 'September Sun'	Vase
Peach 'August Flame'	Vertical Leader
Peach 'August Flame'	Tatura Trellis
Apricot 'Golden May'	Vase
Apricot 'Golden May'	Tatura Trellis
Plum 'Angeleno'	Vase
Plum 'Angeleno'	Tatura Trellis

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Yield and fruit quality performance of peach, nectarine, plum and apricot (see Table 1) for 2015/16 to 2020/21 growing seasons is summarised on the Profitable Stonefruit (Summerfruit) Research website (see Horticulture Industry Network: http://www.hin.com.au).

Virtual orchard tours (360 degree) and time series videos of each crop-canopy design is published on the website: http://www.hin.com.au/networks/profitable-stonefruit-research.

Findings from the experimental orchard study at Tatura show, overall, irrespective of crop type, Vase canopy systems produced greater vegetative growth and tree vigour (pruning biomass, trunk growth, leader growth) compared to Trellis canopy systems. Trellis systems give support (wires) to developing laterals during establishment years to provide the capacity for higher fruit number per tree and consequently greater cumulative yields.

Open vase canopies tend to have less even light distribution compared to 2-D and 3-D trellis systems. From a labour input perspective, a greater level of technical expertise and time (labour cost) is required for pruning management on vase trees relative to trellis canopy systems.

A summary of canopy design options and agronomic comparisons from the experimental orchard study at Tatura on tree vigour and yield and fruit quality is provided for apricot, plum, peach and nectarine:

Apricot 'Golden May' and Plum 'Angeleno': Vase and Tatura Trellis

For Apricot and Plum, Tatura Trellis out yielded vase trees in establishment years due to having larger tree size (light interception) and capacity to carry more fruit number. Tatura Trellis resulted in more uniform fruit weight and maturity compared to vase canopy systems. Greater vegetative growth (pruning biomass, trunk growth) occurred on vase tree despite having lower tree size (light interception).

Peach 'August Flame' and Nectarine 'Autumn Bright': Vertical Leader and Tatura Trellis

For peach and nectarine, similar production (yield, fruit quality) outcomes were observed between Vertical Leader and Tatura Trellis canopy systems.

From a vegetative growth perspective, trunk size was not different between Vertical Leader and Tatura Trellis canopy systems. However, greater pruning biomass (summer and winter) occurred under Tatura Trellis.

Greater and more uniform light interception occurred under Tatura Trellis canopies despite taller trees under Vertical Leader trees. These light regimes responses reflect the canopy design and architecture of each training system (i.e. V shape 3-D Tatura Trellis canopy versus vertical 2-D hedgerow trellis canopy).

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Crop load management in stonefruit

Mark O'Connell, Agriculture Victoria, Tatura

Fruit thinning is an agronomic practice aimed at changing the ratio of carbon partitioning between leaves and fruits.

Crop load management dictates the number of fruit per tree and directly influences tree growth and development, yield and fruit quality outcomes.

Fruit thinning activities contribute to the cost of orchard production via labour required, however optimal crop loads offer savings through reduced picking, packing and transport costs.

Nowadays high-density orchard systems offer greater early cumulative yields, improved canopy light distribution and mature trees fill their allotted canopy space quicker.

However, excessive crop loads result in small fruit size, delayed maturity and poor fruit quality despite yielding higher. Therefore, optimal crop load management is required to achieve high marketable yield, good quality fruit outcomes and trees are more sustainable in the long-term.

Research into crop load management on peach, nectarine, plum and apricot at Tatura has found average fruit weight and fruit sweetness (brix) decreases rapidly with increasing crop load. Fruit maturity (flesh firmness, colour development) is delayed under high crop load. Low fruiting levels increase tree vigour and vegetative growth.

Why fruit thin?

Stonefruit trees set more fruit than they can support to full maturity. Flowers and fruits naturally thin themselves (known as fruit drop), however, stonefruit crops (peach, nectarine, plum and apricot) require thinning for improved horticultural outcomes: yield and fruit quality, and tree health.

Excessive fruit numbers result in greater fruit competition for limited available stored energy (carbohydrates), poor production outcomes such as low fruit weight, reduced quality, limb breakage, biennial bearing and ultimately tree health is reduced.

Fruit thinning methods

Timing of thinning is important to maximise fruit size of remaining fruit. Fruit thinning timing is critical to maximise fruit size. Recommend time for fruit thinning is 30 – 45 days after full bloom when fruit size is 19 – 25 mm.

The main methods for fruit thinning are hand and mechanical (e.g. Darwin 2000), although winter pruning management set the level of tree fruiting structures for each season. Hand thinning is more precise but has higher labour costs.

Precision hand thinning is undertaken by the initial removal of fruit from end of branches, 'doubles', small, disfigured and damaged fruit followed by even thinning of remaining fruitlets to the desired crop load target.

Crop load target

Optimal fruiting levels or 'crop load target' are aimed to maximise fruit size and fruit sweetness. Crop load targets depend on crop type, spring pollination conditions and tree size. Plums and apricots, having smaller fruit are thinned differently to peaches and nectarines. Heavy flowering in spring (i.e. minimal frost incidence, high bee activity, optimal vegetative growth conditions) may require greater thinning. Larger trees (canopy size) have capacity to grow and yield more high-quality fruit.

For plum and apricot, a cropping level of ~ 1 fruit per 5 – 8 cm of fruiting lateral is recommended to maximise cell number and final fruit size and sweetness.

For peach and nectarine, a cropping level of ~ 1 fruit per 10 cm of fruiting lateral is recommended to maximise cell number and final fruit size and sweetness.

Crop load management: yield and fruit quality

Fruit thinning regimes impact vegetative growth and fruit production relationships to increase fruit size and sweetness.

Overall, crop load studies at Tatura on peach, nectarine, plum and apricot have shown excessive fruiting levels result in high yield, small fruit size, delayed maturity and poor fruit quality (i.e. low marketable yield).

On an early-season nectarine and a late-season peach under vase canopy architecture (1,111 trees/ha), high crop loads delayed fruit maturity and lowered marketable yield due to small size fruit with reduced sweetness.

For high-density (2,222 trees/ha) blocks of mid-season peach and nectarine, under Tatura Trellis and Vertical Leader planting systems, high fruit loads produced poor fruit quality: reduced fruit weight and lowered brix.

Similarly, for plum and apricot, irrespective of canopy architecture (vase, Tatura Trellis), low fruiting levels produced large sweet fruit, penalised yield, while excessive crop loads reduced fruit weight, decreased sweetness and delayed fruit maturity.

Crop load management: tree vigour

From a horticulture production perspective, important tree growth and vegetative vigour responses under different crop load regimes have been measured on peach, nectarine, plum and apricot, at Tatura.

On an early-season nectarine under vase canopy architecture, excessive crop loads resulted in lower main branch size, reduced shoot length, less pruning biomass and increased suckering. Similarly, on a late-season peach under vase canopy architecture, high crop loads reduced main branch size.

For both peach and nectarine under high-density Tatura Trellis and Vertical Leader systems, crop load management did not impact vegetative growth.

For plum, irrespective of canopy architecture (vase, Tatura Trellis), low fruiting levels partitioned more assimilates into vegetative growth and produced higher levels of pruning biomass and grew larger trunks. For apricot (vase, Tatura Trellis), trunk size was not impacted by crop load, however, increased pruning weight occurred under low fruiting levels.

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Irrigation scheduling for regulated deficit irrigation (RDI) in stonefruit

Mark O'Connell and Ian Goodwin, Agriculture Victoria, Tatura

Irrigation is generally associated with minimising moisture stress. Under such conditions trees grow quickly and are very vigorous. Until a tree has reached its desired size it should not be stressed for water. Once the tree has grown to its desired size, however, vigorous growth not only increases the need for pruning but can reduce yield. Irrigation needs to be managed in such a way as to control the growth of shoots. Such management is known as regulated deficit irrigation (RDI) and in experimental plots has maintained yields of peaches and nectarines, and reduced irrigation by about 30 - 40 %.

The RDI technique

With RDI, trees are kept short of water when fruit growth is slow or after harvest but are given ample water during the time of rapid growth of fruit. This reduces the growth of shoots. If RDI is properly managed, there is no reduction in the size of fruit or yield and fruit quality (sweetness, maturity, firmness, colour) is maintained. The reason why the above technique works relates to the growth pattern of shoots and fruit. On most deciduous fruit trees, the shoots grow rapidly early in the season and their growth slows down as the fruit begins to grow rapidly. In contrast, early in the season the fruit grows slowly. Water stress at this time will reduce the growth of shoots without markedly affecting the growth of fruit.

With RDI, the irrigation season can be divided into four periods. The duration of these periods is determined by both weather and the relationship between vegetative growth and the growth of fruit.

Period 1

During this period immediately following flowering, care needs to be exercised to avoid water stress particularly in stonefruit. For example, in peaches there is an initial rapid fruit growth for approximately 4 weeks following flowering when the soil should not be allowed to dry out beyond 40 kPa in sandy soil and 60 kPa in clay loam soils.

In most seasons in the Goulburn Valley, crops are not irrigated until reference crop evapotranspiration (ET_o) exceeds rainfall by 125 mm. Generally, this is in late October but could be as late as mid-November in a wet spring. However, in recent years there has been insufficient winter and early spring rain to wet up the root zone. Root zone soil moisture must be measured to avoid water stress. Similarly, in environments dissimilar from the Goulburn Valley (for example, trees growing in lighter soil types) measurements of soil moisture will avoid the root zone drying out excessively.

Period 2

Period 2 commences approximately four to five weeks after flowering and continues until six weeks before harvest for early-maturing fruits (that is, before mid-January), and eight weeks before harvest for later maturing fruits. Trees are irrigated with greatly reduced volumes of water compared to that which would normally be applied. Irrigation to replace 30 % of orchard water use capability is recommended. Soil moisture in the middle of the wetted fibrous root zone should not exceed 100 kPa in sand or 400 kPa in clay loams.

Period 3

In this period six to eight weeks before harvest, the fruit is growing rapidly, and the tree now needs ample water to reach maximum fruit size. Water stress must not occur during this final period of fruit growth. Irrigation to replace 100 % of orchard water use capability is recommended. Soil moisture in the middle of the wetted fibrous root zone should not exceed 40 kPa in sand or 60 kPa in clay loams.

Period 4

After harvest a similar strategy as during period 2 can be implemented. In early maturing varieties and species (for example, cherries and apricots) there is considerable shoot growth after harvest which should be kept in check to maintain fruitfulness and even cropping within the canopy. Irrigation to replace 30 % of orchard water use capability is recommended. Soil moisture in the middle of the wetted fibrous root zone should not exceed 100 kPa in sand or 400 kPa in clay loams.

Scheduling RDI from ET_o

In all three periods, reference crop evapotranspiration (ET_o) readings, which are readily available in most districts, can be used to schedule irrigation. However, it is strongly recommended that soil moisture monitoring be integrated into an irrigation schedule to avoid over- or under-irrigating trees.

In Table 1, examples of how to use ET_o to schedule RDI in a peach/nectarine orchard are shown for drip, microjet and sprinkler irrigation. The table is divided vertically into three sections; each section refers to a different form of irrigation - drip, microjet and sprinkler.

To show the influence that the spacing between trees has on the calculations for scheduling of irrigation, different spacings between trees are used for each of the three systems of irrigation. As previously mentioned, the irrigation season is divided into three periods, and the calculations needed during each of these periods are set out below the appropriate period. These calculations are divided into various sub-headings shown on the left side of Table 1. The following explains these sub-headings and should be read in conjunction with a perusal of the table.

Weekly ET_o

Values for daily and weekly ET_o (mm) can be obtained from the Bureau of Meteorology. Data shown in the table are typical for the Goulburn Valley. To use the table, you merely have to replace the figures given in the example by those that you have collected in the previous week.

Effective area of shade

Orchard effective area of shade (EAS, %) is a simple and practical estimate of tree size and hence the actively transpiring leaf area in an orchard. EAS is determined from measurements of the percent shade cast by the trees at three key times a day (3½ h before solar noon, at solar noon and 3½ h after solar noon). Taking three measurements per day accounts for differences in foliage extent (i.e. training system and tree size), planting arrangement (i.e. row orientation and tree spacing) and leaf area density (i.e. pruning management). EAS is calculated from the average of the three measurements. The percent shade can be estimated visually or measured using a light bar known as a ceptometer.

Understorey coefficient

The understorey coefficient (K_e) is a factor to convert ET_o to understory water use; the combination of soil evaporation and cover crop water use. For modern high-density orchards, micro-irrigation is designed to deliver water requirements to individual trees and minimize the contribution of irrigation to understorey water use. Hence under drip irrigation K_e can be set to 0.1 and under microjet set to 0.2. Whereas under sprinkler irrigation there is substantial understorey water use and K_e can be set to 1-EAS. For example, if EAS = 20 % then K_e = 1-20 % = 0.8.

Stress coefficient

The stress coefficient (K_s) is a factor used for setting the amount of stress deliberately imposed on the orchard. A value of 1.0 is no stress. For example, during period 2 under RDI it is recommended to replace 30 % of orchard water use capability, hence K_s = 0.3.

Weekly orchard irrigation

Weekly irrigation for a peach orchard (I) is calculated from weekly ET_o, effective area of shade (EAS), the understorey coefficient (K_e) and the stress coefficient (K_s) using the following formula:

$$I = K_s \times ET_o \times [(1.1 \times EAS) + K_e]$$

Area of planting square

The area of planting square (m^2) is calculated from the distance between rows multiplied by the in-row distance between trees. Different spacings between trees are given for each form of irrigation in the example in Table 1.

Weekly tree irrigation

Weekly irrigation requirement per tree is calculated from the the weekly orchard irrigation multiplied by the area of planting square.

Recommended interval between irrigations

The interval between irrigations (day) is also important with RDI, and recommended intervals are given in Table 1. For drip irrigation, the rationale behind these recommendations relates to the size of the wetted root zone. In period 2, frequent irrigation (that is, daily) wets a small volume of soil regularly. In contrast, using a two-day interval in period 1 (and daily interval in period 3) enables a much greater volume of water to wet a larger root zone. This manipulation in wetting the root zone could be responsible for the observed improved growth of fruit in period 3 and higher yields on RDI-managed trees. If, with drip irrigation, the system must be run for more than 24 hours every second day to provide the required quantity of water, serious thought should be given to upgrading the system to a higher rate of discharge.

The longer interval between irrigations in period 2, than in period 1 and 3, for both microjet and sprinkler irrigation is necessary to allow enough water to wet the soil to a reasonable depth.

In period 2, with microjet and sprinkler irrigation, an interval of seven and 21 days respectively is recommended. If the combined effects of evaporation, spacing of trees and rate of application result in less than two- and eight-hour irrigation times respectively for microjet and sprinkler irrigations, the interval will need to be extended until such figures are reached. For these long intervals, irrigation is based on the accumulated evaporation since the previous irrigation.

Water required at each irrigation

The quantity of water required at each irrigation is multiplied by the interval between irrigations in days and divided by 7 (that is, by the number of days in the week). For example, if the weekly irrigation requirement is 52 litre but the interval is only two days, then approximately 15 litre of water is applied every 2nd day ($52 \times 2 \div 7$ = approximately 15).

Application rate

Application rate (litre/hour/tree) is the amount of irrigation applied to each tree per hour. This is calculated from the emitter discharge rate multiplied by the number of emitters per tree. If not known, this should be measured.

Run time

Run time (hour) is calculated by dividing the number of litres per tree required at each irrigation by the application rate.

RDI with flood and furrow irrigations

With surface irrigations, such as flood or furrow, it is difficult to control the amount of water applied per irrigation. Nevertheless, the principles discussed above apply; the initial irrigation can be delayed and the interval between irrigations can be increased in period 2. After 12 years of experimenting with RDI it became obvious that in the past, much water was wasted on early irrigation. Our results at Tatura indicate that mature trees would have cropped better with less water.

Table 1. Example calculations of irrigation interval and run time for RDI under drip, microjet and sprinkler irrigation.

	Drip			**Microjet**			**Sprinkler**		
	4.5 m × 1.5 m planting			**4.5 m × 1.5 m planting**			**5 m × 3 m planting**		
	Period 1	**Period 2**	**Period 3**	**Period 1**	**Period 2**	**Period 3**	**Period 1**	**Period 2**	**Period 3**
Weekly ET_o (*mm*)	20	35	45	20	35	45	20	35	45
Effective area of shade *(%)*	30	60	60	30	60	60	20	50	50
Understorey coefficient (K_e)	0.1	0.1	0.1	0.2	0.2	0.2	0.8	0.5	0.5
Stress coefficient (K_s)	1	0.3	1	1	0.3	1	1	0.3	1
Weekly orchard irrigation (*mm*)	8.6	8.0	34.2	10.6	9.0	38.7	20.4	11.0	47.3
Area of planting square (*m^2*)	6.75	6.75	6.75	6.75	6.75	6.75	15	15	15
Weekly tree irrigation (*litre/tree*)	58	54	231	72	61	261	306	165	710
Recommended interval between irrigation *(day)*	**2**	**2**	**1**	**10**	**10**	**3**	**5**	**21**	**5**
Water required at each irrigaton (*litre/tree*)	17	15	33	103	87	112	219	495	507
Application rate *(litre/h/tree)*	8	8	8	40	40	40	120	120	120
Run time *(hour)*	**≈2**	**2**	**≈4**	**2½**	**≈2**	**≈3**	**≈2**	**≈4**	**4⅓**

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Rootstock performance in stonefruit

Mark O'Connell, Agriculture Victoria, Tatura

Rootstock selection at crop establishment governs tree performance and orchard production potential.

Root systems provide access to water and nutrients, provide a barrier to soil stress and a conduit for plant signals for shoot growth and function.

Worldwide there are few rootstock breeding programs for stonefruit. In Australia, Nemaguard is the current industry standard rootstock for peach and nectarine.

Rootstock vigour is an important criterion for orchard management and directly influences tree growth and development, yield and fruit quality. Other agronomic characteristics of root systems include precocity, adaptability to soil type, climate, and tolerance/resistance to abiotic (climatic, salinity) and biotic (nematode, virus, bacterial, fungal) stress.

Research into rootstocks on peach and nectarine, at Tatura using dwarfing, semi-dwarfing and high vigour stocks found rootstock-induced vigour effects on tree growth and development, yield and fruit quality.

Rootstock vigour types

The agronomic performance of dwarfing, semi-dwarfing and vigorous rootstocks were compared at the Tatura Stonefruit experimental orchard on peach 'September Sun' and nectarine 'Rose Bright' (Table 1). The rootstock/scion study was established in 2013 on Shepparton fine sandy loam with tree spacing of 4.5 m x 2 m (1,111 trees per hectare), trained as open vase and drip irrigated.

Nemaguard is a very common and vigorous rootstock and represents the current industry standard for peach and nectarine in Australia.

Table 2 shows comparison of rootstock traits. Some key features of each rootstock are:

Nemaguard – prefers sandy soil,

Elberta - used in heavier soils,

Krymsk® 1 - a new dwarfing rootstock,

Krymsk® 86- a new semi-vigorous rootstock tolerant to drought and wet soil,

Cadaman – prefers well drained soils, and

Cornerstone – tolerant of saline and high pH soils, new stock meant to offer greater vigour and disease resistance.

Table 1. Rootstock/scion combinations at Tatura Stonefruit Orchard

Scion	Rootstock
Nectarine 'Rose Bright'	Cornerstone
	Elberta
	Krymsk® 1
	Krymsk® 86
	Nemaguard
Peach 'September Sun'	Cornerstone
	Elberta
	Cadaman
	Krymsk® 86
	Nemaguard

Table 2. Characteristics of rootstocks.												
Rootstock	**Pedigree (Country of origin)**	**Vigour**	**Anchorage**	**Soil conditions**	**Drought tolerance**	**Iron induced chlorosis**	**Crown Rot**	**Root knot Nematode**	**Root lesion nematode**	**Crown Gall**	**Oak root fungus**	**Bacterial canker**
Nemaguard	Prunus persica x Prunus davidiana (USA)	High	Good	Sandy loam, sensitive to wet soil conditions and calcareous soils	Moderate	Susceptible	Susceptible	Resistant	Susceptible	Moderately susceptible	Susceptible	Susceptible
Cornerstone	Prunus dulcis x Prunus persica (USA)	Very high	Excellent	Good in heavy soils, tolerant to saline and high pH soils	High	Resistant	Susceptible	Strong resistance	Susceptible	Moderate resistance	Unknown	Susceptible
Cadaman	Prunus persica x Prunus davidiana (France, Hungary)	High	Good	Sandy loam, tolerant to alkaline soils and wet conditions	Unknown	Tolerant	Unknown	Resistant	Susceptible	Unknown	Unknown	Unknown
Krymsk® 1	Prunus tomentosa x Prunus cerasifera (Russia)	Dwarfing	Good	Sandy loam, tolerant to alkaline soils and wet conditions	Unknown	Unknown	Susceptible	Susceptible	Tolerant	Susceptible	Unknown	Susceptible
Krymsk® 86	Prunus persica x Prunus cerasifera (Russia)	Semi-vigorous	Good	Tolerant in heavy soils and wet conditions	Unknown	Unknown	Unknown	Moderately susceptible	Moderate tolerance	Moderate resistance	Tolerant	Unknown
Elberta	Prunus persica (USA)	High	Good	Unknown	Unknown	Susceptible	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown

Rootstock performance in stonefruit

Mark O'Connell, Agriculture Victoria, Tatura

Rootstock performance: tree growth

Early-season nectarine 'Rose Bright'

Relative to Nemaguard, Krymsk® 1 exhibited dwarfing characteristics, having reduced tree size and vegetative growth. Krymsk® 1 trees produced less pruning biomass, smaller main branch size, a lower level of canopy light interception and reduced shoot length. From an orchard management perspective, Krymsk® 1 grew an excessive level of suckers each season.

Krymsk® 86 trees showed semi-dwarfing traits: lower canopy light interception compared to Nemaguard. Suckering on Krymsk® 86 trees was greater than Nemaguard.

Elberta and Cornerstone rootstocks showed similar tree growth and development metrics compared to Nemaguard on early-season nectarine 'Rose Bright'.

Late-season peach 'September Sun'

Compared to Nemaguard, Krymsk® 86 trees exhibited semi-dwarfing characteristics: less pruning biomass, smaller main branch size and less canopy light interception. Tree survival in establishment years was lowest on Krymsk® 86. Suckering on Krymsk® 86 trees was greater than Nemaguard.

Cadaman, Elberta and Cornerstone rootstocks showed similar tree growth and development metrics compared to Nemaguard on late-season peach 'September Sun'.

Rootstock performance: yield and fruit quality

Early-season nectarine 'Rose Bright'

Cornerstone rootstock increased average fruit weight and fruit red skin coverage compared to Nemaguard. Krymsk® 1 trees produced equivalent fruit weight and sweetness (brix) and improved skin red colour coverage relative to Nemaguard. Yield and fruit quality on Elberta and Krymsk® 86 were similar to Nemaguard for nectarine 'Rose Bright'.

Late-season peach 'September Sun'

Relative to Nemaguard, Cornerstone and Elberta trees increased fruit weight and skin red coverage.

Krymsk® 86 trees produced similar yield, fruit weight and brix to Nemaguard, however, fruit red skin coverage was improved. Yield and fruit quality on Cadaman trees were similar to Nemaguard for peach 'September Sun'.

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YIELD AND FRUIT QUALITY RESULTS FROM CANOPY – CROP LOAD STUDY: APRICOT 'GOLDEN MAY'

Table 1 presents production results (yield, fruit quality) for apricot 'Golden May' under crop load treatments (high, medium, low) for Vase and Tatura Trellis canopy systems for 6 consecutive seasons: 2016/17, 2017/18, 2018/19, 2019/20, 2020/21 and 2021/22, respectively at Tatura, Victoria, Australia.

Overall, low crop load reduced final fruit number, increased fruit weight, reduced yield, increased fruit sweetness (°Brix), lowered flesh firmness (kgf), advanced fruit maturity (I_{AD}), and decreased fruit skin redness coverage (%). The converse effect on yield and fruit quality occurred in the high crop load treatments.

Characterisation of each individual fruit quality (sample size per season, $n \approx 17{,}000$ fruit) was determined from a combination of fruit weight, maturity and sweetness. Fruit was classified as 'premium' grade when weight ≥ 36 g, sweetness ≥ 12 °Brix, maturity < 1.2 I_{AD}. Typically, results showed high crop load reduced fruit weight, lowered sweetness and delayed fruit maturation and therefore failed to meet the premium grade classification (i.e. poor 'pack-out' performance) compared to medium and low crop load treatments irrespective of canopy system (Table 1).

Table 1. Production parameters in response to crop load treatments (Low, Medium, High) of 'Golden May' apricot under two canopy architectures (Tatura Trellis, Vase) during seasons 2016/17, 2017/18, 2018/19, 2019/20, 2020/21 and 2021/22 (season 1 – 6).

Crop load	Fruit number (#/tree)	Fruit weight (g)	Yield (kg/tree)	Sweetness (°Brix)	Maturity (I_{AD})	Firmness (kgf)	Skin colour (% red)	Premium grade (%)
Season 1: Vase								
Low	21 a	74 c	1.5 a	9.8	0.3	3.2	0	14
Medium	24 a	70 b	1.7 a	9.7	0.3	3.3	0	17
High	43 b	63 a	2.6 b	9.9	0.3	3.1	1	16
ANOVA	***	***	*	ns	ns	ns	ns	ns
Season 1: Tatura Trellis								
Low	90 a	73 c	6.5 a	9.6 b	0.5	3.4	0 a	10
Medium	113 a	69 b	7.7 a	9.8 b	0.5	3.5	0 a	13
High	224 b	55 a	11.7 b	9.4 a	0.5	3.5	2 b	11
ANOVA	***	***	***	***	ns	ns	***	ns
Season 2: Vase								
Low	25	75	1.9	11.7	1.2	3.4	36	40
Medium	33	75	2.5	12.3	1.1	3.2	40	46
High	30	71	2.1	11.8	1.1	3.2	37	40
ANOVA	ns	ns	ns	ns	ns	ns	ns	ns
Season 2: Tatura Trellis								
Low	25	64	1.6	11.8	1.0	3.6	15	26
Medium	19	64	1.2	11.6	1.1	3.9	23	28
High	24	62	1.4	12.0	0.9	3.5	14	31
ANOVA	ns	ns	ns	ns	ns	ns	ns	ns
Season 3: Vase								
Low	30 a	86 c	2.5 a	12.1 b	1.1	4.0	16 a	53
Medium	43 b	81 b	3.5 b	12.2 b	1.0	3.9	20 a	36
High	73 c	72 c	5.2 c	11.7 a	1.3	3.9	26 b	39
ANOVA	***	***	***	**	ns	ns	***	ns
Season 3: Tatura Trellis								
Low	57 a	79 b	4.5 a	13.7 b	0.5 a	2.4 a	8 a	90 b
Medium	63 a	76 b	4.7 a	13.6 b	0.5 a	2.5 a	10 b	87 b
High	83 b	68 a	5.5 b	13.1 a	0.6 b	2.7 b	11 c	80 a
ANOVA	***	***	**	***	***	***	***	*
Season 4: Vase								
Low	115 a	63 c	7.3 a	12.4 c	0.7 a	3.2 a	1 a	60 c
Medium	194 b	51 b	9.4 b	11.6 b	0.8 b	3.5 b	2 a	34 b
High	281 c	36 a	10.0 b	10.5 a	1.1 c	4.2 c	8 b	6 a
ANOVA	***	***	***	***	***	***	***	***
Season 4: Tatura Trellis								
Low	117 a	52 c	6.0 a	12.9 c	0.4 a	2.7 a	0 a	68 c
Medium	136 a	50 b	6.5 a	12.5 b	0.5 b	2.9 b	0 a	53 b
High	246 b	32 a	7.4 b	10.8 a	0.9 c	3.8 c	2 b	8 a
ANOVA	***	***	**	***	***	***	***	***
Season 5: Vase								
Low	54 a	76 b	4.1 a	10.7	1.1	4.6	2 a	15
Medium	108 b	63 a	5.6 b	10.5	1.1	4.8	4 b	14
High	116 b	60 a	6.7 b	10.5	1.1	4.7	4 b	13

ANOVA	***	***	***	ns	ns	ns	**	ns
			Season 5: Tatura Trellis					
Low	44 a	79 c	3.4 a	11.7 b	0.7 a	3.5 a	17 a	38 b
Medium	58 b	72 b	4.0 b	11.5 b	0.7 b	3.7 b	21 b	31 b
High	90 c	58 a	5.1 c	10.7 a	0.9 c	4.1 c	29 c	13 a
ANOVA	***	***	***	***	***	***	***	***
			Season 6: Vase					
Low	18 a	96 b	1.7 a	10.8	1.0	3.5	51 a	25
Medium	30 b	81 a	2.4 b	10.8	1.0	3.3	56 b	19
High	30 b	77 a	2.3 b	10.5	1.1	3.4	57 b	17
ANOVA	**	***	***	ns	ns	ns	*	ns
			Season 6: Tatura Trellis					
Low	25	91 b	2.2 a	11.7	0.7	2.9	36 a	39 b
Medium	40	83 a	3.2 b	11.2	0.8	3.0	43 b	23 a
High	29	79 a	2.2 a	11.3	0.8	2.9	45 b	33 b
ANOVA	ns	***	*	ns	ns	ns	***	*

ns, *, ** and *** indicate non-significant or significant differences at $P < 0.05$, 0.01 or 0.001, respectively, for the two-way interaction crop load treatments.

YIELD AND FRUIT QUALITY RESULTS FROM CANOPY – CROP LOAD STUDY: PEACH ‘AUGUST FLAME’

Table 1 presents production results (yield, fruit quality) for peach ‘August Flame’ under crop load treatments (high, medium, low) for Vertical Leader and Tatura Trellis canopy systems for 7 consecutive seasons: 2015/16, 2016/17, 2017/18, 2018/19, 2019/20, 2020/21 and 2021/22, respectively at Tatura, Victoria, Australia.

Overall, low crop load reduced final fruit number, increased fruit weight, reduced yield, increased fruit sweetness (°Brix) and advanced fruit maturity (I_{AD}). The converse effect on yield and fruit quality occurred in the high crop load treatments. No consistent trends were noted for fruit flesh firmness (kgf) or skin redness coverage (%) under crop loads treatments on either canopy system (Table 1). Notably, high fruit sweetness (≥ 13.3 °Brix) occurred throughout the study period (seasons 1 – 7), irrespective of crop load and canopy system combination.

Table 1. Production parameters in response to crop load treatments (Low, Medium, High) of 'August Flame' peach under two canopy architectures (Tatura Trellis, Vertical Leader) during seasons 2015/16, 2016/17, 2017/18, 2018/19, 2019/20, 2020/21 and 2021/22 (season 1 – 7).

Crop load	**Fruit number (#/tree)**	**Fruit weight (g)**	**Yield (kg/tree)**	**Sweetness (°Brix)**	**Maturity (I_{AD})**	**Firmness (kgf)**	**Skin colour (% red)**
			Season 1: Vertical Leader				
Low	46 a	134 c	6.2 a	16.6 b	0.9 a	5.4 a	83
Medium	58 a	122 b	7.1 a	16.3 ab	0.8 a	5.5 ab	85
High	175 b	82 a	14.1 b	16.0 a	1.1 b	5.8 b	82
ANOVA	***	***	***	**	***	**	ns
			Season 1: Tatura Trellis				
Low	30 a	130 b	4.0 a	16.9 b	0.7 ab	5.4	88 c
Medium	54 b	131 b	7.1 b	17.2 b	0.7 a	5.6	83 a
High	115 c	106 a	11.7 c	16.1 a	0.8 b	5.5	86 b
ANOVA	***	***	***	***	**	ns	***
			Season 2: Vertical Leader				
Low	41 a	195 c	8.0 a	14.0 b	1.0 a	6.6	15
Medium	61 a	163 b	9.9 ab	13.7 ab	1.1 b	6.8	16
High	88 b	138 a	12.1 b	13.3 a	1.1 b	6.6	17
ANOVA	**	***	*	*	*	ns	ns
			Season 2: Tatura Trellis				
Low	72 a	168 b	9.1 a	14.8 b	0.9	6.2	16
Medium	108 b	142 a	13.7 b	14.4 b	1.0	6.4	18
High	122 b	133 a	13.0 b	13.5 a	1.1	6.4	19
ANOVA	*	***	*	**	ns	ns	ns
			Season 3: Vertical Leader				
Low	40 a	192 c	7.7 a	17.0 b	1.2 a	7.5	38
Medium	60 b	167 b	10.0 b	16.9 a	1.2 b	7.5	41
High	88 c	144 a	12.4 c	16.9 a	1.2 b	7.5	41
ANOVA	***	***	***	***	***	ns	ns
			Season 3: Tatura Trellis				
Low	63 a	142 c	8.9 a	16.9	1.2	7.5	34
Medium	87 b	134 b	11.6 b	16.9	1.2	7.5	37
High	110 c	118 a	12.8 b	16.9	1.2	7.5	37
ANOVA	***	***	***	ns	ns	ns	ns
			Season 4: Vertical Leader				
Low	64 a	118 c	7.5 a	15.9 c	1.8 a	8.8 c	26 a
Medium	121 b	96 b	11.6 b	15.5 b	1.8 ab	8.6 b	29 b
High	181 c	79 a	13.8 c	14.8 a	1.9 a	8.3 a	34 c
ANOVA	***	***	***	***	**	***	***
			Season 4: Tatura Trellis				
Low	33 a	119 c	3.8 a	17.8 c	1.3 a	7.9	27 a
Medium	64 a	96 b	6.0 b	16.7 b	1.5 b	7.9	31 b
High	117 b	69 a	7.9 c	15.6 a	1.6 c	7.8	36 c
ANOVA	***	***	***	***	***	ns	***
			Season 5: Vertical Leader				
Low	93 a	142 b	12.9 a	14.8 b	1.3 a	6.9 b	65

Medium	86 a	139 b	12.0 a	14.9 b	1.3 a	6.9 b	63
High	213 b	91 a	19.1 b	13.7 a	1.5 b	6.5 a	63
ANOVA	***	***	***	***	***	***	ns
			Season 5: Tatura Trellis				
Low	56 a	136 b	7.5 a	15.2 b	0.8 a	5.0 b	64
Medium	59 a	137 b	7.9 a	15.1 b	0.8 a	5.0 b	66
High	95 b	104 a	9.7 b	14.1 a	1.0 b	4.8 a	65
ANOVA	***	***	***	***	***	**	ns
			Season 6: Vertical Leader				
Low	30 a	176 b	5.3 a	15.1 b	1.5 a	7.8 b	28 b
Medium	27 a	171 b	4.7 a	15.5 b	1.4 a	7.9 b	28 b
High	132 b	123 a	15.8 b	13.7 a	1.7 b	7.5 a	25 a
ANOVA	***	***	***	***	***	***	*
			Season 6: Tatura Trellis				
Low	61 a	172 b	10.5 a	15.7 b	1.1	6.9 c	33
Medium	72 a	168 b	12.0 a	15.4 b	1.1	6.6 b	34
High	109 b	141 a	15.3 b	14.6 a	1.2	6.3 a	37
ANOVA	***	***	**	**	ns	***	ns
			Season 7: Vertical Leader				
Low	45 a	183 c	8.2 a	13.5	1.4 a	6.3	64 b
Medium	91 b	146 b	12.5 b	13.4	1.5 b	6.3	67 b
High	212 c	94 a	19.8 c	13.1	1.6 c	6.5	60 a
ANOVA	***	***	***	ns	***	ns	*
			Season 7: Tatura Trellis				
Low	69 a	183 c	12.6 a	14.7 b	1.1 a	6.0	69 b
Medium	142 b	141 b	19.9 b	14.5 b	1.3. b	6.2	70 b
High	283 c	90 a	25.5 c	13.7 a	1.5 c	6.3	64 a
ANOVA	***	***	**	***	***	ns	*

ns, *, ** and *** indicate non-significant or significant differences at $P < 0.05$, 0.01 or 0.001, respectively, for the two-way interaction crop load treatments.

YIELD AND FRUIT QUALITY RESULTS FROM CANOPY – CROP LOAD STUDY: NECTARINE 'AUTUMN BRIGHT'

Table 1 presents production results (yield, fruit quality) for nectarine 'Autumn Bright' under crop load treatments (high, medium, low) for Vertical Leader and Tatura Trellis canopy systems for 7 consecutive seasons: 2015/16, 2016/17, 2017/18, 2018/19, 2019/20, 2020/21 and 2021/22, respectively at Tatura, Victoria, Australia.

Overall, low crop load reduced final fruit number, increased fruit weight, reduced yield, and increased fruit sweetness (°Brix). The converse effect on yield and fruit quality occurred in the high crop load treatments. No consistent trends were noted for fruit flesh firmness (kgf), fruit maturity (I_{AD}) or skin redness coverage (%) under crop load treatments on either canopy system (Table 1). Notably, high fruit sweetness (≥ 12.9 °Brix) occurred throughout the study period (seasons 1 – 6), irrespective of crop load and canopy system combination.

Table 1. Production parameters in response to crop load treatments (Low, Medium, High) of 'Autumn Bright' nectarine under two canopy architectures (Tatura Trellis, Vertical Leader) during seasons 2015/16, 2016/17, 2017/18, 2018/19, 2019/20, 2020/21 and 2021/22 (season 1 – 7).

Crop load	Fruit number (#/tree)	Fruit weight (g)	Yield (kg/tree)	Sweetness (°Brix)	Maturity (I_{AD})	Firmness (kgf)	Skin colour (% red)
				Season 1: Vertical Leader			
Low	62 a	143 c	8.7 a	15.9 c	0.5	5.1 b	84
Medium	105 b	120 b	12.3 b	14.6 b	0.5	4.9 ab	84
High	155 c	102 a	15.1 c	13.4 a	0.5	4.6 a	85
ANOVA	***	***	***	***	ns	**	ns
				Season 1: Tatura Trellis			
Low	58 a	142 c	8.3 a	17.0 c	0.6	5.8 b	80
Medium	108 b	126 b	13.5 b	15.9 b	0.5	5.1 a	81
High	142 c	112 a	15.3 b	14.6 a	0.6	5.3 a	81
ANOVA	***	***	***	***	ns	***	ns
				Season 2: Vertical Leader			
Low	46	171 b	3.0 a	13.6 b	0.7	6.7	32
Medium	54	150 a	4.2 b	13.2 ab	0.8	6.7	34
High	51	142 a	2.9 a	12.9 a	0.8	6.6	33
ANOVA	ns	**	*	**	ns	ns	ns
				Season 2: Tatura Trellis			
Low	63 a	132	2.2	13.7	0.9	6.9 b	24
Medium	85 b	122	3.3	13.5	0.8	6.7 a	26
High	95 b	118	4.0	13.5	0.8	6.6 a	28
ANOVA	*	ns	ns	ns	ns	***	ns
				Season 3: Vertical Leader			
Low	46 a	161 b	7.3 a	14.7 b	0.9	7.1	50 a
Medium	64 a	151 b	9.6 b	14.8 b	0.8	7.0	56 b
High	118 b	118 a	13.8 c	14.3 a	0.9	7.0	53 ab
ANOVA	***	***	***	**	ns	ns	**
				Season 3: Tatura Trellis			
Low	64 a	145 b	9.2 a	15.0 b	1.1 b	7.5 b	44 a
Medium	84 a	138 b	11.6 b	15.1 b	1.0 b	7.4 b	46 a
High	144 b	113 a	15.8 c	14.6 a	1.0 a	7.2 a	50 b
ANOVA	***	***	***	*	**	***	**
				Season 4: Vertical Leader			
Low	116 a	95 b	10.7 a	14.5 b	1.2 b	7.4 b	52 a
Medium	173 b	74 a	12.7 b	14.3 a	1.1 a	7.2 a	60 c
High	188 b	73 a	13.2 b	14.3 a	1.1 a	7.2 a	57 b
ANOVA	***	***	**	***	***	***	***
				Season 4: Tatura Trellis			
Low	48 a	98 c	4.6 a	14.7 c	1.3 c	7.8 c	42 a
Medium	93 b	75 b	6.9 b	14.1 b	1.3 b	7.5 c	47 b
High	116 c	67 a	7.5 b	13.9 a	1.2 a	7.4 a	48 c
ANOVA	***	***	***	***	***	***	***
				Season 5: Vertical Leader			
Low	102 a	143 b	14.3 a	15.0 b	0.4 a	6.2 ab	74 a

Medium	89 a	141 b	12. 1 a	15.1 b	0.4 a	6.2 a	77 b
High	175 b	105 a	17.6 b	14.5 a	0.5 b	6.3 b	74 a
ANOVA	***	***	***	***	***	*	*
Season 5: Tatura Trellis							
Low	50 a	140 b	7.0 a	15.7 b	0.7	6.7 c	70
Medium	51 a	138 b	6.9 a	15.6 b	0.7	6.6 b	69
High	99 b	105 a	9.7 b	14.6 a	0.7	6.5 a	69
ANOVA	***	***	***	***	ns	***	ns
Season 6: Vertical Leader							
Low	109	133 b	14.4	14.3	1.1 b	7.4 b	49 a
Medium	99	130 ab	12.7	14.5	1.1 b	7.4 b	53 b
High	118	118 a	13.2	14.5	0.9 a	7.2 a	54 b
ANOVA	ns	*	ns	ns	**	*	**
Season 6: Tatura Trellis							
Low	76	147	11.0	14.7	0.8	7.1	52 a
Medium	94	134	12.5	14.6	0.8	7.0	57 b
High	74	137	9.7	14.7	0.8	7.1	57 b
ANOVA	ns	ns	ns	ns	ns	ns	**
Season 7: Vertical Leader							
Low	78 a	136 c	10.4 a	14.5 c	0.9 a	6.8	58 a
Medium	134 b	113 b	14.9 b	14.1 b	0.9 a	6.8	65 b
High	244 c	136 c	19.8 c	13.3 a	1.0 b	6.7	62 ab
ANOVA	***	***	***	***	***	ns	**
Season 7: Tatura Trellis							
Low	85 a	85 c	12.5 a	15.0 c	1.0	7.3 b	49
Medium	148 b	122 b	18.1 b	14.4 b	1.1	7.2 b	48
High	251 c	148 a	21.3 c	13.5 a	1.0	6.9 a	51
ANOVA	***	***	***	***	ns	***	ns

ns, *, ** and *** indicate non-significant or significant differences at $P < 0.05$, 0.01 or 0.001, respectively, for the two-way interaction crop load treatments.

YIELD AND FRUIT QUALITY RESULTS FROM CANOPY – CROP LOAD STUDY: PLUM 'ANGELENO'

Table 1 presents production results (yield, fruit quality) for plum 'Angeleno' under crop load treatments (high, medium, low) for Vase and Tatura Trellis canopy systems for six consecutive seasons: 2016/17, 2017/18, 2018/19, 2019/20, 2020/21 and 2021/22, respectively at Tatura, Victoria, Australia.

Notably, high fruit sweetness (≥ 17.2 °Brix) occurred across all seasons, canopy systems and crop load treatments. Overall, low crop load reduced final fruit number, increased fruit weight, reduced yield, increased fruit sweetness (°Brix) and decreased fruit skin redness coverage (%). The converse effect on yield and fruit quality occurred in the high crop load treatments. No consistent trends were evident in fruit flesh firmness (kgf) and fruit maturity (I_{AD}) among crop load or canopy system. In season 4, low fruiting levels *per se* under both canopy systems was a consequence of frost damage during flowering.

Characterisation of each individual fruit quality (sample size per season, $n \approx 30{,}000$ – 50,000 fruit) was determined from a combination of fruit weight, maturity and sweetness. Fruit was classified as 'premium' grade when weight ≥ 70 g, sweetness ≥ 12 °Brix, maturity < 1.3 I_{AD}. Typically, results showed despite high sweetness, high crop load reduced fruit weight and therefore failed to meet the premium grade classification (i.e. poor 'pack-out' performance) compared to medium and low crop load treatments irrespective of canopy system (Table 1).

Table 1. Production parameters in response to crop load treatments (Low, Medium, High) of 'Angeleno' plum under two canopy architectures (Tatura Trellis, Vase) during seasons 2016/17, 2017/18, 2018/19, 2019/20, 2020/21 and 2021/22 (season 1 – 6).

Crop load	Fruit number (#/tree)	Fruit weight (g)	Yield (kg/tree)	Sweetness (°Brix)	Maturity (I_{AD})	Firmness (kgf)	Skin colour (% red)	Premium grade (%)
				Season 1: Vase				
Low	53	80 b	4.2	17.2	1.3	3.0	10	71
Medium	75	78 b	5.9	17.5	1.3	3.0	11	65
High	93	73 a	6.8	17.3	1.3	3.0	13	60
ANOVA	ns	*	ns	ns	ns	ns	ns	ns
				Season 1: Tatura Trellis				
Low	177 a	66 b	11.7 c	18.8	1.1 b	3.0 b	8 a	38 c
Medium	260 b	62 b	16.1 b	18.4	1.1 b	3.1 ab	10 a	26 b
High	423 c	51 a	21.6 a	18.2	1.2 a	3.0 a	17 b	10 a
ANOVA	***	***	***	ns	*	*	***	***
				Season 2: Vase				
Low	61 a	71	4.2 a	19.6	1.3	4.7	4	53
Medium	79 b	72	5.6 b	19.6	1.3	4.8	4	55
High	108 c	70	7.4 c	19.3	1.3	4.7	4	51
ANOVA	***	ns	***	ns	ns	ns	ns	ns
				Season 2: Tatura Trellis				
Low	146 a	69 b	9.8 a	21.1 b	1.1 b	4.0 c	5 ab	45 b
Medium	160 a	71 b	11.2 a	21.0 b	1.1 b	3.8 b	4 a	50 b
High	267 b	65 a	16.6 b	20.6 a	1.1 a	3.7 a	5 b	33 a
ANOVA	***	***	***	***	*	***	*	***
				Season 3: Vase				
Low	107 a	56	6.0 a	21.3 b	1.4	3.7 b	13 a	4 a
Medium	177 b	56	9.9 b	20.9 b	1.4	3.6 b	13 a	6 ab
High	288 c	53	15.2 c	20.2 a	1.4	3.4 a	16 b	9 b
ANOVA	***	ns	***	***	ns	***	*	**
				Season 3: Tatura Trellis				
Low	146 a	42 b	6.1 a	21.8 c	1.5 a	3.8 c	22 a	1
Medium	186 b	41 b	7.6 b	21.5 b	1.5 b	3.7 b	23 a	1
High	302 c	37 a	11.1 c	21.0 a	1.5 b	3.5 a	29 b	1
ANOVA	***	***	***	***	**	***	*	ns
				Season 4: Vase				
Low	87 a	66	5.7 a	19.1 b	1.2 b	3.1	4 a	0
Medium	138 b	65	8.8 b	18.8 a	1.1 a	3.1	5 b	0
High	127 b	65	8.1 b	18.7 a	1.1 a	3.1	4 ab	0
ANOVA	***	ns	***	*	***	ns	*	ns
				Season 4: Tatura Trellis				
Low	96	50	4.8	21.1 b	1.1 b	3.6	10 b	0
Medium	100	51	5.0	21.1 b	1.1 b	3.6	10 b	0
High	102	51	5.1	20.8 a	1.1 a	3.5	8 a	0
ANOVA	ns	ns	ns	***	***	ns	***	ns
				Season 5: Vase				
Low	73 a	76	5.5	21.7	0.9	3.6	7	62
Medium	99 ab	75	7.4	21.4	0.9	3.6	6	62

High	111 b	75	8.1	21.4	0.9	3.6	5	61
ANOVA	*	ns	ns	ns	ns	ns	ns	ns
				Season 5: Tatura Trellis				
Low	231 a	61 b	13.9 a	22.2 b	1.0 a	3.6 b	16	26 b
Medium	181 a	63 b	11.2 a	22.4 b	1.0 a	3.7 b	17	31 b
High	528 b	49 a	25.3 b	21.4 a	1.1 b	3.4 a	16	7 a
ANOVA	***	***	***	**	***	***	ns	***
				Season 6: Vase				
Low	265	69.8	18.3	18.7	1.2	2.8	10	0
Medium	327	65.0	20.8	18.2	1.2	2.7	12	0
High	306	66.9	20.4	18.4	1.2	2.8	11	0
ANOVA	ns	ns	ns	ns	ns	ns	ns	ns
				Season 6: Tatura Trellis				
Low	379	60.7	22.5	19.0	1.1 b	2.8	14	0
Medium	364	61.4	22.0	19.1	1.1 b	2.9	13	0
High	360	60.7	21.5	19.5	1.1 a	3.0	15	0
ANOVA	ns	ns	ns	ns	**	ns	ns	ns

ns, *, ** and *** indicate non-significant or significant differences at $P < 0.05$, 0.01 or 0.001, respectively, for the two-way interaction crop load treatments.

YIELD AND FRUIT QUALITY RESULTS FROM ROOTSTOCK – CROP LOAD STUDY ON NECTARINE 'ROSE BRIGHT'

Tables 1 – 6 present production results (yield, fruit quality) for nectarine 'Rose Bright' in response to rootstock ('Nemaguard', 'Krymsk® 1', 'Krymsk® 86', 'Elberta', 'Cornerstone') and crop load (high, medium, low) treatments under a vase canopy system for 6 consecutive seasons: 2016/17, 2017/18, 2018/19, 2019/20, 2020/21 and 2021/22, respectively at Tatura, Victoria, Australia.

Overall, high crop load increased final fruit number, reduced fruit weight, increased yield, decreased fruit maturity (I_{AD}), lowered fruit sweetness (°Brix), and increased flesh firmness (kgf), and had no effect on fruit skin redness coverage (%). Under low crop load regimes, the converse effect on yield and fruit quality occurred.

Overall, from a rootstock perspective, the dwarfing rootstock 'Krymsk® 1' produced equivalent fruit weight and sweetness to the industry standard ('Nemaguard') but had the greater red fruit skin coverage. 'Cornerstone' fruit were the largest, had high red fruit skin coverage and maintained high levels of sweetness compared 'Elberta', 'Nemaguard', 'Krymsk® 1' and 'Krymsk® 86' rootstocks. The fruit quality characteristics on 'Krymsk® 86' and 'Elberta' rootstocks were similar to 'Nemaguard'.

Table 1. Yield and fruit quality performance statistics in response to rootstock (‘Nemaguard’, ‘Krymsk® 1’, ‘Krymsk® 86’, ‘Elberta’, ‘Cornerstone’) and crop load (high, medium, low) treatments of nectarine ‘Rose Bright’ under a vase canopy system during 2016/17 season.

Treatment	Fruit number (#/tree)	Yield (kg/tree)	Fruit weight (g)	Fruit sweetness (°Brix)	Fruit maturity (I_{AD} value)	Fruit firmness (kgf)	Fruit colour (% red)
Cornerstone	217	18.8	97 AB	13.1	0.2	4.8 A	91
Elberta	239	18.7	88 B	12.6	0.2	4.6 A	91
Krymsk®1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Krymsk®86	167	15.3	98 A	12.8	0.2	4.6 AB	92
Nemaguard	222	16.9	90 B	13.5	0.2	4.3 B	92
ANOVA	ns	ns	*	ns	ns	*	ns
High	333 a	24.1 a	78 c	11.5 c	0.3 a	5.0 a	89 a
Medium	220 b	19.5 b	93 b	12.8 b	0.2 b	4.5 b	92 b
Low	80 c	8.6 c	108 a	14.7 a	0.2 c	4.2 c	93 b
ANOVA	**	**	**	**	**	**	***
Cor - High	334	25.4	78	11.5	0.2	5	89
Cor - Medium	240	22.5	97	12.9	0.2	4.6	92
Cor - Low	72	8.5	115	14.9	0.2	4.7	93
Elb -High	370	25.6	72	11.3		5	88
Elb - Medium	252	20.5	84	12.5	0.2	4.8	95
Elb - Low	95	10	106	14	0.2	4.1	92
K1 - High	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
K1 - Medium	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
K1 - Low	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
K86 - High	231	19.6	92	11.7	0.2	4.9	91
K86 - Medium	185	17.3	96	12.7	0.2	4.6	92
K86 - Low	86	8.9	105	15.7	0.2	4.2	92
Nem - High	402	26.2	70	11.6	0.2	5	89
Nem - Medium	203	17.8	94	13.1	0.2	4.2	92
Nem - Low	62	6.5	107	15.7	0.1	3.7	94
ANOVA	ns	ns	ns	ns	ns	ns	ns

nd, ns, *, ** and *** indicate not determined, non-significant or significant differences at $P < 0.05$, 0.01 or 0.001, respectively, for the two-way interaction rootstock x crop load treatments. Significant differences ($P < 0.05$) between crop load treatments are denoted with different lower-case letters. Differences between rootstocks are indicated by different upper-case letters. Rootstock abbreviations: ‘Nemaguard’ (Nem), ‘Krymsk® 86’ (K86), ‘Elberta’ (Elb), ‘Krymsk® 1’ (K1), ‘Cornerstone’ (Cor).

Table 2. Yield and fruit quality performance statistics in response to rootstock ('Nemaguard', 'Krymsk® 1', 'Krymsk® 86', 'Elberta', 'Cornerstone') and crop load (high, medium, low) treatments of nectarine 'Rose Bright' under a vase canopy system during 2017/18 season.

Treatment	Fruit number (#/tree)	Yield (kg/tree)	Fruit weight (g)	Fruit sweetness (°Brix)	Fruit maturity (I_{AD} value)	Fruit firmness (kgf)	Fruit colour (% red)
Cornerstone	69 A	6.4	93 B	12.0 C	0.5 A	7.1 A	67 C
Elberta	87 ABC	7.0	83 A	11.9 C	0.5 AB	7.2 AB	63 BC
Krymsk®1	101 C	7.6	83 A	11.2 A	0.5 C	7.4 C	65 C
Krymsk®86	97 BC	7.5	79 A	11.6 B	0.5 AB	7.2 B	58 A
Nemaguard	79 AB	6.1	79 A	11.8 BC	0.5 BC	7.2 B	60 AB
ANOVA	*	ns	***	***	**	***	***
High	120 c	8.7 c	77 a	11.5 a	0.5 b	7.4 b	62
Medium	83 b	7.1 b	86 b	11.8 b	0.5 a	7.2 a	63
Low	57 a	4.9 a	87 b	11.8 b	0.5 a	7.2 a	63
ANOVA	***	***	***	**	*	***	ns
Cor - High	82	7.2	90	11.8 cd	0.5	7.2	66
Cor - Medium	78	7.5	97	12.2 e	0.4	7.1	69
Cor - Low	47	4.3	92	11.9 de	0.5	7.1	65
Elb -High	126	9.1	74	11.8 cde	0.5	7.3	62
Elb - Medium	81	7.1	88	11.9 de	0.5	7.2	66
Elb - Low	55	4.8	88	12.0 de	0.5	7.1	63
K1 - High	167	10.7	69	10.6 a	0.6	7.6	64
K1 - Medium	73	6.2	85	11.2 b	0.5	7.3	63
K1 - Low	64	5.9	94	11.6 bcd	0.5	7.2	68
K86 - High	121	8.8	74	11.4 bc	0.5	7.4	58
K86 - Medium	103	8.2	81	11.6 bcd	0.5	7.73	58
K86 - Low	67	5.4	81	11.8 cd	0.5	7.1	59
Nem - High	105	7.9	75	11.9 cd	0.5	7.3	60
Nem - Medium	78	6.2	81	11.8 cde	0.5	7.2	60
Nem - Low	54	4.3	80	11.7 cd	0.5	7.2	60
ANOVA	ns	ns	ns	*	ns	ns	ns

ns, *, ** and *** indicate non-significant or significant differences at P < 0.05, 0.01 or 0.001, respectively, for the two-way interaction rootstock x crop load treatments. Significant differences (P < 0.05) between crop load treatments are denoted with different lower-case letters. Differences between rootstocks are indicated by different upper-case letters. Rootstock abbreviations: 'Nemaguard' (Nem), 'Krymsk® 86' (K86), 'Elberta' (Elb), 'Krymsk® 1' (K1), 'Cornerstone' (Cor).

Table 3. Yield and fruit quality performance statistics in response to rootstock ('Nemaguard', 'Krymsk® 1', 'Krymsk® 86', 'Elberta', 'Cornerstone') and crop load (high, medium, low) treatments of nectarine 'Rose Bright' under a vase canopy system during 2018/19 season.

Treatment	**Fruit number (#/tree)**	**Yield (kg/tree)**	**Fruit weight (g)**	**Fruit sweetness (°Brix)**	**Fruit maturity (I_{AD} value)**	**Fruit firmness (kgf)**	**Fruit colour (% red)**
Cornerstone	75 A	7.7 A	105 B	14.3 AB	0.6 BC	6.8 B	66 B
Elberta	100 AB	8.9 AB	95 A	13.9 A	0.6 BC	6.9 BC	63 AB
Krymsk®1	105 BC	10.2 B	106 B	14.5 B	0.4 A	6.5 A	79 C
Krymsk®86	128 C	10.8 B	92 A	13.9 A	0.6 B	6.9 BC	65 AB
Nemaguard	95 AB	8.1 A	91 A	14.1 A	0.6 C	7.0 C	62 A
ANOVA	**	***	***	*	***	***	***
High	159 b	12.5 c	83 a	13.5 a	0.6 b	7.0 b	66
Medium	81 a	8.5 b	105 b	14.5 b	0.5 a	6.7 a	68
Low	62 a	6.4 a	104 b	14.4 b	0.6 ab	6.8 a	67
ANOVA	***	***	***	***	**	**	ns
Cor - High	101	9.5	94	13.6	0.6	7.0	64
Cor - Medium	78	8.8	112	14.6	0.6	6.8	66
Cor - Low	45	4.9	109	14.6	0.6	6.8	68
Elb -High	157	12.4	85	13.8	0.6	6.9	62
Elb - Medium	92	8.9	98	13.9	0.6	6.9	66
Elb - Low	52	5.3	103	14.0	0.6	6.9	68
K1 - High	164	13.6	87	13.4	0.5	6.6	82
K1 - Medium	72	8.2	116	15.2	0.4	6.4	79
K1 - Low	77	8.7	114	14.9	0.5	6.5	78
K86 - High	218	15.8	74	13.1	0.6	7.1	63
K86 - Medium	83	8.6	104	14.4	0.5	6.7	66
K86 - Low	82	7.9	99	14.2	0.5	6.8	66
Nem - High	152	11.4	78	13.6	0.7	7.1	60
Nem - Medium	82	7.9	97	14.5	0.6	6.9	63
Nem - Low	52	5.0	97	14.1	0.7	7.1	62
ANOVA	ns	ns	ns	ns	ns	ns	ns

ns, *, ** and *** indicate non-significant or significant differences at $P < 0.05$, 0.01 or 0.001, respectively, for the two-way interaction rootstock x crop load treatments. Significant differences ($P < 0.05$) between crop load treatments are denoted with different lower-case letters. Differences between rootstocks are indicated by different upper-case letters. Rootstock abbreviations: 'Nemaguard' (Nem), 'Krymsk® 86' (K86), 'Elberta' (Elb), 'Krymsk® 1' (K1), 'Cornerstone' (Cor).

Table 4. Yield and fruit quality performance statistics in response to rootstock ('Nemaguard', 'Krymsk® 1', 'Krymsk® 86', 'Elberta', 'Cornerstone') and crop load (high, medium, low) treatments of nectarine 'Rose Bright' under a vase canopy system during 2019/20 season.

Treatment	**Fruit number (#/tree)**	**Yield (kg/tree)**	**Fruit weight (g)**	**Fruit sweetness (°Brix)**	**Fruit maturity (I_{AD} value)**	**Fruit firmness (kgf)**	**Fruit colour (% red)**
Cornerstone	268 BC	19.9 C	80 C	13.1 B	0.5	5.6	65 B
Elberta	299 C	20.2 C	75 B	12.4 A	0.5	5.8	64 AB
Krymsk®1	201 A	12.7 A	72 B	13.2 B	0.4	5.7	79 C
Krymsk®86	301 C	19.1 BC	67 A	12.6 A	0.5	5.9	62 A
Nemaguard	261 B	17.6 B	75 B	13.0 B	0.5	5.7	62 A
ANOVA	***	***	***	***	ns	ns	***
High	449 c	25.6 c	57 a	11.4 a	0.5 b	6.3 b	66
Medium	198 b	15.6 b	80 b	13.2 b	0.4 a	5.6 a	67
Low	151 a	12.5 a	85 c	14.0 c	0.4 a	5.4 a	67
ANOVA	***	***	***	***	***	***	ns
Cor - High	442	26.7	64 c	11.7 c	0.5	6.1 de	65
Cor - Medium	218	18.9	87 fg	13.4 ef	0.4	5.4 ab	65
Cor - Low	163	14.1	88 fg	14.1 h	0.4	5.4 ab	67
Elb -High	520	29.9	58 bc	11.1 ab	0.5	6.2 e	64
Elb - Medium	221	17.3	79 de	12.8 d	0.5	5.5 b	66
Elb - Low	156	13.6	88 fg	13.3 def	0.5	5.6 bc	61
K1 - High	356	17.7	49 a	10.9 a	0.5	6.6 f	76
K1 - Medium	140	10.8	77 de	13.5 fg	0.4	5.5 bc	81
K1 - Low	108	9.6	89 g	15.1 i	0.4	5.1 a	80
K86 - High	476	26	55 ab	11.6 bc	0.5	6.3 ef	62
K86 - Medium	237	17.2	73 d	12.9 de	0.5	5.8 cd	61
K86 - Low	191	14	74 d	13.3 edf	0.4	5.6 bc	63
Nem - High	474	27.5	59 bc	11.6 bc	0.5	6.1 de	62
Nem - Medium	172	14	81 ef	13.4 edf	0.5	5.6 bc	61
Nem - Low	137	11.4	84 efg	14.1 gh	0.4	5.4 b	65
ANOVA	ns	ns	*	***	ns	**	ns

ns, *, ** and *** indicate non-significant or significant differences at P < 0.05, 0.01 or 0.001, respectively, for the two-way interaction rootstock x crop load treatments. Significant differences (P < 0.05) between crop load treatments are denoted with different lower-case letters. Differences between rootstocks are indicated by different upper-case letters. Rootstock abbreviations: 'Nemaguard' (Nem), 'Krymsk® 86' (K86), 'Elberta' (Elb), 'Krymsk® 1' (K1), 'Cornerstone' (Cor).

Table 5. Yield and fruit quality performance statistics in response to rootstock (‘Nemaguard’, ‘Krymsk® 1’, ‘Krymsk® 86’, ‘Elberta’, ‘Cornerstone’) and crop load (high, medium, low) treatments of nectarine ‘Rose Bright’ under a vase canopy system during 2020/21 season.

Treatment	Fruit number (#/tree)	Yield (kg/tree)	Fruit weight (g)	Fruit sweetness (°Brix)	Fruit maturity (I_{AD} value)	Fruit firmness (kgf)	Fruit colour (% red)
Cornerstone	221 B	21.5 B	105 C	11.0 A	0.2 B	4.8 BC	82 A
Elberta	223 B	20.9 B	97 AB	11.1 A	0.2 B	4.7 B	83 A
Krymsk®1	94 A	7.7 A	92 AB	14.5 C	0.1 A	4.6 B	94 B
Krymsk®86	248 B	21.9 B	91 A	10.9 A	0.3 C	4.9 C	82 A
Nemaguard	218 B	20.3 B	100 BC	11.9 B	0.2 AB	4.2 A	82 A
ANOVA	***	***	**	***	***	**	***
High	285 c	24.0 c	86 a	11.2 a	0.2 b	4.8 b	83
Medium	198 b	18.4 b	95 b	12.4 b	0.2 b	4.6 a	85
Low	119 a	12.9 a	109 c	12.0 b	0.2 a	4.5 a	86
ANOVA	***	***	***	**	*	***	ns
Cor - High	329	28.4	89	11.3 ab	0.2	4.7 cde	77 a
Cor - Medium	226	22.7	103	11.1 a	0.2	4.8 de	84 bcd
Cor - Low	108	13.4	124	10.6 a	0.2	5.0 ef	85 d
Elb -High	280	24.9	88	11.1 a	0.2	4.7 cde	86 d
Elb - Medium	233	21.6	97	11.2 a	0.2	4.6 cd	84 cd
Elb - Low	154	16.2	106	11.1 a	0.2	4.7 cde	79 abc
K1 - High	145	11.7	87	11.2 a	0.2	5.2 f	93 e
K1 - Medium	93	6.7	87	16.3 c	0.1	4.8 def	94 e
K1 - Low	43	4.5	101	15.9 c	0.2	3.9 a	95 e
K86 - High	323	26.2	82	10.9 a	0.3	5.2 f	83 bcd
K86 - Medium	264	23.9	91	10.7 a	0.2	4.8 de	78 ab
K86 - Low	159	15.5	100	11.0 a	0.3	4.8 de	83 cd
Nem - High	349	28.8	86	11.5 ab	0.2	4.4 bc	77 a
Nem - Medium	173	17.0	98	12.7 b	0.2	4.0 a	83 bcd
Nem - Low	133	15.0	115	11.5 ab	0.2	4.2 ab	86 d
ANOVA	ns	ns	ns	***	ns	***	**

ns, *, ** and *** indicate non-significant or significant differences at $P < 0.05$, 0.01 or 0.001, respectively, for the two-way interaction rootstock x crop load treatments. Significant differences ($P < 0.05$) between crop load treatments are denoted with different lower-case letters. Differences between rootstocks are indicated by different upper-case letters. Rootstock abbreviations: ‘Nemaguard’ (Nem), ‘Krymsk® 86’ (K86), ‘Elberta’ (Elb), ‘Krymsk® 1’ (K1), ‘Cornerstone’ (Cor).

Table 6. Yield and fruit quality performance statistics in response to rootstock ('Nemaguard', 'Krymsk® 1', 'Krymsk® 86', 'Elberta', 'Cornerstone') and crop load (high, medium, low) treatments of nectarine 'Rose Bright' under a vase canopy system during 2021/22 season.

Treatment	Fruit number (#/tree)	Yield (kg/tree)	Fruit weight (g)	Fruit sweetness (°Brix)	Fruit maturity (I_{AD} value)	Fruit firmness (kgf)	Fruit colour (% red)
Cornerstone	247 A	18.2 B	76 D	10.3 BC	0.9 C	7.2	68 AB
Elberta	310 BC	18.7 B	63 C	9.9 A	0.9 BC	7.1	70 B
Krymsk®1	260 AB	11.4 A	49 A	10.6 C	0.8 A	7.4	84 C
Krymsk®86	353 C	19.3 B	58 B	9.9 AB	0.9 B	7.2	66 A
Nemaguard	305 BC	18.8 B	63 C	9.7 A	0.9 B	7.1	66 A
ANOVA	***	***	***	***	***	ns	***
High	430 c	21.5 c	52 a	9.4 a	0.9	7.2	69 a
Medium	270 b	17.3 b	63 b	10.1 b	0.9	7.1	71 b
Low	185 a	13.0 a	71 c	10.7 c	0.9	7.2	72 b
ANOVA	***	***	***	***	ns	ns	**
Cor - High	289 cd	19.6	69	10.0 cd	0.9	7.0	66
Cor - Medium	284 cd	21.4	77	10.2 de	0.9	7.0	68
Cor - Low	167 a	13.5	82	10.6 e	1.0	7.6	70
Elb -High	460 ef	24.5	54	9.5 bc	0.8	7.1	70
Elb - Medium	281 bcd	18.0	65	10.1 de	0.9	7.1	71
Elb - Low	190 ab	13.6	71	10.2 de	0.9	7.1	68
K1 - High	465 ef	15.9	34	8.8 a	0.8	7.4	82
K1 - Medium	178 a	9.5	49	10.6 e	0.8	7.4	85
K1 - Low	136 a	8.7	64	12.3 f	0.8	7.3	86
K86 - High	521 f	24.4	47	9.5 bc	0.9	7.4	63
K86 - Medium	316 d	19.0	60	10.1 de	0.9	7.1	66
K86 - Low	223abcd	14.5	65	10.2 de	0.8	7.0	68
Nem - High	415 e	23.3	56	9.1 ab	0.9	7.1	62
Nem - Medium	290 cd	18.4	64	9.8 cd	0.9	7.1	65
Nem - Low	209 abc	14.6	71	10.3 de	0.9	7.1	70
ANOVA	**	ns	ns	***	ns	ns	Ns

ns, *, ** and *** indicate non-significant or significant differences at P < 0.05, 0.01 or 0.001, respectively, for the two-way interaction rootstock x crop load treatments. Significant differences (P < 0.05) between crop load treatments are denoted with different lower-case letters. Differences between rootstocks are indicated by different upper-case letters. Rootstock abbreviations: 'Nemaguard' (Nem), 'Krymsk® 86' (K86), 'Elberta' (Elb), 'Krymsk® 1' (K1), 'Cornerstone' (Cor).

YIELD AND FRUIT QUALITY RESULTS FROM DEFICIT IRRIGATION STUDY ON NECTARINE 'SEPTEMBER BRIGHT'

Tables 1 – 6 present production results (yield, fruit quality) for nectarine 'September Bright' in response to irrigation treatments under an Open Tatura canopy system for 6 consecutive seasons: 2016/17, 2017/18, 2018/19, 2019/20, 2020/21 and 2021/22, respectively at Tatura, Victoria, Australia.

During fruit growth stage I, II and III, discrete irrigation levels were applied: 0, 20, 40 and 100% of crop evapotranspiration (ETc).

The results showed that deficit irrigation had a significant effect on fruit quality and yield. Overall, yield and fruit quality were maintained at 40% ETc during stage II; however, yield and fruit size were reduced in both stage I and III under 40% ETc regimes. More severe irrigation deficits (0% ETc and 20% ETc) penalised yield and fruit size, irrespective of fruit growth stage timing.

Notably, high fruit sweetness (≥ 14.4 °Brix) occurred across all seasons and irrigation management treatments. Nevertheless, increased fruit sweetness (°Brix), delayed fruit maturity (I_{AD}), greater flesh firmness (kgf) and higher skin redness coverage (%) occurred under late season (stage IIIb) deficit regimes (0, 20 % ETc). Whereas early season (stage I) deficit regimes reduced fruit skin redness coverage (%).

In summary, deficit irrigation management during either stage I or stage III reduced fruit weight and penalised yield compared to the fully watered control. However, a moderate level of water stress afforded by deficit irrigation during stage II (40% ETc) maintained fruit weight, yield and fruit quality (sweetness, firmness, maturity, colour).

Table 1. Yield and fruit quality performance statistics in response to deficit irrigation treatments of nectarine 'September Bright' under an Open Tatura canopy system during 2016/17 season.

Treatment	Fruit number (#/tree)	Yield (kg/tree)	Fruit weight (g)	Fruit sweetness (°Brix)	Fruit maturity (I_{AD})	Fruit firmness (kgf)	Fruit colour (% red)
0_I	115 abcde	12.6 bc	113 b	15.7 c	0.8 bcd	3.9 bc	53 a
0_II	95 ab	12.6 bc	136 d	15.2 ab	0.7 bc	3.9 bc	66 d
0_IIIa	121 bcde	12.9 bc	111 b	15.1 ab	0.7 bc	3.6 ab	60 c
0_IIIb	122 cde	10.0 a	84 a	18.1 e	1.0 f	5.6 d	74 e
20_I	89 a	12.0 abc	135 d	15.5 bc	0.7 ab	3.8 abc	57 bc
20_II	100 abc	13.2 c	135 d	15.1 a	0.6 a	3.2 a	66 d
20_IIIa	127 de	14.2 cd	113 b	15.3 ab	0.7 bc	3.6 ab	59 bc
20_IIIb	117 bcde	10.4 ab	90 a	17.3 d	1.2 g	5.8 d	69 d
40_I	137 e	16.1 d	119 bc	15.4 abc	0.9 ef	4.4 c	52 a
40_II	106 abcd	13.3 c	128 cd	15.3 ab	0.8 cde	4.2 bc	59 bc
40_IIIa	113 abcde	13.8 cd	124 c	15.3 ab	0.9 de	4.1 bc	57 b
Control	113 abcde	14.3 cd	129 cd	15.3 ab	0.9 cde	4.2 bc	57 bc
ANOVA	*	***	***	***	***	***	***

ns, *, ** and *** indicate not determined, non-significant or significant differences at $P < 0.05$, 0.01 or 0.001, respectively, for the two-way interaction irrigation treatments. Significant differences ($P < 0.05$) between irrigation treatments are denoted with different lower-case letters. Treatment values 0, 20 and 40 depict deficit (0, 20, 40% ETc) irrigation treatments and the period of fruit growth when deficit regime was applied (Stage I, III, IIIa, IIIb) compared to the control (100% ETc), respectively.

Table 2. Yield and fruit quality performance statistics in response to deficit irrigation treatments of nectarine 'September Bright' under an Open Tatura canopy system during 2017/18 season.

Treatment	Fruit number (#/tree)	Yield (kg/tree)	Fruit weight (g)	Fruit sweetness (°Brix)	Fruit maturity (I_{AD})	Fruit firmness (kgf)	Fruit colour (% red)
0_I	142 abc	11.3 bc	80 c	17.2 e	1.0 ef	5.8 d	64 a
0_II	163 cd	16.6 def	104 fg	15.5 a	0.7 ab	5.2 a	75 cd
0_IIIa	126 a	11.1 bc	90 de	16.2 cd	0.8 bc	5.3 ab	73 bcd
0_IIIb	158 bcd	8.4 a	54 a	18.8 g	1.1 g	6.8 e	80 e
20_I	149 abcd	12.9 c	88 cd	17.1 e	0.9 de	5.8 d	60 a
20_II	155 bcd	16.3 de	106 gh	15.8 ab	0.7 a	5.2 a	77 de
20_IIIa	134 ab	11.9 bc	91 de	16.3 d	0.7 ab	5.1 a	72 bc
20_IIIb	151 abcd	9.6 ab	66 b	17.8 f	1.3 h	6.7 e	77 de
40_I	173 d	16.7 def	98 ef	16.4 d	1.0 f	5.9 d	62 a
40_II	166 cd	18.7 f	112 h	15.7 ab	0.8 cd	5.5 bc	70 b
40_IIIa	163 cd	15.5 d	97 ef	16.0 bc	0.9 cde	5.5 b	71 bc
Control	172 d	18.3 ef	109 gh	16.1 cd	0.9 de	5.7 cd	71 bc
ANOVA	*	***	***	***	***	***	***

ns, *, ** and *** indicate not determined, non-significant or significant differences at $P < 0.05$, 0.01 or 0.001, respectively, for the two-way interaction irrigation treatments. Significant differences ($P < 0.05$) between irrigation treatments are denoted with different lower-case letters. Treatment values 0, 20 and 40 depict deficit (0, 20, 40% ETc) irrigation treatments and the period of fruit growth when deficit regime was applied (Stage I, III, IIIa, IIIb) compared to the control (100% ETc), respectively.

Table 3. Yield and fruit quality performance statistics in response to deficit irrigation treatments of nectarine 'September Bright' under an Open Tatura canopy system during 2018/19 season.

Treatment	Fruit number (#/tree)	Yield (kg/tree)	Fruit weight (g)	Fruit sweetness (°Brix)	Fruit maturity (I_{AD})	Fruit firmness (kgf)	Fruit colour (% red)
0_I	140 abcd	7.7 ab	57 ab	19.2 g	1.3 cd	6.7 cd	48 ab
0_II	122 ab	11.9 de	102 g	18.1 bc	1.1 a	5.9 a	55 c
0_IIIa	137 abcd	11.1 cd	82 d	17.5 a	1.0 a	5.9 a	56 c
0_IIIb	121 ab	5.7 a	49 a	20.0 h	1.3 de	6.9 de	63 d
20_I	133 abcd	9.1 bc	70 c	19.3 g	1.2 c	6.5 c	48 ab
20_II	112 a	10.9 cd	100 g	18.8 ef	1.0 ab	6.0 ab	56 c
20_IIIa	124 abc	10.6 cd	85 de	18.6 de	1.0 ab	6.1 ab	54 c
20_IIIb	123 abc	7.2 ab	60 b	19.0 fg	1.5 e	7.1 e	64 d
40_I	156 bcd	10.9 cd	70 c	19.3 g	1.4 d	6.8 d	47 a
40_II	157 cd	14.2 ef	91 ef	17.8 ab	1.2 b	6.1 b	57 c
40_IIIa	162 d	14.1 ef	88 def	17.9 abc	1.2 b	6.2 b	54 c
Control	163 d	14.8 f	94 fg	18.2 cd	1.2 b	6.2 b	52 bc
ANOVA	*	***	***	***	***	***	***

ns, *, ** and *** indicate not determined, non-significant or significant differences at $P < 0.05$, 0.01 or 0.001, respectively, for the two-way interaction irrigation treatments. Significant differences ($P < 0.05$) between irrigation treatments are denoted with different lower-case letters. Treatment values 0, 20 and 40 depict deficit (0, 20, 40% ETc) irrigation treatments and the period of fruit growth when deficit regime was applied (Stage I, III, IIIa, IIIb) compared to the control (100% ETc), respectively.

Table 4. Yield and fruit quality performance statistics in response to deficit irrigation treatments of nectarine 'September Bright' under an Open Tatura canopy system during 2019/20 season.

Treatment	Fruit number (#/tree)	Yield (kg/tree)	Fruit weight (g)	Fruit sweetness (°Brix)	Fruit maturity (I_{AD})	Fruit firmness (kgf)	Fruit colour (% red)
0_I	113 ab	9.8 a	88 c	16.3 c	0.8 b	5.8 cd	78 bc
0_II	115 ab	13.0 bc	113 g	15.1 a	0.7 a	5.4 ab	82 cd
0_IIIa	143 bc	12.9 bc	90 cd	16.3 c	0.8 b	5.5 bc	82 cd
0_IIIb	160 c	9.0 a	57 a	17.6 e	1.0 d	6.5 e	85 de
20_I	99 a	9.7 a	98 de	17.1 d	0.9 bc	5.9 d	75 b
20_II	134 bc	14.9 cd	111 g	15.1 a	0.6 a	5.1 a	86 e
20_IIIa	136 bc	13.3 bc	98 de	16.0 bc	0.7 a	5.3 ab	83 de
20_IIIb	153 c	11.7 ab	76 b	16.9 d	1.0 d	6.4 e	83 de
40_I	131 bc	13.0 bc	100 ef	16.9 d	1.0 d	6.3 e	70 a
40_II	142 bc	15.5 cd	110 g	15.7 b	0.9 bc	5.9 d	75 b
40_IIIa	153 c	16.5 d	109 fg	16.2 bc	0.9 cd	6.0 d	77 b
Control	146 c	16.5 d	114 g	15.9 bc	0.8 b	5.8 cd	78 bc
ANOVA	**	***	***	***	***	***	***

ns, *, ** and *** indicate not determined, non-significant or significant differences at $P < 0.05$, 0.01 or 0.001, respectively, for the two-way interaction irrigation treatments. Significant differences ($P < 0.05$) between irrigation treatments are denoted with different lower-case letters. Treatment values 0, 20 and 40 depict deficit (0, 20, 40% ETc) irrigation treatments and the period of fruit growth when deficit regime was applied (Stage I, III, IIIa, IIIb) compared to the control (100% ETc), respectively.

Table 5. Yield and fruit quality performance statistics in response to deficit irrigation treatments of nectarine 'September Bright' under an Open Tatura canopy system during 2020/21 season.

Treatment	Fruit number (#/tree)	Yield (kg/tree)	Fruit weight (g)	Fruit sweetness (°Brix)	Fruit maturity (I_{AD})	Fruit firmness (kgf)	Fruit colour (% red)
0_I	138 ab	16.8 abcd	124 cde	15.0 d	0.6 ab	5.4 b	74 bcd
0_II	157 b	19.7 de	128 def	14.0 a	0.6 ab	5.0 a	74 bcd
0_IIIa	146 ab	15.8 abc	110 ab	15.1 d	0.6 bc	5.2 ab	71 ab
0_IIIb	130 ab	13.2 a	104 a	15.9 f	0.8 de	5.8 c	83 e
20_I	139 ab	17.6 bcde	129 ef	14.8 cd	0.5 a	5.1 a	75 cd
20_II	121 a	16.1abcd	134 f	14.4 b	0.5 a	4.9 a	77 d
20_IIIa	134 ab	15.4 ab	119 bcd	14.8 cd	0.5 a	5.0 a	73 abc
20_IIIb	138 ab	15.8 abc	116 bc	15.5 e	0.8 ef	5.8 c	77 d
40_I	149 ab	19.6 de	132 ef	14.5 bc	0.9 fg	5.9 c	70 a
40_II	154 b	19.2 cde	126 def	14.4 b	0.7 cde	5.4 b	74 bcd
40_IIIa	194 c	21.2 e	110 ab	14.7 cd	0.9 g	5.7 c	70 a
Control	140 ab	18.4 bcde	134 f	14.6 bc	0.7 cd	5.4 b	74 bcd
ANOVA	**	***	***	***	***	***	***

ns, *, ** and *** indicate not determined, non-significant or significant differences at $P < 0.05$, 0.01 or 0.001, respectively, for the two-way interaction irrigation treatments. Significant differences ($P < 0.05$) between irrigation treatments are denoted with different lower-case letters. Treatment values 0, 20 and 40 depict deficit (0, 20, 40% ETc) irrigation treatments and the period of fruit growth when deficit regime was applied (Stage I, III, IIIa, IIIb) compared to the control (100% ETc), respectively.

Table 6. Yield and fruit quality performance statistics in response to deficit irrigation treatments of nectarine 'September Bright' under an Open Tatura canopy system during 2021/22 season.

Treatment	**Fruit number (#/tree)**	**Yield (kg/tree)**	**Fruit weight (g)**	**Fruit sweetness (°Brix)**	**Fruit maturity (I_{AD})**	**Fruit firmness (kgf)**	**Fruit colour (% red)**
0_I	154	17.9	117 cde	17.8 abc	0.1 a	1.9 ab	89 cd
0_II	177	19.8	113 cde	17.3 ab	0.1 a	1.7 a	89 cd
0_IIIa	174	19.0	109 cd	17.9 bcd	0.2 ab	1.8 a	86 bc
0_IIIb	184	15.6	86 a	19.5 e	0.6 de	3.6 f	93 e
20_I	172	20.3	119 e	17.9 bc	0.1 a	2.0 abc	87 cd
20_II	193	20.8	109 c	17.8 abc	0.2 a	1.9 ab	91 de
20_IIIa	168	18.5	110 cd	17.8 abc	0.1 a	1.7 a	88 cd
20_IIIb	190	18.9	99 b	18.6 d	0.6 e	3.5 f	89 cd
40_I	186	21.8	118 de	18.1 cd	0.4 cd	2.8 e	82 a
40_II	170	20.5	121 e	17.8 abc	0.3 bc	2.3 bcd	83 ab
40_IIIa	204	23.0	113 cde	18.0 bcd	0.5 d	2.7 de	83 ab
Control	176	21.1	120 e	17.1 a	0.3 bc	2.4 cde	82 a
ANOVA	ns	ns	***	***	***	***	***

ns, *, ** and *** indicate not determined, non-significant or significant differences at $P < 0.05$, 0.01 or 0.001, respectively, for the two-way interaction irrigation treatments. Significant differences ($P < 0.05$) between irrigation treatments are denoted with different lower-case letters. Treatment values 0, 20 and 40 depict deficit (0, 20, 40% ETc) irrigation treatments and the period of fruit growth when deficit regime was applied (Stage I, III, IIIa, IIIb) compared to the control (100% ETc), respectively.

YIELD AND FRUIT QUALITY RESULTS FROM ROOTSTOCK – CROP LOAD STUDY ON PEACH 'SEPTEMBER SUN'

Tables 1 – 6 present production results (yield, fruit quality) for peach 'September Sun' in response to rootstock ('Nemaguard', 'Cadaman®', 'Krymsk® 86', 'Elberta', 'Cornerstone') and crop load (high, medium, low) treatments under a vase canopy system for six consecutive seasons: 2016/17, 2017/18, 2018/19, 2019/20, 2020/21 and 2021/22, respectively at Tatura, Victoria, Australia.

Over the 6 seasons, the late season peach 'September Sun' produced large (≥ 189 g) sweet (≥ 14.1 °Brix) fruit when grown on the industry standard, 'Nemaguard' rootstock under a medium crop load (control treatment for rootstock x crop load study) regime.

Overall, high crop load increased final fruit number, reduced fruit weight, increased yield, lowered fruit sweetness and improved fruit skin redness coverage. Under low crop load regimes, the converse effect on yield and fruit quality occurred.

Overall, from a rootstock perspective, 'Cornerstone' and 'Elberta' fruit weight were larger and produced greater red fruit skin coverage compared to the industry standard ('Nemaguard'). Most seasons, the semi-dwarfing rootstock 'Krymsk® 86' produced equivalent fruit weight, yield and sweetness to 'Nemaguard' and had greater red fruit skin coverage.

Table 1. Yield and fruit quality performance statistics in response to rootstock ('Nemaguard', 'Cadaman®', Krymsk® 86', 'Elberta', 'Cornerstone') and crop load (high, medium, low) treatments of peach 'September Sun' under a vase canopy system during 2016/17 season.

Treatment	**Fruit number (#/tree)**	**Yield (kg/tree)**	**Fruit weight (g)**	**Fruit sweetness (°Brix)**	**Fruit maturity (I_{AD} value)**	**Fruit firmness (kgf)**	**Fruit colour (% red)**
Cadaman®	38 BC	9.3 AB	257 B	22.9 BC	0.9 BC	7.6	16 A
Cornerstone	91A	18.9 C	243 AB	23.2 C	0.8 AB	7.7	16 A
Elberta	22 C	5.7 A	288 C	21.8 AB	1.0 D	7.3	16 A
Krymsk®86	34 BC	7.4 AB	226 A	21.5 A	0.8 A	7	23 B
Nemaguard	56 B	11.6 B	239 AB	21.9 AB	0.9 CD	7.3	15 A
ANOVA	**	***	***	*	***	ns	**
High	75 a	14.3 b	220 a	22.1	0.8 a	7.3	17
Medium	49 b	11.5 b	252 b	22.4	0.9 b	7.5	18
Low	21 c	5.9 a	280 c	22.3	0.9 b	7.4	17
ANOVA	**	***	***	ns	***	ns	ns
Cad - High	67	15.3	229	23.1	0.8	7.7	15
Cad - Medium	28	7.4	269	22	0.9	7.1	17
Cad - Low	19	5.2	273	23.8	0.9	8	17
Cor - High	152	26.9	190	22.3	0.7	7.4	16
Cor - Medium	85	18.8	243	23.8	0.8	8	17
Cor - Low	36	11.0	296	23.5	0.9	7.8	14
Elb -High	20	5.3	282	21.6	1	7.2	14
Elb - Medium	36	9.0	281	22.9	0.9	7.7	15
Elb - Low	10	2.9	301	20.9	1	6.9	17
K86 - High	42	7.7	193	21.9	0.6	6.9	23
K86 - Medium	42	9.4	222	21	0.8	7	22
K86 - Low	19	5.0	262	21.6	0.8	7.2	26
Nem - High	92	16.3	204	21.6	0.8	7.2	16
Nem - Medium	54	12.8	245	22.4	0.9	7.6	14
Nem - Low	21	5.6	269	21.7	1	7.3	14
ANOVA	ns	ns	ns	ns	ns	ns	ns

ns, *, ** and *** indicate not determined, non-significant or significant differences at $P < 0.05$, 0.01 or 0.001, respectively, for the two-way interaction rootstock x crop load treatments. Significant differences ($P < 0.05$) between crop load treatments are denoted with different lower-case letters. Differences between rootstocks are indicated by different upper-case letters. Rootstock abbreviations: 'Nemaguard' (Nem), 'Krymsk® 86' (K86), 'Elberta' (Elb), 'Cadaman®' (Cad), 'Cornerstone' (Cor).

Table 2. Yield and fruit quality performance statistics in response to rootstock ('Nemaguard', 'Cadaman®', Krymsk® 86', 'Elberta', 'Cornerstone') and crop load (high, medium, low) treatments of peach 'September Sun' under a vase canopy system during 2017/18 season.

Treatment	Fruit number (#/tree)	Yield (kg/tree)	Fruit weight (g)	Fruit sweetness (°Brix)	Fruit maturity (I_{AD} value)	Fruit firmness (kgf)	Fruit colour (% red)
Cadaman®	42 B	6.4	283	15.8	0.6 AB	5.3 AB	44 B
Cornerstone	45 B	6.2	273	15.8	0.7 B	5.6 C	45 B
Elberta	46 B	6.0	258	16.1	0.5 A	5.0 A	45 B
Krymsk®86	31 A	4.4	274	15.2	0.6 B	5.3 AB	48 B
Nemaguard	39 AB	4.1	251	15.9	0.6 AB	5.4 BC	36 A
ANOVA	*	ns	ns	ns	*	**	***
High	60 b	8.6 b	240 a	15.3	0.6	5.3	46 b
Medium	33 a	3.9 a	267 b	16.0	0.7	5.4	44 ab
Low	28 a	3.7 a	297 c	16.0	0.6	5.3	41 a
ANOVA	***	***	***	ns	ns	ns	*
Cad - High	62 d	8.8	243	14.9	0.8	5.7	47
Cad - Medium	38 abc	5.6	297	16.3	0.5	5	41
Cad - Low	28 ab	4.8	310	16.3	0.6	5.2	45
Cor - High	66 de	9.8	236	15.8	0.7	5.7	46
Cor - Medium	30 ab	2.5	276	16.2	0.7	5.6	46
Cor - Low	40 bc	6.2	307	15.4	0.8	5.7	44
Elb -High	81 e	12	226	15.4	0.5	4.9	45
Elb - Medium	36 abc	4.2	248	16.7	0.6	5.2	47
Elb - Low	21 a	1.7	302	16.1	0.6	5	42
K86 - High	42 bc	6.8	271	14.5	0.6	4.9	54
K86 - Medium	26 ab	3.6	261	15.1	0.8	5.7	49
K86 - Low	24 ab	2.8	289	16.1	0.6	5.3	42
Nem - High	50 cd	5.7	222	16.2	0.6	5.4	37
Nem - Medium	37 abc	3.8	255	15.7	0.7	5.4	39
Nem - Low	29 ab	2.8	276	15.9	0.6	5.2	33
ANOVA	*	ns	ns	ns	ns	ns	ns

ns, *, ** and *** indicate not determined, non-significant or significant differences at $P < 0.05$, 0.01 or 0.001, respectively, for the two-way interaction rootstock x crop load treatments. Significant differences ($P < 0.05$) between crop load treatments are denoted with different lower-case letters. Differences between rootstocks are indicated by different upper-case letters. Rootstock abbreviations: 'Nemaguard' (Nem), 'Krymsk® 86' (K86), 'Elberta' (Elb), 'Cadaman®' (Cad), 'Cornerstone' (Cor).

Table 3. Yield and fruit quality performance statistics in response to rootstock ('Nemaguard', 'Cadaman®', Krymsk® 86', 'Elberta', 'Cornerstone') and crop load (high, medium, low) treatments of peach 'September Sun' under a vase canopy system during 2018/19 season.

Treatment	Fruit number (#/tree)	Yield (kg/tree)	Fruit weight (g)	Fruit sweetness (°Brix)	Fruit maturity (I_{AD} value)	Fruit firmness (kgf)	Fruit colour (% red)
Cadaman®	132	22.7	198 BC	16.4	1.2 A	7.3 AB	36 AB
Cornerstone	110	19.0	206 C	16.2	1.3 B	7.9 B	39 B
Elberta	118	23.1	203 C	15.9	1.2 A	7.1 A	37 AB
Krymsk®86	137	19.8	170 A	15.7	1.1 A	7.1 A	42 C
Nemaguard	119	19.4	184 AB	16.4	1.2 A	7.4 AB	35 A
ANOVA	ns	ns	***	ns	*	ns	***
High	217 c	29.6 c	143 a	15.1 a	1.2	7.4	41 c
Medium	96 b	19.7 b	205 b	16.3 b	1.2	7.4	37 b
Low	57 a	13.2 a	228 c	17.0 b	1.2	7.3	34 a
ANOVA	***	***	***	***	ns	ns	***
Cad - High	247 h	33.4 f	136 ab	14.9	1.3	7.7	40
Cad - Medium	96 bc	22.5 bcd	229 g	16.9	1.2	7.4	37
Cad - Low	53 ab	12.3 a	229 g	17.4	1.1	7.0	31
Cor - High	223 gh	31.3 ef	146 bc	15.1	1.2	7.7	45
Cor - Medium	56 ab	13.5 a	236 g	16.3	1.3	8.0	35
Cor - Low	51 a	12.2 a	236 g	17.1	1.3	8.0	36
Elb -High	166 ef	29.7 ef	181 de	15.6	1.2	7.3	41
Elb - Medium	143 de	28.5 def	198 ef	15.0	1.2	7.1	34
Elb - Low	45 a	11.1 a	231 g	17.1	1.1	6.9	35
K86 - High	252 h	28.7 def	118 a	14.6	1.2	7.1	43
K86 - Medium	84 abc	13.4 a	164 cd	16.4	1.0	6.9	45
K86 - Low	76 abc	17.4 ab	227 g	16.1	1.1	7.3	38
Nem - High	195 fg	25.0 cde	136 ab	15.3	1.2	7.5	38
Nem - Medium	103 cd	20.5 bc	199 ef	16.9	1.2	7.6	35
Nem - Low	60 abc	12.7 a	215 fg	17.1	1.1	7.2	31
ANOVA	***	ns	***	ns	ns	ns	ns

ns, *, ** and *** indicate not determined, non-significant or significant differences at $P < 0.05$, 0.01 or 0.001, respectively, for the two-way interaction rootstock x crop load treatments. Significant differences ($P < 0.05$) between crop load treatments are denoted with different lower-case letters. Differences between rootstocks are indicated by different upper-case letters. Rootstock abbreviations: 'Nemaguard' (Nem), 'Krymsk® 86' (K86), 'Elberta' (Elb), 'Cadaman®' (Cad), 'Cornerstone' (Cor).

Table 4. Yield and fruit quality performance statistics in response to rootstock ('Nemaguard', 'Cadaman®', Krymsk® 86', 'Elberta', 'Cornerstone') and crop load (high, medium, low) treatments of peach 'September Sun' under a vase canopy system during 2019/20 season.

Treatment	**Fruit number (#/tree)**	**Yield (kg/tree)**	**Fruit weight (g)**	**Fruit sweetness (°Brix)**	**Fruit maturity (I_{AD} value)**	**Fruit firmness (kgf)**	**Fruit colour (% red)**
Cadaman®	161	30.7	201	14.1	1.0	6.8	37 A
Cornerstone	144	31.2	219	14.3	1.0	6.8	37 A
Elberta	160	31.4	205	14.0	1.0	6.6	40 B
Krymsk®86	133	25.4	203	14.1	1.0	6.7	38 AB
Nemaguard	151	29.8	201	14.2	0.9	6.5	36 A
ANOVA	ns	ns	ns	ns	ns	ns	*
High	200 b	35.2 b	182 a	13.9 a	1.0	6.7	39
Medium	138 a	29.2 a	215 b	14.2 ab	1.0	6.7	38
Low	111 a	24.7 a	220 b	14.3 b	1.0	6.6	37
ANOVA	***	**	***	**	ns	ns	ns
Cad - High	227	38.5	177	13.9	1.0	6.9	37 abcd
Cad - Medium	145	32.8	230	14.1	1.0	6.7	38 abcd
Cad - Low	110	20.9	197	14.3	1.0	6.7	36 abcd
Cor - High	199	38.7	195	14.0	1.0	6.9	40 de
Cor - Medium	134	31.1	233	14.4	1.0	6.9	35 a
Cor - Low	97	23.7	228	14.4	0.9	6.5	37 abcd
Elb -High	227	36.8	178	13.5	0.9	6.4	42 e
Elb - Medium	134	29.2	216	14.3	1.0	6.8	37 abcd
Elb - Low	118	28.1	237	14.3	0.9	6.5	41 de
K86 - High	162	30.4	199	14.2	1.0	6.7	37 abcd
K86 - Medium	120	20.1	188	13.9	1.0	6.7	39 cde
K86 - Low	118	25.6	223	14.3	1.0	6.6	38 abcde
Nem - High	183	31.7	178	14.2	1.0	6.6	35 abc
Nem - Medium	156	32.4	209	14.1	0.9	6.3	39 bcde
Nem - Low	113	25.1	217	14.3	1.0	6.6	35 abc
ANOVA	ns	ns	ns	ns	ns	ns	*

ns, *, ** and *** indicate not determined, non-significant or significant differences at P < 0.05, 0.01 or 0.001, respectively, for the two-way interaction rootstock x crop load treatments. Significant differences (P < 0.05) between crop load treatments are denoted with different lower-case letters. Differences between rootstocks are indicated by different upper-case letters. Rootstock abbreviations: 'Nemaguard' (Nem), 'Krymsk® 86' (K86), 'Elberta' (Elb), 'Cadaman®' (Cad), 'Cornerstone' (Cor).

Table 5. Yield and fruit quality performance statistics in response to rootstock ('Nemaguard', 'Cadaman®', Krymsk® 86', 'Elberta', 'Cornerstone') and crop load (high, medium, low) treatments of peach 'September Sun' under a vase canopy system during 2020/21 season.

Treatment	Fruit number (#/tree)	Yield (kg/tree)	Fruit weight (g)	Fruit sweetness (°Brix)	Fruit maturity (I_{AD} value)	Fruit firmness (kgf)	Fruit colour (% red)
Cadaman®	119 AB	27.7 AB	252	15.4	1.3 B	8.0 B	35 B
Cornerstone	132 B	33.2 B	266	14.9	1.5 C	8.7 C	37 BC
Elberta	79 A	19.5 A	261	15.4	1.1 A	7.4 A	39 C
Krymsk®86	81 A	19.3 A	254	15.3	1.3 B	8.0 B	36 BC
Nemaguard	128 B	29.8 B	241	15.4	1.3 B	8.0 B	31 A
ANOVA	*	**	ns	ns	***	***	***
High	129 b	27.9	239 a	15.1	1.3 a	7.9 a	36
Medium	109 ab	27.2	259 b	15.4	1.4 b	8.2 b	35
Low	86 a	22.6	266 b	15.4	1.3 b	8.0 ab	35
ANOVA	*	ns	**	ns	*	*	ns
Cad - High	167	35.2	226	15.2	1.3	7.9	35
Cad - Medium	125	30.8	264	15.5	1.3	8.1	35
Cad - Low	64	17.2	266	15.4	1.4	8.1	35
Cor - High	153	33.8	247	14.9	1.4	8.4	39
Cor - Medium	115	29.7	266	15.0	1.6	8.9	37
Cor - Low	128	36.3	284	14.9	1.6	8.8	35
Elb -High	83	20.8	268	15.3	1.1	7.1	38
Elb - Medium	87	20.8	248	15.7	1.3	7.8	36
Elb - Low	74	17.0	267	15.3	1.1	7.2	42
K86 - High	82	17.3	235	15.3	1.2	7.9	36
K86 - Medium	86	22.6	269	15.2	1.3	8.2	36
K86 - Low	74	17.9	257	15.4	1.3	8.0	38
Nem - High	160	32.7	217	15.0	1.3	8.0	31
Nem - Medium	130	32.1	247	15.4	1.3	8.1	33
Nem - Low	95	24.8	258	15.7	1.4	8.1	28
ANOVA	ns	ns	ns	ns	ns	ns	ns

ns, *, ** and *** indicate not determined, non-significant or significant differences at $P < 0.05$, 0.01 or 0.001, respectively, for the two-way interaction rootstock x crop load treatments. Significant differences ($P < 0.05$) between crop load treatments are denoted with different lower-case letters. Differences between rootstocks are indicated by different upper-case letters. Rootstock abbreviations: 'Nemaguard' (Nem), 'Krymsk® 86' (K86), 'Elberta' (Elb), 'Cadaman®' (Cad), 'Cornerstone' (Cor).

Table 6. Yield and fruit quality performance statistics in response to rootstock ('Nemaguard', 'Cadaman®', Krymsk® 86', 'Elberta', 'Cornerstone') and crop load (high, medium, low) treatments of peach 'September Sun' under a vase canopy system during 2021/22 season.

Treatment	**Fruit number (#/tree)**	**Yield (kg/tree)**	**Fruit weight (g)**	**Fruit sweetness (°Brix)**	**Fruit maturity (I_{AD} value)**	**Fruit firmness (kgf)**	**Fruit colour (% red)**
Cadaman®	142 C	21.7 C	200 B	14.5 AB	1.3 C	7.6 C	35 A
Cornerstone	53 A	10.7 A	234 C	15.3 C	1.3 C	7.7 C	36 A
Elberta	111 BC	17.7 BC	195 AB	14.8 ABC	1.0 A	6.8 A	45 C
Krymsk®86	74 AB	13.2 AB	202 B	15.1 BC	1.1 B	7.2 B	39 B
Nemaguard	140 C	23.1 C	176 A	14.4 A	1.2 C	7.6 C	37 AB
ANOVA	***	***	***	*	***	***	***
High	179 b	24.6 c	160 a	14.4 a	1.2	7.3 a	41b
Medium	85 a	16.6 b	210 b	14.7 a	1.2	7.5 b	39 b
Low	48 a	10.6 a	234 c	15.3 b	1.1	7.3 a	34 a
ANOVA	***	***	***	**	ns	*	***
Cad - High	299 d	35.9	140 a	14.4	1.3 d	7.5 def	36
Cad - Medium	77 ab	18.2	233 ef	14.3	1.2 cd	7.7 ef	36
Cad - Low	49 a	11.2	226 cdef	14.6	1.2 cd	7.6 def	31
Cor - High	87 ab	14.8	196 bcd	14.8	1.2 cd	7.7 ef	39
Cor - Medium	35 a	8.4	245 f	15.1	1.3 d	7.9 f	35
Cor - Low	36 a	9.0	260 f	15.9	1.2 cd	7.5 def	33
Elb -High	203 c	26.7	141 a	13.8	1.0 b	6.9 b	49
Elb - Medium	103 ab	19.0	190 bc	14.8	1.1 bc	7.3 bcde	43
Elb - Low	29 a	7.3	254 f	15.9	1.0 b	6.3 a	42
K86 - High	108 ab	17.6	183 b	15.3	1.1 b	6.9 bc	40
K86 - Medium	75 ab	13.7	193 bcd	14.6	1.1 b	7.2 bcd	44
K86 - Low	39 a	8.2	229 def	15.3	1.1 bc	7.4 bcde	34
Nem - High	197 c	27.9	142 a	13.8	1.2 cd	7.4 cde	41
Nem - Medium	135 bc	23.9	189 b	14.6	1.2 cd	7.6 def	39
Nem - Low	89 ab	17.4	199 bcde	14.7	1.3 d	7.7 ef	31
ANOVA	*	ns	*	ns	*	*	ns

ns, *, ** and *** indicate not determined, non-significant or significant differences at $P < 0.05$, 0.01 or 0.001, respectively, for the two-way interaction rootstock x crop load treatments. Significant differences ($P < 0.05$) between crop load treatments are denoted with different lower-case letters. Differences between rootstocks are indicated by different upper-case letters. Rootstock abbreviations: 'Nemaguard' (Nem), 'Krymsk® 86' (K86), 'Elberta' (Elb), 'Cadaman®' (Cad), 'Cornerstone' (Cor).