Final Report

Australian Sweet Persimmon Industry Development Project- Phase 4

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The Department of Agriculture and Fisheries (DAF)

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Summary

The Australian persimmon industry grows mostly non-astringent varieties and is totally reliant upon overseas breeding programs for new varieties to satisfy consumer preferences into the future. Several new non-astringent varieties have been identified, mostly from the Ministry of Agriculture, Forestry and Fisheries (MAFF) persimmon breeding program in Japan, as potentially relevant to the Australian industry.

Australian growers now have the ability to store persimmons for up to eight weeks by treating fruit with 1MCP then cold storing at 0°C. Embracing the new storage regimen will enable the industry to minimize the peaks and troughs of supply in the domestic market and extend fruit supply beyond the Australian harvest season. An export trade to distant markets is now feasible with the improved postharvest storage technique, as exporters and buyers will be confident of fruit quality on arrival.

Persimmon orchard productivity could be improved by moving from the use of seedling rootstocks to vegetatively propagated rootstocks. Firstly, a vegetative propagation technique with the capacity to reliably produce large numbers of rootstock plants is required. Establishing the most productive rootstock selections will require long term field trials in the different persimmon production environments across Australia.

Australian persimmon growers have new options for the control of mealybug following research quantifying the effectiveness of systemic insecticides clothianidin and sulfoxaflor. The systemic insecticides are more compatible with IPM programs where growers are using predators to assist in the control of mealybug.

Keywords

Persimmon, kaki, mealybug, rootstock, postharvest, deastringency, 1-MCP

Introduction

The diverse range of environments over which persimmons are grown in Australia, from the subtropics of Queensland, the hot Mediterranean climate in south-east Australia to the cool, temperate environment in southern Victoria; presents a challenge in developing the many solutions for issues specific to one or another production environment.

Whilst persimmon growing has a reasonably long history in Australia, there is considerable scope to develop advanced improved production practices in numerous key aspects of persimmon growing. There is a contrast of modern (eg plastic reflective mulch, netting) and elementary (eg seedling rootstock) technologies used in persimmon production in Australia.

Growth of the industry has been slow over recent years, from 2465 tonnes valued at $7.9M in 2012/13 to 2660 tonnes valued at $10.3M in 2016 (Persimmon Strategic Investment Plan 2017-2021), nevertheless there is considerable potential for growth in both the domestic and export sectors. Achieving the growth opportunities will require support through a program of well-coordinated RD&E activities.

The persimmon industry identified several key issues prior to this project, including:

- Availability of effective control measures for clearwing moth and mealybug
- Evaluation of new varieties including 'Rojo Brillante'
- Ongoing access to chemicals and future access to chemicals for specific pests of concern to persimmon growers
- Managing supply peaks and troughs to minimize unnecessary disruption to market prices
- Postharvest management protocols to extend storage life of fruit.

The project was designed to assist growers and support development of the persimmon industry by:

- Developing effective preharvest practices for control of the major pests of persimmon, mealybug and clearwing moth;
- Gather information from the latest overseas research on topics relevant to persimmon growing in Australia and establish relationships with delegates at the 6th International Symposium on Persimmon for future information exchange;
- Finalize improved cool storage practices to extend the storage duration of persimmons, enabling industry to extend the supply season and moderate supply fluctuations in the market.

Methodology

Mealybug

Monitoring

A range of methods were evaluated to monitor early movement of overwintering mealybug at bud burst as well as general increases in populations during the cropping cycle. Techniques included pheromone trapping, sticky bands, and visual inspections of roots. Monitoring methods were trailed in various growing regions with a range of sub-tropical and temperate environments.

Delta traps with citrus mealybug pheromone lures mounted on sticky base traps were installed in three orchards in south-east Queensland during the 2015/16 season. Lures were replaced every 6 weeks to ensure a sufficient level of pheromone was present. Eight traps were placed in each orchard. Traps were monitored every eight weeks with male citrus mealybug numbers recorded. Twenty fruit from six trees within each orchard were assessed for citrus mealybug numbers during the harvest period.

Sticky bands were evaluated on individual trees with band placement ranging from just above the soil on the lower trunk to lateral branches within the tree canopy. Six sticky bands were applied to 10 trees within an orchard in south-east Queensland. Sticky bands were comprised of blue cloth tape painted with a clear adhesive gel. They were monitored once a month for female mealybug.

Visual inspections of roots and soil at the trunk base was evaluated in three orchards in south-east Queensland, two orchards in northern Victoria and two orchards in South Australia. Twenty trees at each location were inspected by digging approximately ten centimetres below the soil in a 20 centimetre radius from the trunk to visually inspect for the presence of overwintering mealybug.

Fortnightly visual inspections of ten fruiting shoots on ten trees was carried out between August 2016 and April 2017. This included visual inspections of bark, leaves and fruit to monitor the development of mealybug populations between budbreak and harvest.

Insecticides and effective management practices

Field studies were conducted over two seasons, building on mealybug research undertaken in the previous project. The research culminated in an improved strategy for control of mealybug, suitable for Integrated Pest Management and with a focus on systemic insecticides.

A trial was conducted in the 2014/15 season on 7 year-old trees (cv. Jiro) in an orchard located in coastal south-east Queensland. Six replicate trees in a randomized block design received either Samurai® at 5 g/tree) soil drench at budburst, or foliar sprays of Transform® at 0.4 ml/L or Movento® at 0.4 ml/L applied at 14 days or 28 days before harvest. At harvest, 20 fruit per tree were collected and inspected for adult mealybug, crawlers and egg masses. The objective was to ascertain the comparative effectiveness of late season foliar sprays of two IPM compatible chemicals and a clothianidin soil drench at budburst.

The effectiveness of a late season application and lower (half label) rates of Samurai® (clothianidin) was investigated in two field trials in coastal south-east Queensland in the 2015/16 season. The treatments were 5 g/tree at flowering or 2.5 g/tree applied one month later (cv Jiro) and 5 g/tree at flowering or one month later, or 2.5 g/tree applied two months after flowering (cv Fuyu). Each chemical treatment was applied as a soil drench to six individual trees in a randomized block. Twenty fruit per tree collected at harvested were inspected for mealybug.

Clonal propagation (rootstocks)

An existing relationship with a nursery in north Queensland led to the nursery operators expressing interest in trying to develop a reliable technique for the clonal propagation of persimmon rootstock. The work was not funded by the project and the arrangement with the nursery owner was verbal only. DAF supplied the nursery with two plants each of five seedling rootstock selections. The sale of the business led to a disruption in progress on developing a reliable clonal propagation technique, just as the initial positive results were achieved. Potted plants of five seedling rootstock selections were forwarded to the nursery, namely the industry standard rootstocks Kaki Sun and FxG, along with the experimental selections MKN, Telco and *Diospyros glandulosa*. The nursery achieved mixed success in clonal propagation producing a small number of plants of 2 rootstocks and none of the other 3 rootstocks. There was insufficient repetition to ascertain whether the number of trees produced reflects differences between rootstock selections in propensity to be clonally propagated or the reliability of the propagation technique. The nursery did not divulge details of the technique as this was their intellectual property. The few details gleaned suggests the technique involved using small pieces of semi-hard green shoot. It appears the dormancy period of persimmon trees will reduce the time available for clonal propagation using green shoot tips, and hence how quickly large numbers of rootstock can be propagated. The small number of clonally propagated plants of two rootstock selections have been returned to DAF. Moderate success reported in the literature with tissue culture, single bud cuttings and buried one year old woody shoots (layering) warrants a thorough study to develop a reliable technique for vegetative propagation of persimmon rootstocks in Australia.

Rootstock agronomic performance

A replicated rootstock trial grafted to 'Jiro' was planted September 2015 at Maroochy Research Facility, Nambour. The trial consists of four replicate single tree plots each of nine rootstocks (Table 1). Graft compatibility along with an initial assessment of plant size (shoot length and trunk diameter) was completed prior to planting. The trees were very small and no tangible difference in tree size or graft compatibility was evident between the rootstocks. Trees of Thai glandulosa have required replanting in three of the four replicates. First crop of sufficient quantity of fruit to allow data collection is expected in 2019. Five rootstocks grafted to 'Fuyu' have been propagated and were planted in a replicated field trial in September 2016.

Table 1. Seedling rootstock selections included in the 'Jiro' and 'Fuyu' field trials.

Jiro	**Fuyu**
BDI	BDI
MKN	MKN
Kaki Sun (industry standard)	Kaki Sun
Fuyu (industry standard)	Fuyu
Hunsley	Hunsley
Thai glandulosa	
Telco	
G1 (industry standard)	
Dai Dai Maru	

New varieties

The Australian industry is totally reliant upon overseas breeding programs for new varieties to satisfy consumer preferences into the future. A scan of overseas breeding programs for varieties of potential suitability for the Australian industry is an ongoing activity.

Trees of six varieties were added to the orchard at Maroochy Research Facility for variety evaluation. All trees are grafted to the seedling rootstock selection Kaki sun. The varieties include three non-astringent ('Isahay', 'Sunami', 'Kazusa') and three astringent ('Otanenashi', 'Tone Wase', 'Yoho') varieties. Observations of growth and crop load were made in the 2015 summer, as the trees were too small to obtain meaningful data from shoot measurements. By the 2016/17 season, the trees were of a size to allow shoot length to be measured on ten shoots per tree at 2 monthly intervals (ie 3 times). A sample of 10 fruit were measured in November, January and March to ascertain fruit size of each variety.

Three new non-astringent persimmon varieties have been recently released by MAFF, Japan. The Australian industry predominately grows non-astringent or sweet persimmon varieties, and is totally reliant upon overseas breeding programs for new varieties to satisfy consumer preferences into the future. The new varieties offer the potential to extend the fruit supply season and provide fruit quality features sought by consumers.

Postharvest deastringency

Carbon dioxide (CO2) deastringency is standard industry practice in Spain to render fruit of the astringent variety 'Rojo Brillante' into a sweet (non-astringent) persimmon product that can be eaten firm. The Australian industry does not practice deastringency on the small volume of astringent persimmon produced. A pilot trial was conducted to gain experience with CO2 deastringency, as part of evaluating the potential suitability of 'Rojo Brillante' for the Australian persimmon industry. As there is only one tree of 'Rojo Brillante' in the orchard at Maroochy Research Facility and limited fruit, mostly fruit of an unidentified astringent variety was used. The budwood imported of 'Rojo Brillante' also contained budwood of the unidentified astringent variety.

A small gas chamber was constructed inside a cold-room for the deastringency trial. Ten trays of fruit of the unidentified astringent variety were exposed to >95% CO2 at 20°C for 24 hours. The fruit was stored at 15°C for 7 days then presented to a taste panel. Individual fruit was sliced into wedges and three wedges placed in small plastic cups for assessment by taste panelists. Fruit of the non-astringent variety 'Fuyu' was prepared in the same way and used as the control in the taste assessment.

Postharvest storage – temperate Australia

A study of advanced cool storage techniques for fruit grown in temperate Australia was conducted in 2015. The storage techniques were an untreated control, modified atmosphere (MA) bags (Lifespan® 342), SmartFresh℠ (1-MCP), and SmartFresh℠ plus MA bags. Fruit was sourced from three orchards (30 trays each) in the Shepparton region in May 2015, treated with SmartFresh℠ (500 ppb at 15°C for 24 hours) and transported by road to Maroochy Research Facility. The fruit was transferred to a cold-room on arrival and stored at 0°C or placed in MA bags before transfer to the cold-room. Two randomly selected trays from each orchard were destructively sampled prior to cold storage and evaluated for appearance, firmness, Brix and dry matter to establish maturity.

One tray of each postharvest treatment was removed at two week intervals and evaluated for calyx quality, skin blemish, colour and hand firmness. Fruit was then transferred into an ambient cool room and held at 20°C for seven days to simulate shelf conditions. After seven days of ambient temperature storage the fruit was again assessed for calyx quality, skin blemish, colour, hand firmness, penetrometer firmness, internal discolouration and rots.

The study is a follow-on to a similar study for fruit from subtropical growing regions and aimed to quantify the potential to extend the storage period of fruit from a temperate environment.

Clearwing moth

Clearwing moth is a major pest of persimmon in the subtropics (i.e. Queensland). A mating disruption pheromone trial was established in an orchard at Woombye. Pheromone twist ties were installed in one block in early September 2014 at a density of 1200 per hectare. A second application of pheromones was applied in February 2015 at the same density. A control block separated by different vegetation was left untreated as the control. Monitoring traps were placed in the treated and untreated blocks, and monitored weekly.

6th International Symposium on Persimmon

The ISHS International Symposium on Persimmon is the premier event for the exchange of technical information on the latest advances in the production, postharvest storage, processing and marketing of persimmon. The 6th International Symposium on Persimmon (16-20 Oct 2016) was held in Valencia and Huelva. The region around Valencia is the largest persimmon growing region in Spain and home to many of the research institutes and the principal export cooperative in Spain for persimmon. Huelva is the second largest persimmon growing area, although much smaller than Valencia, located on the south-west coast close to Portugal. The symposium attracted 150 attendees including large contingents from China, Japan, Korea and Spain, plus individuals from Brazil, Italy, France, Portugal, Turkey, Israel, and New Zealand. Japan will host the next symposium. Two oral papers were presented on the mealybug and postharvest storage work undertaken in this persimmon project.

Discussions were had with numerous researchers during the course of the symposium, as well as most of the small number of exporters and growers in attendance. The relationships established with these individuals will be valuable in the future for the exchange of information that will assist the Australian persimmon research program and technical inquiries from individual local growers.

Outputs

Farm visits in May 2015 to growers in central Victoria to provide advice on orchard management and an update on the latest R&D in the project.

Farm visits and update to growers in South Australia on the latest R&D from the project (Nov 2015).

Industry workshop held at Maroochy Research Facility, 17th December 2015, to provide an update to growers on activities in the project to S.E. Queensland growers.

Australian Persimmon Industry Conference, Feb 2016, Barooga, NSW. One oral presentation and accompanying paper for the event proceedings.

> Australian sweet persimmon industry development R&D update. Grant Bignell, David Bruun and David Oag.

6th International Symposium on Persimmon, Valencia, Spain. October 16-20, 2016. Two oral presentations and one paper in the symposium proceedings.

> Effect of 1-MCP and MA Bags on Postharvest Storage and Quality of 'Jiro' and 'Fuyu' Persimmon from Major Growing Regions of Australia. G. Bignell, D. Bruun and D. Oag.

> Monitoring and control strategies for mealybug of persimmon in Australia. G. Bignell, L. Senior and D. Oag.

Australian Persimmon Industry Conference and Field Day, 14 & 15 June 2017, Sydney, NSW. Three oral presentations and accompanying articles for the event proceedings.

> Postharvest technologies and the potential for market growth. David Oag

> Overview of the advances in strategies for control of mealybug of persimmon in Australia. David Oag

> An overview of the persimmon industry in Spain. David Oag.

Persimmon Press, May 2017

> The Potential of Rootstocks in the Australia Persimmon Industry. David Oag

> Review of the VI International Symposium on Persimmon. David Oag

Diagnostic services for pests and diseases were delivered to growers on demand during the project term.

- January 2015 – Commercial grower in south Brisbane – tree and branch dieback.
- April 2015 - Commercial grower in south Brisbane – tree and branch dieback.
- November 2015- Commercial grower – Adelaide Hills – identification of western flower thrips and disease isolation performed.
- June 2016 - Commercial grower – Adelaide Hills – diagnosis of fruit marking as humidity marks following prolonged rain.
- August 2016 – Large grower, Renmark, South Australia – Trunk borer identification request.
- February 2017 – Commercial grower – Lockyer Valley, Queensland – damaged fruit at harvest attributed to an early season infestation of fruit spotting bug.

Outcomes

Mealybug

At the outset of the project the use of Samurai® (clothianidin) in Australian persimmon orchards was governed by a minor use permit and has now progressed to a label registration. Use has become widespread across the industry with growers now having an understanding of the effectiveness of the chemical in controlling mealybug.

A new strategy for the effective control of mealybug consists of a Samurai® soil drench at flowering with the option of a Transform® (sulfoxaflor) foliar spray before harvest, where monitoring of mealybug numbers indicates the need to control a late season population outbreak. A preharvest foliar spray of Movento® effectively reduced the mealybug infestation and an early season soil drench provided a level of control comparable to Samurai®. A permit or label registration for Movento® will be required before Australian persimmon growers will be able to use the chemical for control of mealybug.

Samurai® applied at the rate of 5 g/tree gave the greatest control of longtailed mealybug adults followed by Transform® applied 28 days (2 April) prior to harvest (Figure 1). Transform® applied 28 days prior to harvest achieved the lowest level of crawlers followed by the Samurai® treatment. Movento® was generally the least effective treatment, nevertheless the incidence of mealybug on fruit was substantially less than on untreated fruit. The untreated control had the highest numbers of adults, crawlers and egg masses.

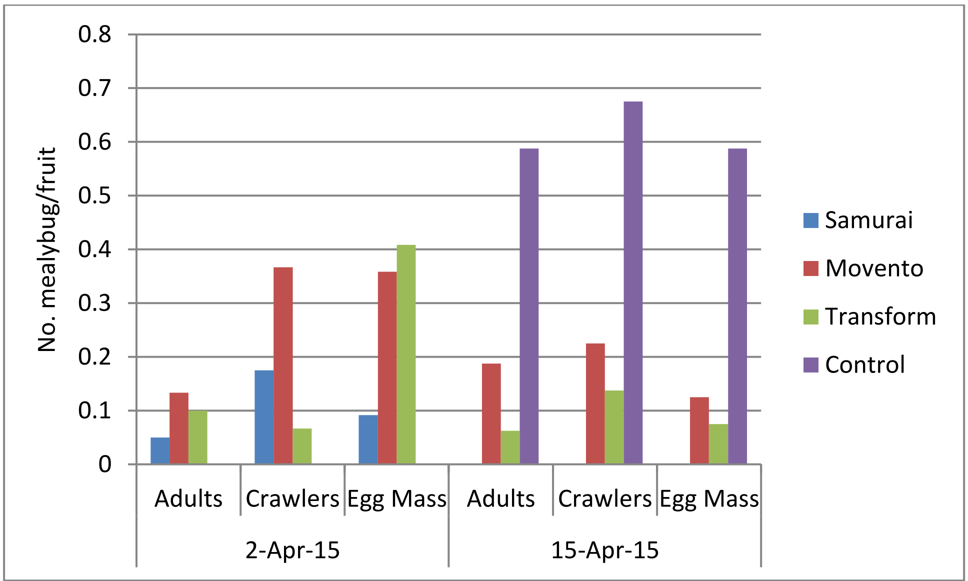

Figure 1. Average number of mealybug per fruit (cv Jiro) at harvest following a soil drench of Samurai® or preharvest foliar sprays of Movento® or Transform®.

Samurai® applied to 'Jiro' in October at the rate of 5 g/tree had greater efficacy in controlling both longtailed and citrus mealybug adults and crawlers compared to the lower rate of Samurai® applied in November and the untreated control (Figure 2). The number of egg masses was greatest in the untreated control with similar levels in both Samurai® treatments.

Samurai® applied to 'Fuyu' in October and November at the rate of 5 g/tree gave the best control of longtailed mealybug. The greatest control of citrus mealybug was achieved by the Samurai® rate of

2.5 g/tree applied in December. Trees treated with Samurai® at the rate of 5 g/tree applied in October experienced the highest level of citrus mealybug with infestations higher than the control. The number of crawlers per fruit was lowest in the Samurai® treatment applied in November followed closely by the October treatment. Samurai® applied at 2.5 g/tree in December had the highest number of crawlers per fruit of all treatments apart from the control, however the same treatment experienced the lowest number of egg masses.

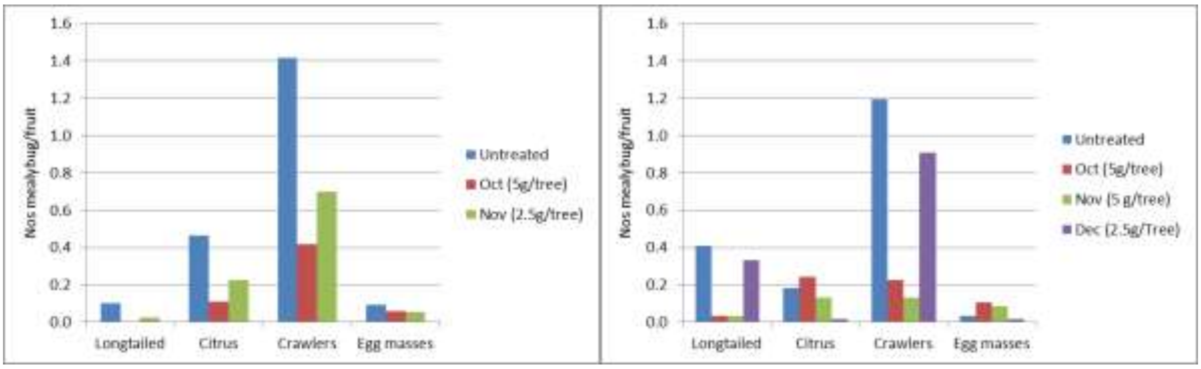

Figure 2. Average number of mealybug individuals per fruit of 'Jiro' (left) and 'Fuyu' (right) for different application times and rates of Samurai®.

Preharvest visual inspections of the fruit calyx was the most reliable method for monitoring mealybug populations, however by this stage of fruit development it is usually too late for effective control. Destructive sampling of bark before flowering identified overwintering mealybug (Figure 3), however sampling of shoots and roots at bud break and dormancy failed to identify populations. A significant number of mealybug infestations were found in frass caused by clearwing moth, a common pest in the subtropical coastal area of Queensland. Root inspections are laborious and unreliable for monitoring mealybug. The failure to detect any mealybug on tree roots suggests mealybug predominantly overwinter on the above ground parts of the tree under Australian conditions.

Figure 3. Overwintering mealybug found in the bark of Fuyu trees in northern Victoria.

Fortnightly monitoring of ten fruiting shoots on ten trees between early August 2016 and April 2017 in one SE Queensland orchard failed to identify any mealybug before early December. Rapid infestation was evident between mid-December and early February (Figure 4). All mealybug were located under the calyx of fruit (Figure 5).

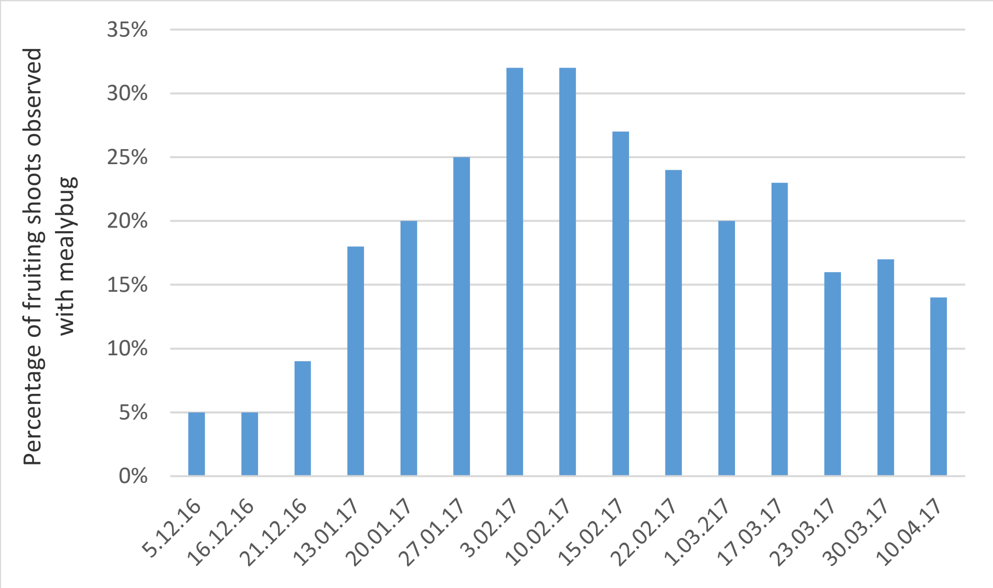

Figure 4. Percentage of fruiting shoots with mealybug between December and April.

Figure 5. Stage of fruit growth when first mealybug were identified in early December

Pheromone trapping appeared to be an effective method for monitoring citrus mealybug populations, with the number of males trapped in November/December corresponding with the level of infestation at harvest (Figure 6). Further trials to establish optimum trap densities, interval between trap inspections and longevity of lures, would help to improve the effectiveness of this monitoring option. Lures for longtailed and citrophilous mealybug are not available in Australia and are required to provide persimmon growers with the capability to monitor all mealybug pest species.

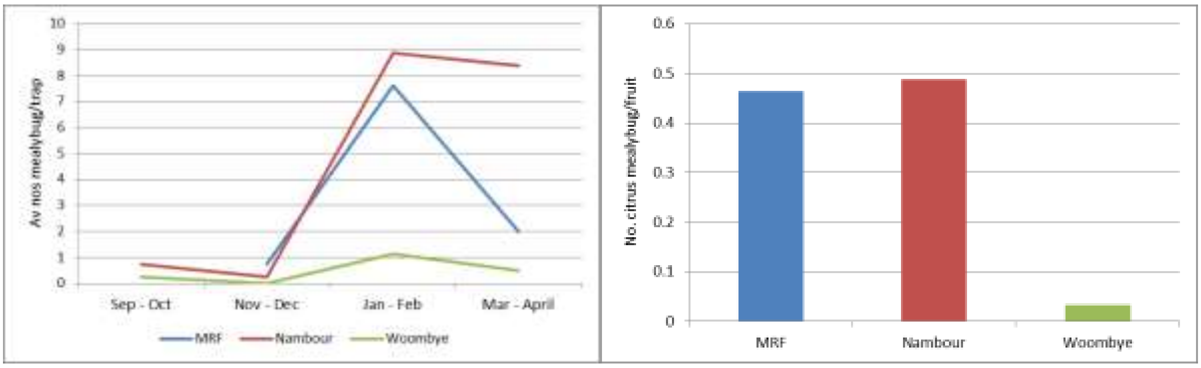

Figure 6. Average number of male citrus mealybug per pheromone trap (left) and average number of adult mealybug per fruit at harvest (right) in three orchards of 'Jiro' during 2015/16.

Pheromone trapping is a valuable practice for monitoring the timing of citrus mealybug infestations. Development of a pheromone trap for longtailed mealybug will greatly enhance the ability to control mealybug, with minimal chemical use and impact on beneficial insects. Systemic insecticides (eg Samurai®) provide effective control and greatly improve control of mealybug over the broad spectrum, contact insecticides previously used by persimmon growers.

Clearwing moth

The efficacy of mating disruption pheromones for controlling damage caused by clearwing moth (*Ichneumenoptera chrysophanes*) has been investigated in most of the Australian Sweet Persimmon Industry Development projects. Previous trials conducted on orchards planted on slopes with exposure to high winds showed limited efficacy due to the pheromone being displaced. One trial was established on a flat protected persimmon orchard in Woombye. Two separate Fuyu blocks were used for the trial; one treated with pheromone twist ties and the other untreated. Traps were placed in each block to monitor the incursion flights of clearwing moth between September 2014 and June 2015 (Figure 7). Minimal numbers of moths were trapped between September and December. Two distinct flights were observed during the monitoring period.

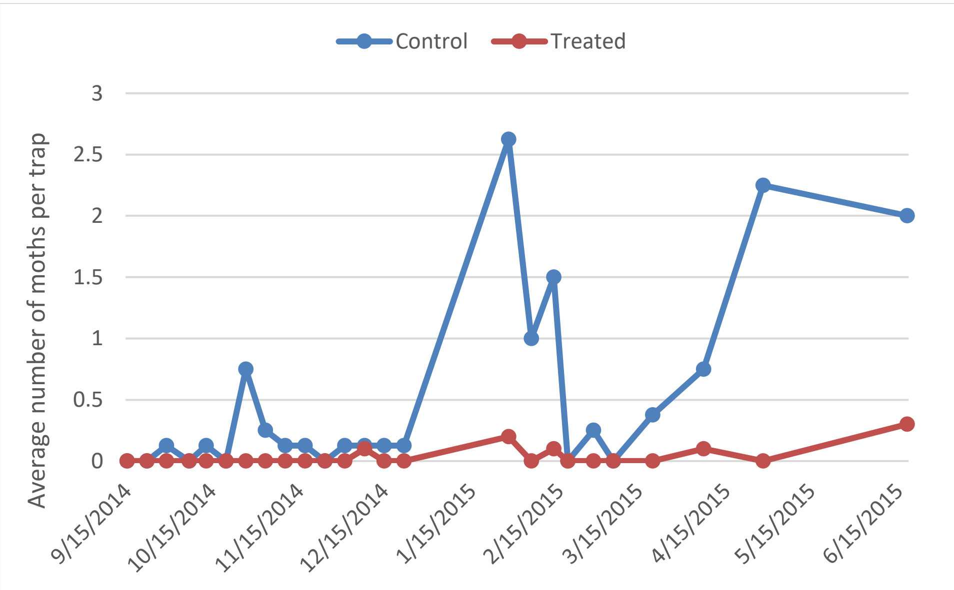

Figure 7. Average number of clearwing moths per trap between September 2014 and June 2015.

Fifty shoots per tree, or approximately 2000 shoots per block, were evaluated for clearwing moth damage (Figure 8) in March 2015 and August 2015 in treated and untreated blocks.

Figure 8. New shoots with visible clearwing moth damage.

Trees in the untreated block showed much higher levels of clearwing moth damage compared the treated block in both March and August (Figure 9).

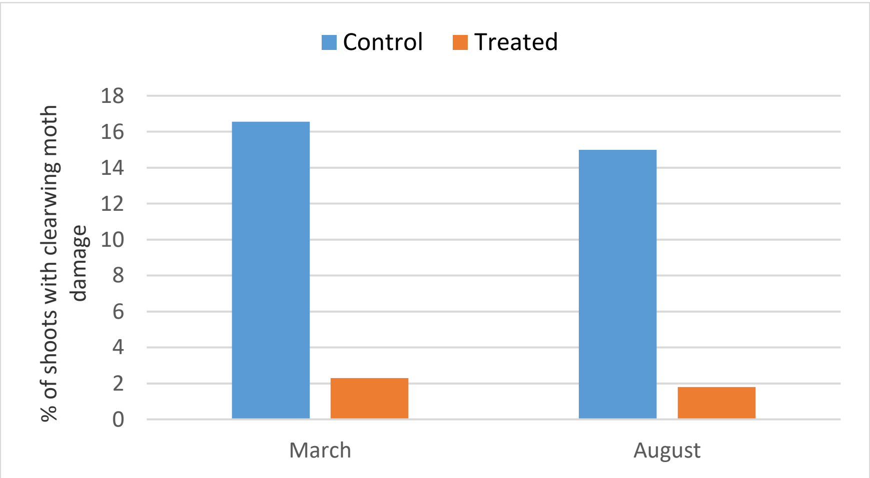

Figure 9. Average percent of shoots per tree with clearwing moth damage.

This result has shown that mating disruption pheromones can successfully reduce the damage caused by clearwing moth in persimmon orchards. The orchard used in this trial was protected from high winds, therefore results may vary in more exposed orchards.

CO_2 deastringency

Removal of astringency from astringent persimmon cultivars allows the fruit to be consumed while still firm and crunchy. Traditionally astringent cultivars need to fully ripen before tannins dissolve which results in the fruits texture becoming very soft and jelly like. The aim of astringency removal is to also maintain the firmness of the fruit so the texture remains similar to non-astringent varieties.

The taste panelists rated the CO_2 treated fruit as equally as palatable as fruit of the non-astringent variety 'Fuyu' (Table 2). The lower flavour and sweetness ratings of 'Fuyu' reflects the lower Brix (14.1°B) reading of the sample fruit, compared to the fruit of 'Rojo Brillante' (16.3°B) and the unidentified astringent variety (17.6°B).

Fruit were removed after seven days storage at 15°C and assessed for hand firmness (Figure 10.) Fruit treated with CO_2 had similar hand firmness levels compared to the untreated control.

Table 2. Taste panel ratings of fruit after CO_2 deastringency and the industry standard non-astringent variety 'Fuyu'.

	Unidentified astringent	**Fuyu**	**Rojo Brillante**
Flavour	6.5	5.0	7.1
Sweetness	5.7	5.0	6.8
Texture	6.1	5.7	7.2

Rating scales. 1 to 9, where 9 is highly preferred.

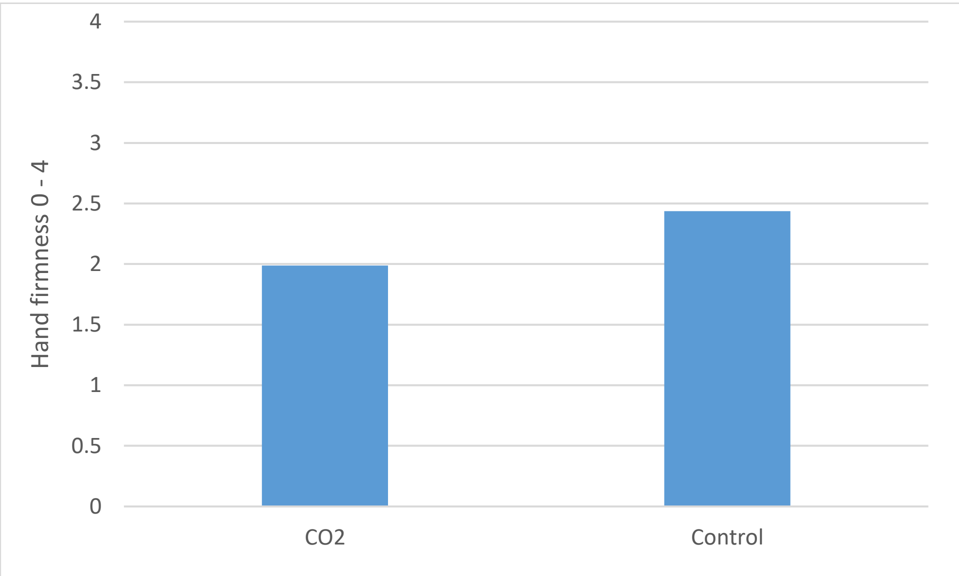

Figure 10. Average hand firmness of fruit treated with CO_2 compared with untreated fruit, after seven days cool storage following CO_2 deastringency treatment. Rating scale 0 (very firm) to 4 (soft).

This initial study reaffirms the ongoing evaluation and potential suitability of 'Rojo Brillante' to the Australian persimmon industry, and highlights the opportunity for CO_2 deastringency to be applied to astringent varieties currently grown in Australia. The capacity to transform astringent fruit to a non-astringent product, warrants the inclusion of CO_2 deastringency as part of the evaluation process for all astringent varieties. Late and early ripening, new astringent varieties present the opportunity to extend the supply season of the Australian persimmon industry, until a new non-astringent variety of the same harvest time becomes available in Australia.

Variety evaluation

'Isahay' and 'Sunami' have medium to high vigour (Figure 11), and the considerable late season extension growth of 'Isahay' indicates this variety has high vigour when not suppressed by crop load. 'Otanenashi', 'ToneWase', 'Yoho' and 'Kazusa' are low to medium vigour varieties. The reportedly early-ripening strains of 'Fuyu' (WW and AS) are more vigorous than 'Fuyu'. Evaluation in future years of the crop load to canopy size ratio will quantify the comparative yield productivity and establish if the earliness is due to excess vigour.

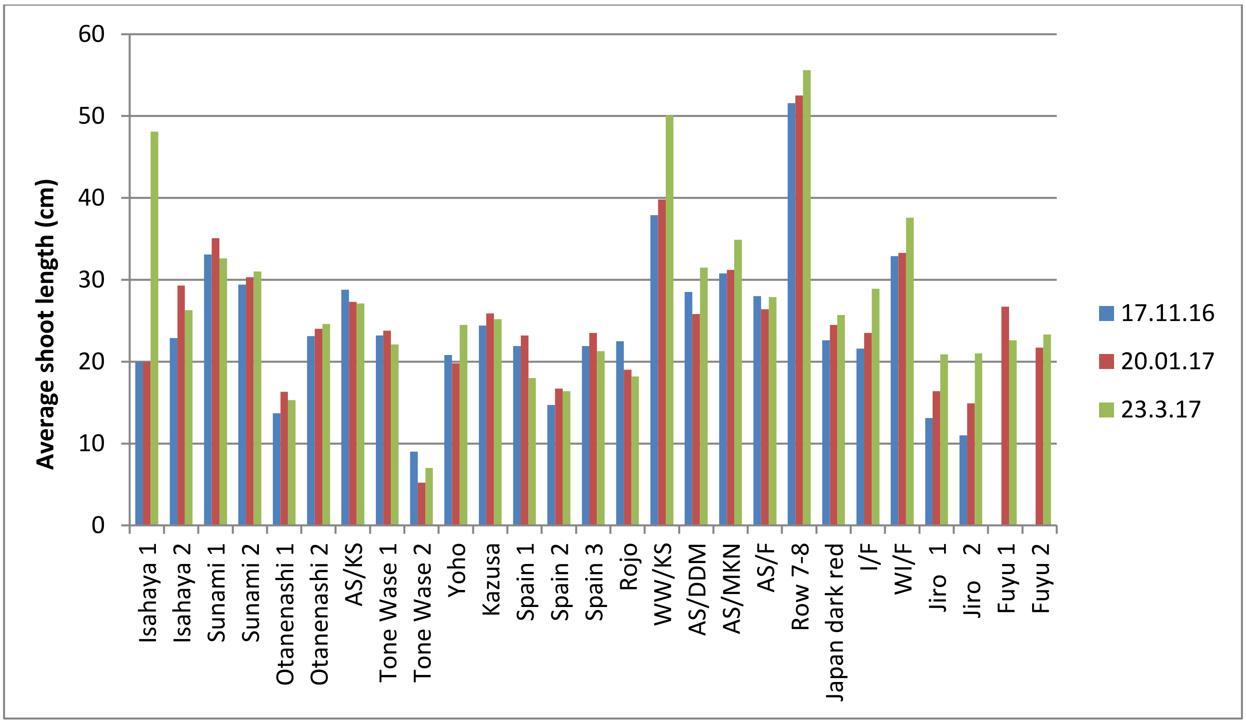

Figure 11. Shoot length of persimmon varieties as a measure of vigour.

Most of the varieties produced medium sized fruit (ie 20-30 mm) (Figure 12). Fruit size (diameter) mirrored shoot vigour, measured as shoot length (Figure 11). The very large fruit size (ie 50+ mm) of the selections 'WW' and 'Row 7-8' (Figure 9) warrants further evaluation of these selections. The impact of crop load on fruit size is unclear, as fruit yield of each tree was not recorded.

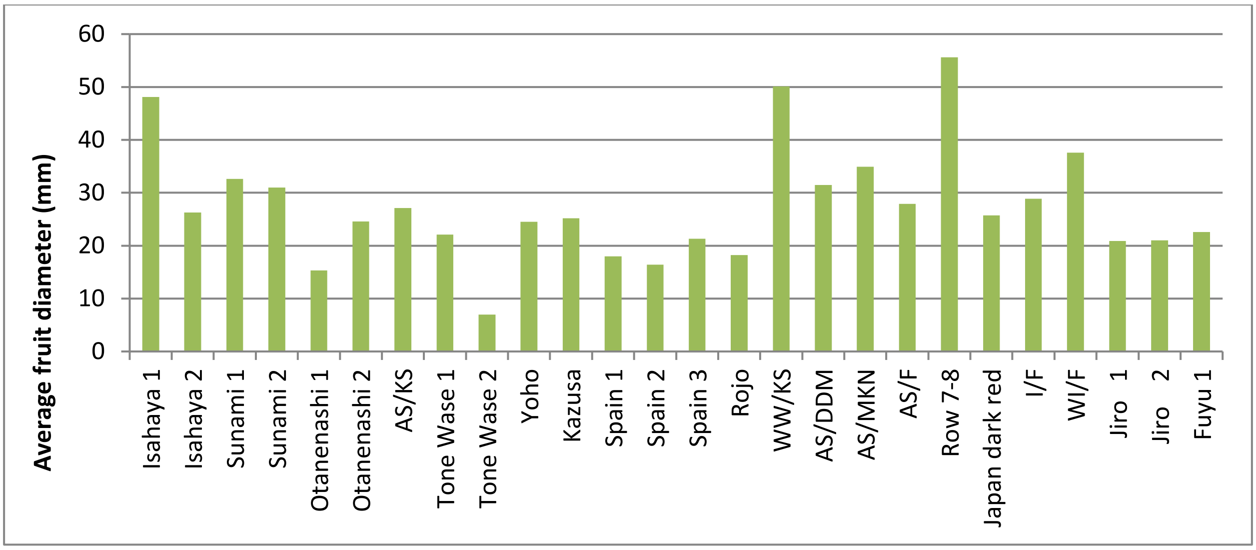

Figure 12. Average fruit diameter measurements at harvest for evaluated persimmon varieties

The Australian persimmon industry predominately grows non-astringent varieties and is totally reliant upon accessing new varieties from overseas breeding programs. MAFF (Japan) has released three new non-astringent varieties in recent years. Discussions with the MAFF persimmon breeder at the 6th International Symposium on Persimmon (Spain) ascertained a new willingness of MAFF to commercialize the Japanese-bred, and established a professional relationship for future negotiations. The recently signed (Jan 2017) Memorandum of Understanding between MAFF and Department of Agriculture and Fisheries (Queensland Government) is an opportunity to leverage access to the MAFF-bred non-astringent varieties for evaluation in Australia.

6th International Symposium on Persimmon

The Australian persimmon industry was keen to obtain the variety 'Rojo Brillante', the most widely grown variety and key to the success of the Spanish industry. Budwood was imported from persimmon grower in Portugal, however the budwood was mostly of an unknown astringent variety. Discussion with the grower established that the orchard was non-fruiting at the time the budwood was collected and subsequently turned out to be a mix of 'Rojo Brillante' and trees of another astringent variety. The fruit of 'Rojo Brillante' is quite distinctive and sufficient to identify the fruiting trees at Maroochy Research Station. From discussions with several delegates, it appears 'Rojo Brillante' has a narrow range of preferred environments in which the variety is successful, and that it is not a universal variety for all environments.

Agronomy and productivity

The number of scientists worldwide working on persimmon is relatively small and very few work in the area of agronomy and orchard productivity. This necessitates self-reliance to address agronomy and production issues affecting the local industry. Equally, cooperation and strong networks with the small number of persimmon production researchers is key to efficient information sharing to assist with local issues. To maintain and increase orchard productivity in Australia will require research to understand the physiological responses to environmental stress and variable weather, particularly low chill, heat stress (i.e. sunburn) and water stress. Several presentations highlighted the sensitivity of persimmon to saline conditions. Salt stress is a potential challenge for orchards in the Murray-Darling Basin, particularly during drought years. Managing tree architecture, pruning and tree training also contribute to the potential to improve orchard productivity and fruit quality. Water use efficiency in persimmon is an area foreseeably requiring attention as demands on irrigation water supplies increase in Australia. Other topics of agronomic research undertaken in Europe of potential relevance to Australia, include restricted irrigation supply to improve fruit retention, accelerate colour development and advance harvest time; scheduling for salinity management; and use of growth regulators for fruit quality.

Pest and disease management

Mealy bug is a major pest of persimmon in many countries, as it is in Australia. Australia leads the world on research in control strategies for mealybug using systemic insecticides. The small research team in Spain are the leaders in research on the use of biological controls (predators and parasitoids) and developing monitoring techniques. Identifying the species of mealybug is difficult using visual identification, yet important for the application of the correct biological control. Researchers in Spain have been working on identifying species using DNA measured by PCR. Similar initial research using DNA has recently been undertaken in Queensland to identify mealybug species in apple and presents an opportunity for collaboration to progress the technique. A symposium delegate from Brazil spoke of a fungus based biological control used for mealybug control and suggested it could be particularly relevant to the subtropical environments in Australia, which are similar to conditions in the persimmon growing regions in Brazil. Understanding how to integrate systemic insecticides, biological controls and monitoring practices into an annual programme for control of mealybug, will facilitate adoption within industry. A research collaboration with the team in Spain would be most relevant for undertaking this work.

Information was presented on Botryosphaeria trunk disease in persimmon. Whilst fungal disease is generally a minor issue in Australia, attention by growers to Botryosphaeria is warranted, particularly in the subtropical growing conditions in Queensland. Botryosphaeria trunk disease is most prevalent in subtropical environments and one or more of the fungi species causing the disease have been found in Queensland on other crops.

Rootstocks

All persimmon industries around the world propagate rootstocks from seed, which leads to considerable variability between trees, in size and performance, and in turn makes managing trees more difficult. Vegetative propagation (asexual) of rootstocks will produce uniformity of trees and thus improve orchard productivity. Therefore, developing an effective technique for the vegetative propagation of persimmon rootstocks is a fundamental step in improving orchard productivity in persimmon. Work is required to develop a reliable vegetative propagation technique and the subsequent adoption of the technique by the local nursery industry. The next step will then be to establish vegetatively propagated rootstock trials to quantify the relative performance of rootstock selections currently used in the Australian industry, identify the most appropriate scion/rootstock combinations and the best performing rootstocks for production districts across Australia.

Market growth (domestic and export)

The Australian industry was keen to learn of the factors behind the success of the persimmon industry in Spain. A variety in demand by consumers ('Rojo Brillante'), a technique (CO_2 deastringency) for producing the product sought by the market, the technical expertise to produce fruit of a consistent quality across the industry, and marketing the product in volume overseas (through principal cooperatives) are the key factors. In practice, this amounts to a high level of cooperation and collaboration along the persimmon supply chain in Spain. The expertise and technology available in Spain and around the world highlights the real potential to grow the domestic and export markets for Australian persimmons. Achieving success in market growth will require sustained R, D & E activities in production agronomy, postharvest and market access over consecutive years.

Postharvest storage

Treatment with SmartFresh[SM] (1-MCP) of 'Fuyu' fruit from temperate Australia reliably extended the postharvest storage period to eight weeks at 0°C (Figure 13). Modified atmosphere bags did not increase the postharvest storage period beyond the two weeks typical of current industry standard storage practices. The results suggest the potential to increase the storage period to 12 weeks using SmartFresh[SM], whilst retaining acceptable fruit firmness.

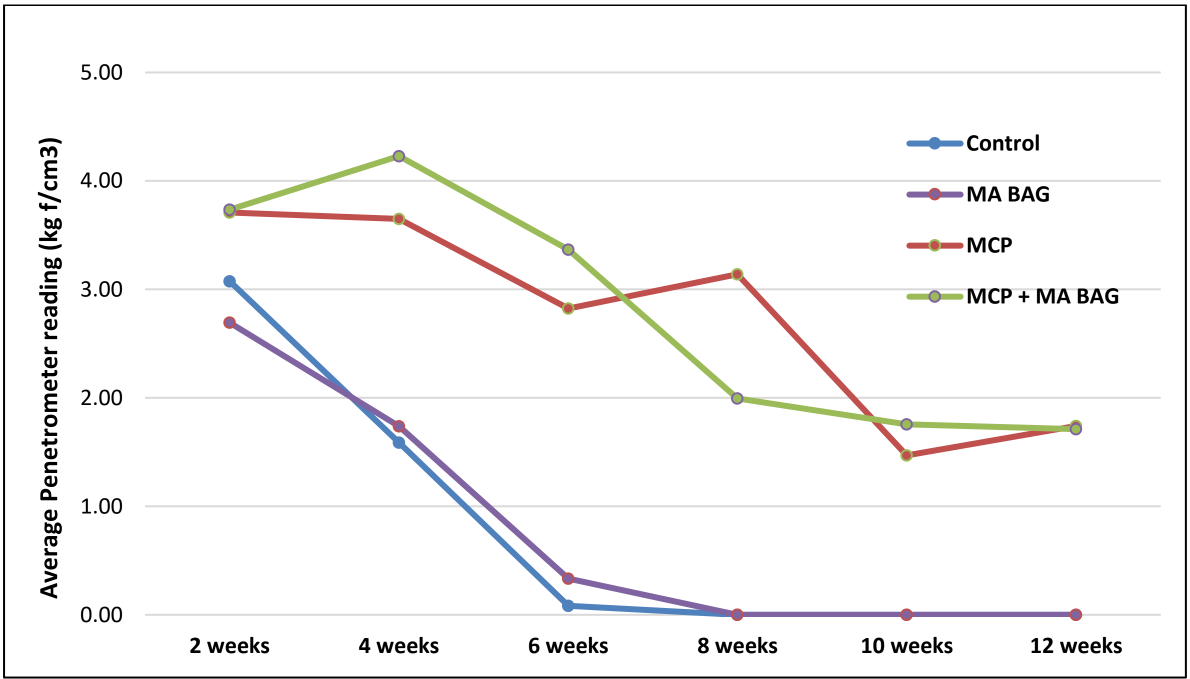

Figure 13. Firmness of 'Fuyu' fruit from southern Australia after storage at 0°C for several treatments to extend storage period.

After two weeks cold storage at 0°C and a subsequent 7 days shelf storage at ambient conditions, the untreated (control) fruit was comparable to the 1-MCP treated fruit (Figure 10), with 100% of fruit above the industry threshold for acceptable firmness. At eight weeks cold storage, 100% of the untreated fruit was gelled after 7 days shelf storage (Figure 14). This was in stark contrast to fruit treated with 1-MCP. After being held for 7 days at ambient conditions following 8 weeks cold storage, most fruit retained acceptable firmness. Firmness is a primary quality parameter of persimmon sold as sweet persimmon for consumption as a crunchy fruit.

Figure 14. Fruit of ‘Fuyu’ from a temperate growing environment treated with 1-MCP (right) or untreated (left), after 2, 8 and 12 weeks storage at 0ºC followed by 7 days ‘shelf’ conditions (20ºC).

Evaluation and Discussion

The ISHS international persimmon symposium remains an important event for the Australian persimmon industry as a source of information to directly assist the local R&D program, ideas that lead to improved production practices in Australian orchards, and building valuable networks amongst overseas researchers for the future exchange of information. The symposium is primarily an event designed for researchers to share technical information from the latest research. The symposium is the sole international meeting with a focus on persimmon, plus there are few national events for the dissemination of new information on persimmon and most are in non-English speaking countries.

The key learnings from the symposium relevant to the Australian industry were the:

- new non-astringent varieties released in recent years from breeding programmes in Japan and Korea,
- persimmon fresh cuts as a value-added product,
- the key time for control of the fungus causing circular leaf spot,
- salt sensitivity of persimmon rootstocks.

The breeder at the MAFF (Japan) program reported on the release of three non-astringent varieties. As the most recent releases from the principal persimmon breeding program in the world producing non-astringent varieties, it is reasonable to conclude that these varieties are improvements on the multiple non-astringent varieties previously released from the program.

'Taishuu' is a mid to late ripening variety, easy to grow with large fruit. 'Taiho' (released in 2014) is a late season variety and hence of particular relevance to Australia for the potential to extend the harvest season. Little is known of the fruit characteristics of 'Reigyoku', a mid-season variety released in 2015. A subsequent search has unearthed three additional non-astringent varieties released from the MAFF breeding program since 2003. The non-astringent variety 'Jowan' from Korea was released in 2014 and warrants further inquiry to determine potential suitability for the Australian industry.

The Australian industry predominately grows non-astringent or sweet persimmon varieties, and is totally reliant upon overseas breeding programs for new varieties to satisfy consumer preferences into the future. The new varieties offer the potential to extend the fruit supply season and provide fruit quality features sought by consumers.

Discussions with the MAFF persimmon breeder whilst at the 6th International Symposium on Persimmon (Spain) ascertained a new willingness of MAFF to commercialize the Japanese-bred varieties and established a professional relationship for future negotiations. The recently signed (Jan 2017) Memorandum of Understanding between MAFF and Department of Agriculture and Fisheries (Queensland Government) is an opportunity to leverage access to the MAFF-bred, non-astringent varieties for evaluation in Australia.

Obtaining new varieties from overseas has a medium to long term timeframe for delivery of outputs to Australian growers. Negotiation with the breeder and conclusion of a contract for the plant material is likely to take a minimum two years. Waiting for the season to collect budwood could add six months before dispatch to Australia. Then there is the time in quarantine before the propagation of trees post-quarantine for planting in the orchard for evaluation under local growing conditions.

Continuation of the evaluation of new varieties planted at Maroochy Research Facility will provide outputs in the interim. The varieties include the three non-astringent ('Isahay', 'Sunami', 'Kazusa') and three astringent (‘Yoho’, ‘Tone Wase’, ‘Otanenashi’) varieties.

The symposium was an opportunity to meet the grower from Portugal who supplied Australia with the budwood of ‘Rojo Brillante’ and establish how the budwood contained a mix of two varieties. Visits to ‘Rojo Brillante’ orchards in Spain was enough to be confident of the identity of the one fruiting tree of ‘Rojo Brillante’ in the orchard at Maroochy Research Facility. The identity of the highly fruitful, unnamed astringent variety included with the budwood of ‘Rojo Brillante’ remains unknown and will be difficult to confirm now that the Portuguese grower has removed the source orchard.

The trees of ‘Rojo Brillante’ distributed to a number of growers scattered across Australia provides the opportunity for a comparative evaluation of performance in different growing environments. It was noted at the international persimmon symposium that ‘Rojo Brillante’ is not well suited to a wide variety of environments. ‘Rojo Brillante’ fruit treated with CO_2 deastringency to create a sweet persimmon product, was well received by a small taste panel, indicating the potential for this variety in the domestic market with consumers accustomed to non-astringent persimmon varieties. The positive response of taste panelists to the CO_2-treated fruit of the unnamed astringent variety, justifies further evaluation to determine the potential suitability of this variety within the local industry. The variety is highly productive, has good fruit size and ripens just before ‘Fuyu’.

Where an astringent variety would be have been immediately discounted in the past, the success of CO_2 deastringency in the pilot study illustrates the importance of applying deastringency to all astringent varieties as part of the evaluation process in the future. CO_2 deastringency requires an air-tight chamber (eg a cold room unit) and whilst feasible on a small scale, will not suit all growers. This could limit the adoption by industry of a new astringent variety in the future. A single dedicated CO_2 deastringency unit located in one district could effectively service multiple growers, as occurs in Spain with cooperative packing facilities.

Australian persimmon growers now have available the capacity to extend postharvest storage to at least 8 weeks. Common practice in the Australian industry is short duration postharvest storage (2 weeks) at relatively high temperature (15^{o}C). This leads to limited capacity to modulated oversupply during peaks in the harvest season. The maximum storage duration is achieved by treating fruit with SmartFresh^{SM} (1-MCP) and cold storage at 0^{o}C. Research results suggested a potential for cold storage up to 12 weeks, however further research is required to refine the technique and improve the reliability of product quality on outturn.

The postharvest storage regime is effective for both fruit grown in subtropical and temperate environments. The greatest variation in results was between fruit from different orchards in the same district, suggesting orchard management practices contribute to the potential storage life of fruit. Quantifying the ideal fruit maturity for cold storage will potentially further extend the maximum storage duration and increase the predictability of fruit quality on removal from cold storage.

The Australian persimmon industry experiences periods of oversupply in the domestic market during the peak of the harvest in each production region. The ability to store fruit for longer periods provides growers with the flexibility to modulate supply. The longer storage duration also enables Australian growers to extend the supply season beyond the harvest period, potentially replacing some of the product imported from New Zealand and providing the basis for growth of the Australian industry.

A relatively small proportion of the Australian persimmon crop is exported (3% in 2016). A longer storage interval will enable export to distant markets with the confidence the product will arrive in good condition. Adoption of SmartFresh^{SM} within one to two seasons easily feasible, particularly in persimmon production districts where 1-MCP is already used for pomefruit. Equally, SmartFresh[SM] is feasible for small growers, as only require a small cool room unit for treatment. Investment in additional cold room capacity may be necessary to accommodate the larger quantity of fruit being held for longer periods.

The failure of MA bags to reliably increase the storage period when used without 1-MCP was unexpected. Further research is required to clarify the effectiveness of MA bags for the storage of persimmon. MA bags are likely to suit the operations of some growers interested in extending the storage duration of fruit and providing flexibility for marketing.

Persimmon industries around the world use seedling propagated rootstock, which gives rise to considerable variation between individual trees, leading to unrealized yield, inefficiency from increased difficulty in tree management and suboptimal orchard productivity. Propagation of seedling rootstock is easy, convenient, requires little technical knowledge or equipment, and is low cost. Persimmon orchards in Australia are grown on seedling rootstock of local selections of *Diospyros kaki*. Vegetative (asexual) propagation produces identical plants, which in turn introduces uniformity across the orchard. Vegetative propagation of rootstocks enables a quantum increase in plant productivity and is now standard practice in several mature perennial fruit industries (apple, grape). Persimmon rootstocks can be propagated by tissue culture, single bud cuttings and layering, with limited success. These techniques require varying amounts of specialized equipment and are relatively expensive. Developing an effective technique for the vegetative propagation persimmon rootstock is essential for achieving an improvement in orchard productivity in Australia. A reliable rootstock propagation technique capable of producing large numbers is fundamental to future expansion of the Australian industry.

Developing a reliable vegetative propagation technique for the propagation of persimmon rootstocks is a short term goal. Quantifying the grafting success rates of the main rootstock selections used by the Australian industry is an important medium term objective, to ensure the adoption of the propagation technique, along with the easy to propagate rootstocks, by nursery operators. Local seedling rootstock selections have emerged for reasons such as convenient availability of abundant seed and high germination rates. Data on rootstock traits and comparative performance does not exist for individual selections and amounts to anecdotal observations only. Replicated field trials in orchards in different production regions around Australia will quantify the relative performance of each rootstock, both with individual scion varieties and in different growing environments.

The salt sensitivity of *Diospyros lotus*, the predominant rootstock used in Spain, was reported at the symposium. The considerable variation in sensitivity between seedlings within the same species provides scope for selecting a rootstock less sensitive to salinity. The salt sensitivity of *Diospryos kaki* has implications for managing orchards to prevent salt damage in Australia, particularly in drought years and those parts of southern Australia where saline water is commonplace.

Fresh cuts of persimmon is an expanding product for the industry in Spain and demonstrates the scope for different products to meet consumer preferences whilst adding value. Postharvest scientists at IVIA in Spain have developed a treatment regime of 1% ascorbic acid or 1% citric acid solutions to prevent enzymatic browning, 1% CaCl to prevent softening and modified atmosphere packaging to maintain the gas environment, enabling a storage life of 9 days at 5oC without loss of quality. Persimmon fresh cuts could be quickly adopted within the Australian industry and would provide an alternate opportunity of introducing the fruit to new consumers.

In Australia, most of the persimmon crop is packed in a single pack type, namely a single layer tray

(4 kg). The industry in Spain uses a diverse range of pack types, each tailored to the needs of the individual buyer or market, to differentiate product quality and to add value at the high end of the market. High quality graphics are used on cartons to differentiate product and to infer quality, particularly for premium fruit targeting high value market sectors. Small boutique cartons containing 6 or 8 pieces of fruit are used for premium quality fruit, whilst 3 pieces of fruit on a tray and clear wrapped service personal shoppers. Greater use of pack sizes and presentation could be made by the Australian industry to add value and service the preferences the different consumers within the market.

Systemic insecticides provide new options to Australian persimmon growers for the effective control of mealybug. The systemic insecticides are more compatible with IPM programs where growers are using predators to assist in the control of mealybug. Further, the systemic insecticides are of different chemical activity groups to the contact insecticides, thereby enhancing resistance management. The use pattern of Samurai® (clothianidin) in persimmon has now been added to the label and a permit has recently been issued for Transform® (sulfoxaflor). Samurai® has been widely adopted in the persimmon industry for control of mealybug.

Samurai® and Movento® (spirotetramat) were most effective when applied as a soil drench. The registered label rate in Australia for Samurai® is 5 g/tree applied at flowering. Movento® was highly effective as a soil drench, applied 5 weeks before harvest, however the product is not registered in Australia for use as a soil drench. Samurai® was the most effective systemic insecticide and constitutes the basis of an annual program for the control of mealybug.

Flowering appears to be the most appropriate time to apply Samurai® (clothianidin) for the effective control of mealybug. Hence, the time for application in the subtropical region of Queensland is October for 'Jiro' and November for the later ripening variety 'Fuyu'. Differences in the early season population dynamics of mealybug species may lead to small differences in the optimum timing of chemical controls, a topic requiring further study.

A new strategy for the effective control of mealybug consists of a Samurai® soil drench at flowering with the option of a Transform® (sulfoxaflor) foliar spray before harvest, where monitoring of mealybug numbers indicates the need for an additional chemical application. Australian persimmon growers were reliant upon highly toxic, broad spectrum, contact insecticides for the control of mealybug.

Recommendations

A number of key recommendations are able to be made as a result of project activities, these include:

- The application of systemic insecticides at the correct time and concentration can significantly reduce mealybug populations at harvest
- Monitoring for mealybug in persimmon orchards is challenging, and from the methods tested in this project, monitoring of the fruit's calyx in early December will give the best indication of early mealybug infestation
- The use of male citrus mealybug lures has been identified as a potential monitoring tool for predicting female mealybug populations. However with multiple mealybug species often infesting the same orchard there is a requirement for the development of pheromone lures for other species
- The use of mating disruption pheromones for clearwing moth can significantly reduce the damage caused by this pest in SE Queensland
- There is still significant rootstock variability in Australian persimmon orchards. Trials established in this project will identify suitable rootstocks for both Fuyu and Jiro varieties
- Results from limited clonal propagation of persimmon rootstocks has shown that clonal replication of some rootstock selections is possible. This will require long term regional trials to identify the performance of clonal rootstocks compared to the currently used seedling rootstocks
- Alternative persimmon varieties evaluated during this project has failed to identify any non-astringent varieties that would be commercially suitable to the Australian sweet persimmon industry. Rojo Brillante has performed well in Nambour, however young trees in other growing regions will need to be monitored to establish the performance and suitability of this variety in different regions
- Treatment of currently available astringent varieties with CO_2 at >95% for 24 hours can remove astringency and retain an acceptable flesh texture and flavour. Larger scale trials will need to be established before a protocol can be developed for industry. The use of SmartFresh^{SM} (1-MCP) can significantly increase the storage life of Fuyu from southern Australia. Trials undertaken in this project have shown that fruit can be held at 0^{o}C for eight weeks if treated with SmartFresh^{SM} (1-MCP). This will extend the availability of Australian fruit at the end of the season
- Negotiate with MAFF, Japan, for the importation of new non-astringent persimmon varieties for evaluation in Australia. Australia is totally reliant upon sourcing new non-astringent varieties from overseas breeding programmes, to meet the future preferences of consumers in the domestic and export markets.
- Improve tree uniformity and orchard productivity by introducing the use of clonally propagated rootstock planting material into the Australian industry. Conduct a field research study of persimmon rootstock propagation techniques to develop a cost effective technique, quantify the propagation success (rooting, grafting) of Australian persimmon rootstock selections, and establish long –term field trials to quantify the performance of clonally propagated rootstock selections in orchard production systems.
- Include CO_2 deastringency as a procedure in the future evaluation of all new astringent persimmon varieties. The capacity to transform astringent fruit to a non-astringent product, warrants the inclusion of CO_2 deastringency as part of the evaluation process for all astringent varieties. Late and early ripening, new astringent varieties, including 'Rojo

Brillante', present the opportunity to extend the supply season of the Australian persimmon industry, until a new non-astringent variety of the same harvest time becomes available in Australia.

- Investigate canopy management techniques for the dual purposes of increasing productivity and managing excessive tree vigour. There is a lack of well-developed best practices for canopy management of persimmon under Australian growing conditions. Best practices for canopy management in other tree fruit crops provide an opportunity to substantially increase the productivity of persimmon in Australia.
- Facilitate the adoption by growers of improved cold storage techniques to extend storage duration, and assist in modulating supply during the harvest peaks. The widespread adoption of SmartFresh^{SM} (1-MCP) within a short period of time is feasible, however persimmon growers have been slow to respond and capitalize on the opportunity to exercise greater control over supply of fruit into the market. Active engagement with growers appears will be necessary to facilitate a change in behaviour and adoption of the improved postharvest storage technique.
- Industry to explore with the manufacturer to potential for a permit to use Movento® against mealybug in persimmon. Field studies indicate Movento® is equally as effective as Samurai®, and importantly as a different chemical family will add to managing resistance in the control of mealybug.

Scientific Refereed Publications

Bignell, G., Senior, L. and Oag, D. (2017) Monitoring and control strategies for mealybug of persimmon in Australia. *Acta Horticulturae; Proceedings of the 6th International Symposium on Persimmon, 2016. (In press)*

Intellectual Property/Commercialisation

No commercial IP generated

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The project team was Grant Bignell, David Oag, David Bruun and Lara Senior.

Appendices

The following files as examples of information outputs are attached:

Mealybug paper_proceedings 6isP.pdf

Persimmon Press_2017_rootstock.pdf

Persimmon Press_2017_6isP.pdf

Monitoring and control strategies for mealybug of persimmon in Australia.

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Keywords:

Abstract
Mealybug is the most important pest of persimmon in temperate environments and one of the three most important pests in subtropical growing areas of Australia. The species of concern to the sweet persimmon industry are citrus mealybug (*Planococcus citri*), longtail mealybug (*Pseudococcus longispinus*) and citrophilous mealybug (*Pseudococcus calceolarieae*). The dominant pest species in subtropical environments (eg Queensland) is citrus mealybug, whereas longtailed and citrophilous mealybug predominate in the temperate growing regions across southern Australia. Little is known of the population dynamics of these mealybug pest species, particularly in relation to crop phenology. Knowledge of the timing of mealybug infestation and particularly the presence of the susceptible juvenile stages, is a key factor in the effective control of mealybug. Several methods for monitoring mealybug population dynamics were investigated, including pheromone traps, sticky bands and the visual inspection of roots. Field trials conducted to establish the efficacy of preharvest chemical treatments in controlling mealybug. The objective was to replace broad-spectrum insecticides with chemistry compatible with the use of predators and an IPM strategy. Field trials included clothianidin, spirotetramat, sulfoxaflor, thiamthoxam, and imidacloprid, as well as the timing of applications of clothianidin. The effectiveness of monitoring techniques and preharvest insecticide treatments will be discussed.

INTRODUCTION

Mealybug is a major issue for the persimmon industry. Three species are important pests of persimmon in Australia namely, citrus mealybug (*Planococcus citri*), longtailed mealybug (*Pseudococcus longispinus*) and citrophilous mealybug (*Pseudococcus calceolariae*)(George et al, 2011). The dominant pest species in subtropical environments such as Queensland is citrus mealybug, whereas longtail and citrophilous mealybug predominate in the temperate growing regions across southern Australia (Ceballo et al, 1998; Gullan, 2000). The honeydew excreted by mealybugs leads to the development of sooty mould, which detracts from the appearance of fruit and often leads to a downgrade in fruit quality in the market. Heavy infestations can affect the plant by reducing vigour and causing leaf and shoot deformation (Ben-Dov, 1994).

The most serious impact is contamination of product for export. Many countries have phytosanitary protocols requiring fruit to be free of pests, including mealybug. Reliable, effective controls for mealybug are fundamental for the Australian industry to grow the export volume of quality persimmons and to gain access to new markets. In addition, fruit rejected for export because of signs of mealybug contamination, are redirected to the domestic market where the increased supply can cause downward pressure on price.

The Australian industry has relied on a few contact insecticides for control of mealybug, namely petroleum and paraffinic oils, methidathion (Suprathion®) and buprofezin (Applaud®) (Bignell et al, 2012). Frequent use of broad spectrum insecticides such as methidathion is disruptive to naturally occurring predators and parasitoids, and may exacerbate the pest problem (Franco et al, 2004). Effective mealybug control, as part of an integrated pest management programme (IPM), requires selective insecticides with minimal impact on natural enemies. Control with contact insecticides is also made difficult due to the waxy coating secreted by older stages, and the fact that for much of the season mealybug are located in protected sites such as crevices in the bark and beneath the calyx of the fruit (McKenzie, 1967; Swaine et al, 1991). Contact insecticides should therefore be targeted against the dispersing early instar nymphs (crawlers), which have not yet developed a protective waxy coating. A good understanding of pest and fruit phenology coupled with more effective mealybug monitoring techniques is required to enable the accurate timing of chemical applications, along with spray technology capable of providing comprehensive coverage.

A series of studies undertaken to meet the need of the persimmon industry for insecticides with little or no impact on beneficial and non-target insects, whilst providing improved control of mealybug is reported.

METHODS

Experiment 1. Systemic insecticides as a soil drench

The objective of a field trial in the 2011/12 season was to ascertain the effectiveness of four systemic insecticides when applied as a soil drench. The insecticides Confidor® (imidacloprid) at 7.25 ml/tree, Movento® (spirotetramat) at 6.0 g/tree, Samurai® (clothianidin) at 3.0 g/tree and Actara® (thiamethoxam) at 6.0 g/tree, were each applied to four individual Fuyu trees in 2 litres water per tree followed by a small irrigation to assist dispersal through the root zone. All chemicals were applied five weeks before harvest. Longtailed mealybug was prevalent throughout the orchard located in coastal south-east Queensland. Ten fruit per tree were harvested and inspected for mealybug.

Experiment 2. Soil drench and foliar applied systemic insecticides

A trial was conducted (2012/13) in a commercial persimmon orchard in coastal south-east Queensland to study the effectiveness of a single application of five systemic insecticides in controlling mealybug. A history of mealybug in the orchard was supported by high numbers of longtailed mealybug observed during the season. A standard spray programme consisting of Suprathion® (methidathion) and Applaud® (buprofezin) was applied in addition to the insecticide treatments. The trial consisted of six replicates in a randomized block design. The treatments were a soil drench of Confidor® at 6 ml/tree, Samurai® at 5 g/tree or Actara® at 6 g/tree applied 12 October 2012; or foliar sprays of Movento® at 40 ml/100L or Transform® at 40 ml/100L applied 16 October 2012. Soil applied insecticides were mixed in 2 L water followed by a light irrigation, whilst foliar sprays were applied to the point of run-off and contained the surfactant Maxx organosilicone surfactant™ at the label rate. Twenty fruit per replicate tree were randomly collected at intervals during the fruit development period (ie January 2013, early March and late March immediately prior harvest) and inspected under the calyx for mealybug.

Experiment 3. Rates of Samurai

The minimum rate of Samurai® for acceptable control of mealybug was investigated in a field trial in coastal south-east Queensland in the 2013/14 season. Each rate of Samurai® was applied as a soil drench (as described above) to four replicate trees of cv Jiro on 23 October 2013. The rates were 2.5 g/tree, 2.5 g/tree (Oct) plus 2.5 g/tree (Dec), 3.5 g/tree, or 5.0 g/tree. No other insecticides were applied for mealybug control. Longtailed mealybug was prevalent throughout the orchard. Immediately before harvest, 10 fruit per tree were collected and inspected under the calyx for mealybug.

Experiment 4. Late season foliar sprays

A trial was conducted in the 2014/15 season on 7 year-old trees (cv. Jiro) in an orchard located in coastal south-east Queensland. Six replicate trees in a randomised block design received either Samurai® at 5 g/tree) soil drench at budburst, or foliar sprays of Transform® at 0.4 ml/L or Movento® at 0.4 ml/L applied at 14 days or 28 days before harvest. At harvest, 20 fruit per tree were collected and inspected for adult mealybug, crawlers and egg masses. The objective was to ascertain the comparative effectiveness of late season foliar sprays of two IPM compatible chemicals and a clothianidin soil drench at budburst.

Experiment 5. Delayed application of Samurai (2015/16)

The effectiveness of a late season application and lower (half label) rates of Samurai® (clothianidin) was investigated in two field trials in coastal south-east Queensland in the 2015/16 season. The treatments were 5 g/tree at flowering or 2.5 g/tree applied one month later (cv Jiro) and 5 g/tree at flowering or one month later, or 2.5 g/tree applied two months after flowering (cv Fuyu). Each chemical treatment was applied as a soil drench to six individual trees in a randomised block. Twenty fruit per tree collected at harvested were inspected for mealybug.

Monitoring
A range of methods were evaluated to monitor early movement of overwintering mealybug at bud burst as well as general increases in populations during the cropping cycle. Techniques included pheromone trapping, sticky bands, and visual inspections of roots. Monitoring methods were trialled in various growing regions with a range of sub-tropical and temperate environments.

Delta traps with pheromone lures mounted on sticky base traps were installed in three orchards in south-east Queensland during the 2015/16 season. Lures were replaced every 6 weeks to ensure a sufficient level of pheromone was present. Eight traps were placed in each orchard. Traps were monitored every eight weeks with male citrus mealybug numbers recorded. Twenty fruit from six trees within each orchard were assessed for citrus mealybug numbers during the harvest period.

Sticky bands were evaluated on individual trees with band placement ranging from just above the soil on the lower trunk to lateral branches within the tree canopy. Six sticky bands were applied to 10 trees within in an orchard in south-east Queensland. Sticky bands were comprised of blue cloth tape painted with a clear adhesive gel. They were monitored once a month for female mealybug.

Visual inspections of roots and soil at the trunk base was evaluated in three orchards in south-east Queensland, two orchards in northern Victoria and two orchards in South Australia. Twenty trees at each location were inspected by digging approximately ten centimetres below the soil in a 20 centimetre radius from the trunk to visually inspect for the presence of overwintering mealybug.

RESULTS

Experiment 1. Systemic insecticides as a soil drench.
Fruit assessed for mealybug immediately after harvest showed Confidor® to be the least effective in controlling mealybug with over 60% of fruit having mealybug under the calyx (Figure 1). Actara® and Samurai® were also ineffective compared with the control recording 41% and 23% of fruit with mealybug, respectively. Movento® provided the most effective control with no mealybug recorded on any fruit. The low levels of mealybug in the control fruit may be explained by no chemical disruption of natural enemies of mealybugs such as *Cryptolaemus montrouzieri,* which were observed in relatively high numbers at the trial site.

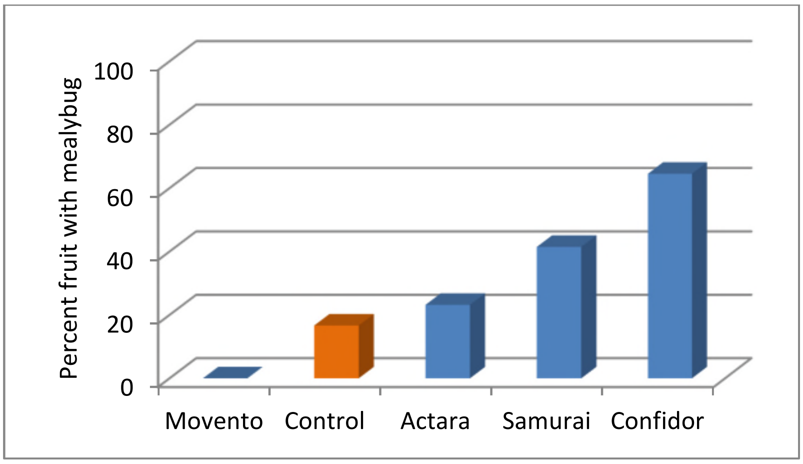

Figure 1. Percent of fruit infested with longtailed mealybug, (*Pseudococcus longispinus*) in the orchard*.*

Experiment 2. Systemic insecticides – soil drench and foliar
All treatments recorded a lower percentage of fruit infested with mealybug than the untreated control in early January. Samurai® and Movento® were the most effective with 6.7% and 8.3%, respectively, of fruit with mealybug under the calyx. The trend across treatments was similar in early March. By late March, a sharp increase in the percentage of infested fruit had occurred for the foliar applied insecticides and Confidor, with the result for Transform® similar to the untreated control. Samurai® was the most effective treatment with the percentage of infested fruit largely unchanged throughout the season.

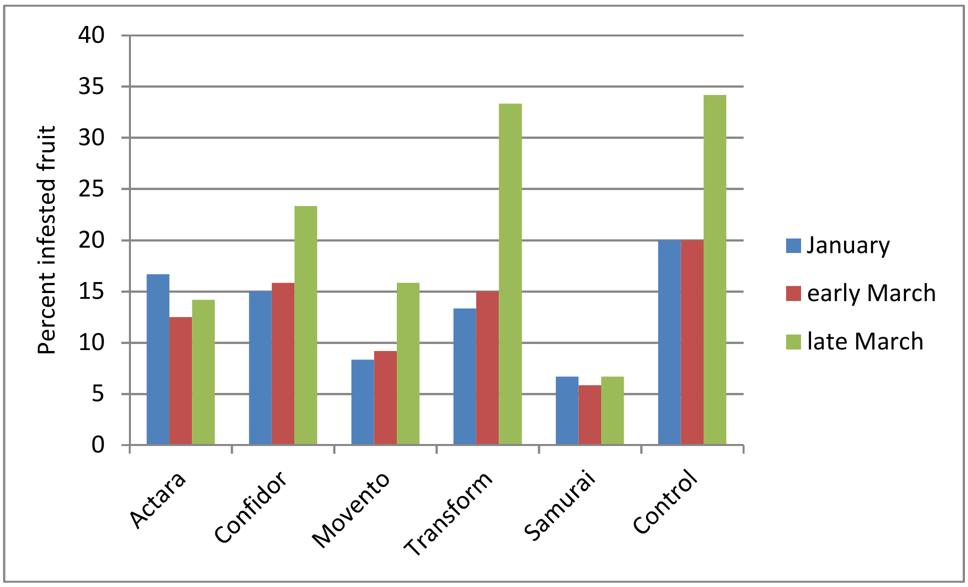

Figure 2. Percent of infested 'Jiro' fruit throughout the season following applications of systemic insecticides early in the season (2012/13).

Experiment 3. Samurai rates
All Samurai® treatments produced a significantly lower percentage of fruit infested with mealybug at harvest compared to the untreated control. Whilst the percentage of infested fruit declined with increasing Samurai rate the difference was not significant.

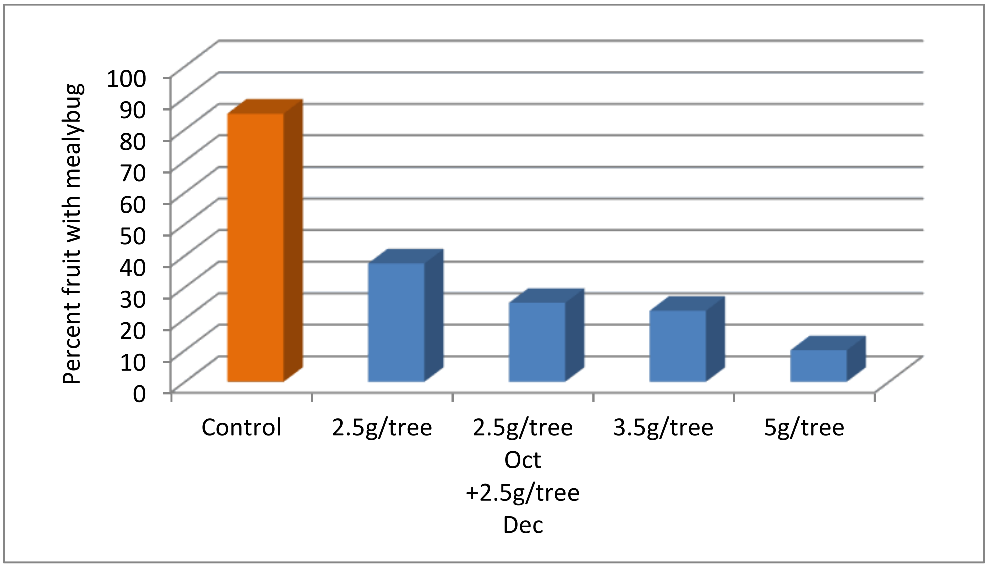

Figure 3. Percent of fruit at harvest infested with mealybug for different rates of Samurai®.

Experiment 4. Late season foliar sprays

Samurai® applied at the rate of 5 g/tree gave the greatest control of longtailed mealybug adults followed by Transform® applied 28 days (2 April) prior to harvest. Transform® applied 28 days prior to harvest achieved the lowest level of crawlers followed by the clothianidin treatment. Movento® was generally the least effective treatment, nevertheless the incidence of mealybug on fruit was substantially less than on untreated fruit. The untreated control had the highest numbers of adults, crawlers and egg masses.

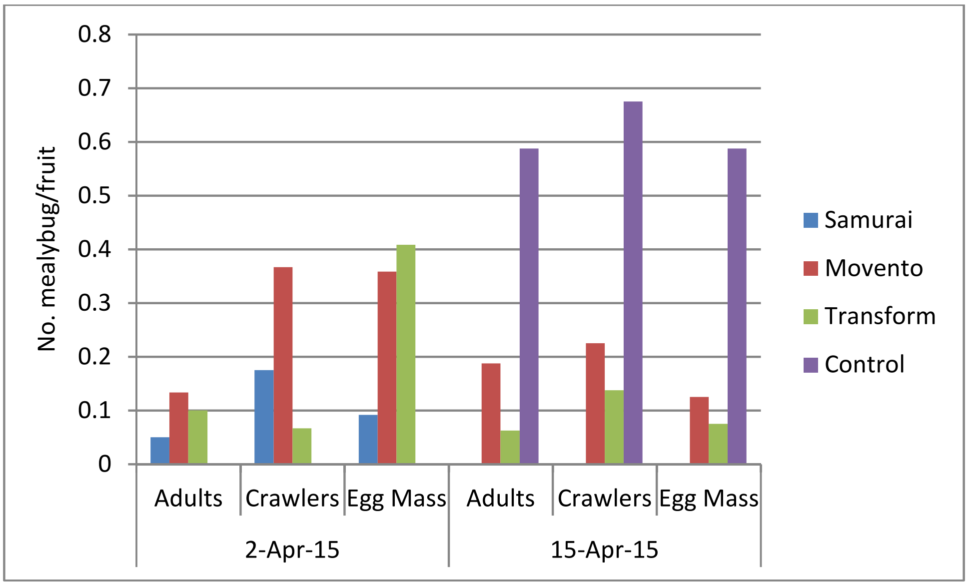

Figure 4. Average number of mealybug per fruit (cv Jiro) at harvest following a soil drench of Samurai® or preharvest foliar sprays of Movento® or Transform®.

Experiment 5. Delayed application of Samurai

Samurai® applied to 'Jiro' in October at the rate of 5 g/tree had greater efficacy in controlling both longtailed and citrus mealybug adults and crawlers compared to the lower rate of Samurai® applied in November and the untreated control (Figure 5). The number of egg masses was greatest in the untreated control with similar levels in both Samurai® treatments.

Samurai® applied to 'Fuyu' in October and November at the rate of 5 g/tree gave the best control of longtailed mealybug. The greatest control of citrus mealybug was achieved by the Samurai® rate of 2.5 g/tree applied in December. Trees treated with Samurai® at the rate of

5 g/tree applied in October experienced the highest level of citrus mealybug with infestations higher than the control. The number of crawlers per fruit was lowest in the Samurai® treatment applied in November followed closely by the October treatment. Samurai® applied at 2.5 g/tree in December had the highest number of crawlers per fruit of all treatments apart from the control, however the same treatment experienced the lowest number of egg masses.

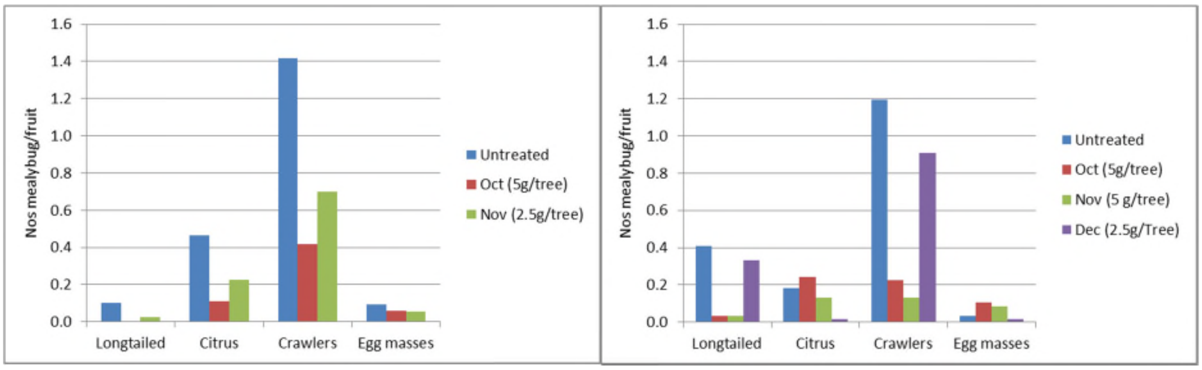

Figure 5. Average number of mealybug individuals per fruit of 'Jiro' (left) and 'Fuyu' (right) for different application times and rates of Samurai®.

Monitoring

Visual inspection of roots and soil in orchards in various growing regions failed to identify any overwintering mealybug. Destructive sampling of bark was laborious and not reliable in detecting mealybug or predicting population size. Mealybug was found in the frass and crevices of bark damaged by clearwing moth (*Ichneumenoptera chrysophanes)*.

Only four female mealybugs were recorded on 60 sticky bands from ten trees (six bands per tree) over the fruit development period. One problem was contamination of the sticky bands by other flying insects and organic matter on the lower bands, which reduced the surface area available for trapping mealybug.

Pheromone traps

Monitoring of three orchards in coastal south-east Queensland between September 2015 and March 2016 showed a peak in mealybug males trapped during the months of November and December (Figure 6). Numbers in the Maroochy orchard significantly declined in the months of January, February and March. The average number of adult mealybug per fruit at harvest was consistent with the maximum number of male mealybug trapped (Nov/Dec) at each orchard. For example, the low numbers of male mealybug trapped in the Woombye orchard were reflected in the low average mealybug per tree.

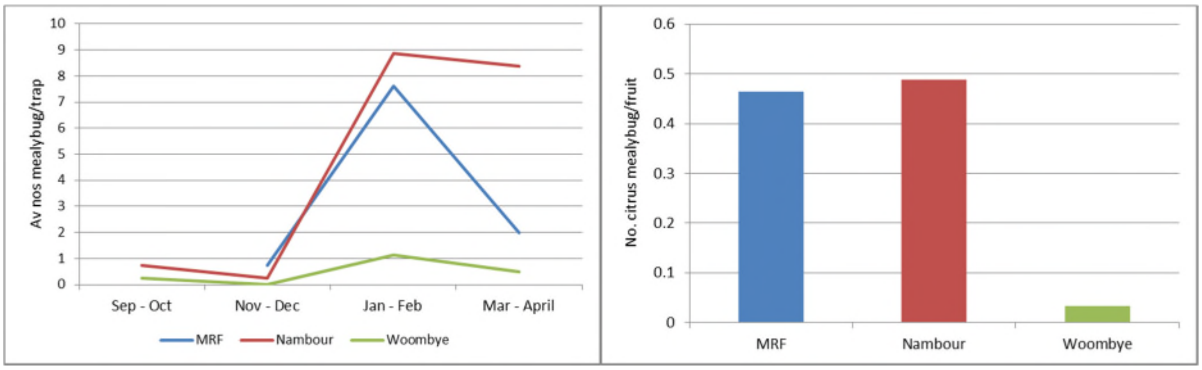

Figure 6. Average number of male citrus mealybug per pheromone trap (left) and average number of adult mealybug per fruit at harvest (right) in three orchards of 'Jiro' during 2015/16.

DISCUSSION

Systemic insecticides provide new options to Australian persimmon growers for the effective control of mealybug. The systemic insecticides Samurai® (clothianidin) and Movento®

(spirotetramat) were most effective when applied as a soil drench. The registered label rate in Australia for Samurai® is 5 g/tree applied at flowering. Movento® was highly effective as a soil drench, applied 5 weeks before harvest, however the product is not registered in Australia for use as a soil drench. Samurai® was the most effective systemic insecticide and constitutes the basis of an annual programme for the control of mealybug.

Flowering appears to be the most appropriate time to apply Samurai® (clothianidin) for the effective control of mealybug. Hence, the time for application in the subtropical region of Queensland is October for 'Jiro' and November for the later ripening variety 'Fuyu'. Differences in the early season population dynamics of mealybug species may lead to small differences in the optimum timing of chemical controls, a topic requiring further study.

A new strategy for the effective control of mealybug consists of a Samurai® soil drench at flowering with the option of a Movento® or Transform® (sulfoxaflor) foliar spray before harvest, where monitoring of mealybug numbers indicates the need for an additional chemical application.

Visual inspections of the fruit calyx was the most reliable method for monitoring mealybug populations however by this stage of fruit development it is usually too late for effective control. Destructive sampling of bark before flowering identified overwintering mealybug, however sampling of shoots and roots at bud break and dormancy failed to identify populations. A significant number of mealybug infestations were found in frass caused by clearwing moth, a common pest in the subtropical coastal area of Queensland. The failure to detect any mealybug on tree roots suggests mealybug predominantly overwinter on the above ground parts of the tree under Australian conditions.

Pheromone trapping appeared to be an effective method for monitoring citrus mealybug populations, with the number of males trapped in November/December corresponding with the level of infestation at harvest. Further trials to establish optimum trap densities, interval between trap inspections and longevity of lures, would help to improve the effectiveness of this monitoring option. Lures for longtailed and citrophilous mealybug are not available in Australia and are required to provide persimmon growers with the capability to monitor all mealybug pest species.

The new generation of systemic insecticides provided effective control of mealybug in persimmon. Nevertheless, more filed studies are required to determine the optimum timing of chemicals, either as a soil drench or foliar spray, for consistent outcomes in mealybug control.

ACKNOWLEDGEMENTS
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The Potential of Rootstocks in the Australian Persimmon Industry | David Oag, Principal Horticulturist, Department of Agriculture and Fisheries

Propagation of rootstocks from seed is standard practice in the persimmon industry in Australia and around the world, primarily because it is a relatively cheap and easy method of propagation. However, each seedling rootstock is genetically different, even within the one rootstock seed line and irrespective of how uniform the seed line is purported to be. The variation between individual rootstock seedlings leads to variation in tree size and performance in the orchard. The considerable genetic and performance variation between individual plants was illustrated in a salinity study of ungrafted rootstock seedlings in Spain (Gil-Munoz *et al.*, 2016).

In Australia, propagators have selected a number of rootstock seed lines (eg Telco, Kaki Sun, MKN, BD1, DDM) over the years, inspired by a diversity of reasons. The existence of measurable differences in performance between rootstock seedling selections in Australia has not been quantified through field studies. Equally the small number of field studies in other countries comparing the performance of rootstocks means there is little information available to guide Australian persimmon growers and propagators.


Picture 1. Visible graft union on a mature Rojo Briallante tree in Spain.

Vegetative propagation results in each rootstock plant being genetically the same and introduces uniformity of trees in the orchard. The adoption of vegetatively propagated rootstocks in the apple and grape industries led to a quantum shift in productivity. Likewise, development of a vegetative propagation technique for persimmon rootstocks has the potential to deliver significant benefits to the Australian persimmon industry, including improved orchard productivity, evenness in timing of growth stages including harvest and increased yield.

Most efforts to develop a vegetative propagation technique have been in micropropagation. Moderate success rates have been reported in several studies of leaf-bud cutting micropropagation of persimmon rootstock (Tetsumura *et al.*, 2008), however micropropagation remains costly, is technically difficult, requires specialist equipment and can take longer to grow a grafted tree ready for planting. Micropropagation is used in several crops (eg banana) because the benefits outweigh the additional cost of propagation and a similar economic analysis is required in persimmon.

Propagation of persimmon rootstock by hardwood cuttings is difficult and has a low rate of success, although a study in Japan greatly improved the propagation success rate of basally etiolated cuttings with the application of plant hormones (Tetsumura *et al.*, 2003). Layering is widely used for the vegetative propagation of clonal apple rootstock material and could be applicable to persimmon; a deciduous tree fruit as is apple.

Developing a method for the vegetative propagation of persimmon rootstock is a medium to long term plan. It will involve exploring the feasibility of micropropagation, etiolated hardwood cuttings and layering; grafting

Picture 2. Potted persimmon rootstocks prior to grafting

success of rootstocks produced by each method; then the comparative cropping performance of vegetatively propagated and seedling rootstock grafted trees in the orchard. As trees need to be affordable, an economic analysis will establish the cost effectiveness of each propagation method. Vegetatively propagated rootstocks have the potential to create uniformity of trees in persimmon orchards and increase productivity, which will enable the next stage of growth and development in the Australian persimmon industry.

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Review of the VI International Symposium on Persimmon | David Oag, Principal Horticulturist, Department of Agriculture and Fisheries

The VI International Symposium on Persimmon was held in October 2016 in Spain. It was located in the two persimmon growing regions in Spain, starting in Valencia and then moving to Huelva on the south-west coast near the border with Portugal. Around 150 mostly researchers with a few producers and marketers attended. Large contingents were present from China, Japan, Korea and Spain, with smaller numbers from Brasil and Turkey, as well as delegates from France, Italy, Portugal, Ukraine, Israel, USA, Australia, New Zealand and Viet Nam. The symposium programme is primarily scientific with many of the presentations on research in breeding, genetics or postharvest. Japan will host the next symposium.

Delegates to VI International Symposium on Persimmon at field tour in Valencia.

Persimmon industry in Spain

The persimmon industry has grown dramatically over the last 15 years and is a profitable crop for growers in Spain. Approximately 90% of the national crop is grown in the region around Valencia and production is set to increase 3-fold by 2020. In 2015, persimmon production in the Valencia region was around 240,000 t. Orchards are less than 3 ha in size; grow 'Rojo Brillante' almost exclusively and over half of production is exported. 'Rojo Brillante' is sold as a firm fruit after treatment with CO_2 to remove astringency. The declining profitability of citrus production in Spain is resulting in citrus orchards being replanted with persimmon.

Leaf burn on persimmon leaves due to salt toxicity (Rojo Brillante).

Selecting rootstocks for salt tolerance

The Instituto Valenciano de Investigaciones Agrarias (IVIA) has initiated a breeding programme to develop rootstocks tolerant of salt stress. Irrigation water in the Valencia region is moderately saline and the widespread use of the salt sensitive *Diospyros lotus* as a rootstock has resulted in significant damage occurring in orchards. Damage to leaf chlorophyll occurs at ≥1% Cl^-. Plant water status is disrupted and leaf function impaired at ≈1.3% Cl-, despite no visible symptoms of salt damage on leaves. Seedlings of *D. lotus*, *D. virginiana* and *D. kaki* were irrigated with saline water to test for salt tolerance. Seedlings of *D. virginiana* had relatively low Cl- and Na+ content in leaves. *D. kaki* and *D. lotus* are salt sensitive and the degree of sensitivity varies hugely between seedlings (genotypes) of each species. In the absence of genetic tolerance to salinity, orchard management practices become the primary tool for managing saline conditions. The persimmon industry can look to other horticultural industries in Australia for lessons on how to regulate the supply of saline water for irrigation, particularly in drought years, so as to minimize damage from salinity.

Persimmon tannin as the next probiotic

A daily low dose of tannin derived from persimmon fruit can increase the number of beneficial bacteria (eg *Lactobacillus*), whilst reducing pathogen numbers (eg *E. coli*) in the gut. A study in China suggests the potential of persimmon tannin as a probiotic with benefits for human health.

A natural medicine with wide appeal

Research in Japan has led to the development of a natural medicine to alleviate the symptoms of excessive alcohol consumption. Fruit of the astringent variety 'Saijo' is processed into a drink, powder or granule products, which are increasingly popular in the market. Tannin in persimmon fruit helps to metabolize the acetaldehyde that accumulates in the body following alcohol consumption.

Persimmon juice in Spain.

New non-astringent varieties

The persimmon breeding programme at the National Agriculture and Food Research Organization (NARO) is generating new varieties for the local industry, where 'Fuyu' is the most widely grown variety although astringent varieties are also grown. The objective of the breeding programme is to produce new varieties with crunchy fruit, no fruit cracking and trees of high vigour that are easy to grow. NARO has recently released two non-astringent varieties to add to 'Taishu' released in 1994. 'Taiho' is a late season variety and was released in 2014. 'Reigyoku' was released in 2015 as a mid-season variety. All three varieties are relevant to the Australian sweet persimmon industry, particularly 'Taiho' with the potential to extend the Australian season. 'Taishu' is grown in China where it has been found to be graft incompatible with *D. lotus* rootstock.


Rojo Brillante fruit.

In Spain, IVIA started a persimmon breeding programme in 2002 with the objective of generating new varieties to extend the harvest season, yet with similar fruit characteristics as 'Rojo Brillante', and creating non-astringent (PCNA) varieties. Research quickly established the characteristics of non-astringent varieties from Japan were substantially different under the growing conditions in Spain. Two selections with similar fruit quality to 'Rojo Brillante' have been identified and are currently undergoing agronomic evaluation prior to release to industry.

The persimmon breeding programme of the National Institute of Horticultural and Herbal Science in Korea released the early ripening, non-astringent (PCNA) variety 'Jowan' in 2012. Plant protection rights have been issued in Korea for 'Jowan'.

Flesh discolouration of 'Fuyu'

Research in Japan identified a strong correlation between flesh discolouration due to brown specks and increasing number of seeds in 'Fuyu'. 'Fuyu' seeds exude ethanol and acetaldehyde, which oxidise tannins in the fruit flesh. No seeds; no flesh discolouration.

Internet as the new market place

Consumers are increasingly purchasing fresh produce online, through websites like Fruttaweb.com and Amazon is now selling food online in Italy. In China, online is the most important way of selling persimmon to consumers and JD.com is one of the biggest players in fresh produce sales.

Fresh cuts

The increasing popularity of 'fresh cut' products is being driven by consumer preference of fresh, healthy products with convenience. Minimally processed, 'fresh cut' products often appeal to a different group of consumers and as such, potentially increase the market for a commodity. Research in Spain identified processing and packing treatments to prevent the loss of fruit quality; an essential development in 'fresh cut' persimmon


Packaged Rojo Brillante.

becoming a successful product. Factors associated with a loss of product quality include enzymatic browning, loss of firmness, increase in respiration rate and microbial growth. The combined treatment of 1% ascorbic acid or 1% citric acid solutions to prevent enzymatic browning, 1% CaCl to prevent softening and modified atmosphere packaging to maintain the gas environment, enabled storage for 9 days at 5°C without loss of quality.
A second study in Spain identified the effectiveness of (permeable) MAP film in extending the shelf-life of 'fresh cut' persimmon to 20 days when stored at 1°C and 15 days at 6°C. Persimmon pieces are packed in a gas mixture of 5% CO_2 + 5% O_2.

Mealybug

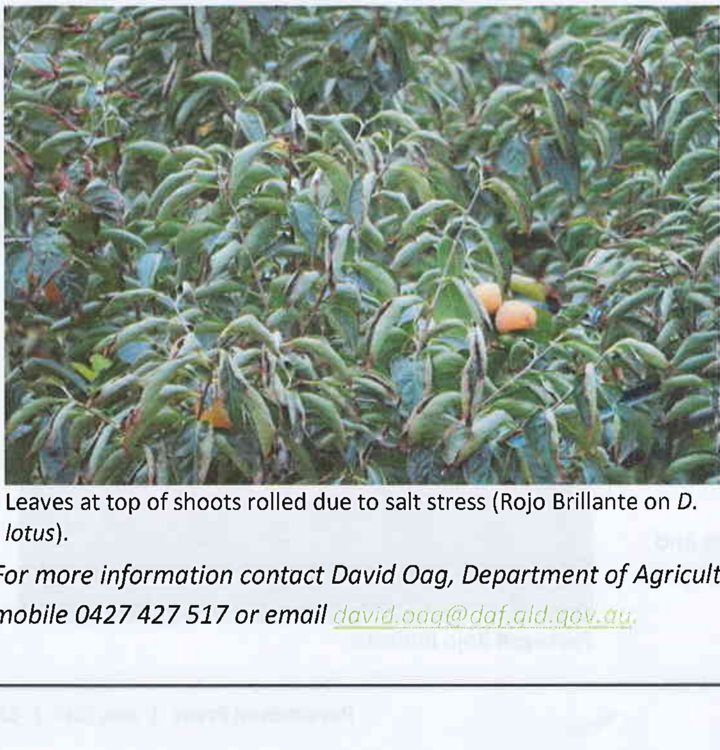
Mealybug is a serious pest for the persimmon industry in Spain due to the few insecticides available to growers and the requirement for zero mealybug on fruit for export. IVIA scientists have developed a PCR technique to enable the accurate identification of mealybug juveniles (nymphs). A DAF scientist in Queensland has recently been working on a similar technique for identifying juveniles of longtailed (*Pseudococcus longispinus*), tuber (*Pseudococcus viburni*) and citrus (*Planococcus citri*). In Brazil, a biological fungus is used for mealybug control and works well in the humid growing conditions common in persimmon production regions.

Circular leaf spot (*Mycosphaerella nawae*)

Circular leaf spot of persimmon causes defoliation leading to early ripening of fruit or complete crop loss. The disease is prevalent in the humid, summer-rainfall climate of Japan and Korea. Recent research has established the pathogen has become well adapted to the arid growing conditions of Spanish summers. The release of spores occurs earlier (early spring) and whilst infections coincide with rain events, can occur with as little as 1 mm of rain. A delay between infection (March to June, Spain; mid-May, Korea) disease symptoms becoming visible (Sept, Spain; Aug, Korea) highlights the importance of knowing when the risk of infection (spore release) occurs each season for effective disease management with fungicides. Spore traps deployed in the orchard before the season to monitor spore release have required the manual counting of spore numbers. Research in Spain and Korea developed PCR techniques for the rapid counting of spores. The fungicides mancozeb, trifloxystrobin and pyraclostrobin provided effective control of circular leaf spot in field trials in Spain.

Postharvest disease control in stored fruit

Alternaria black spot caused by *Alternaria alternata* can cause significant fruit losses during storage and is becoming a major disease in Spain. Infection occurs during flowering and early fruit growth then remains latent until after harvest when symptoms develop. Late season wound infections of fruit significantly increase losses during cold storage. A gas treatment (95 kPa CO_2, for 48 hours at 20°C and 95% RH) significantly reduces postharvest decay in fruit stored at 1°C for up to 40 days. In fruit of 'Rojo Brillante', the CO_2 treatment reduces the incidence of *Alternaria* whilst delaying ripening and retaining fruit firmness. CO_2 as an antifungal treatment can be easily adopted in packinghouses with CO_2 facilities for deastringency.


Leaves at top of shoots rolled due to salt stress (Rojo Brillante on *D. lotus*).

Interested in more from the symposium. A copy of the abstracts of oral and poster presentations can be accessed at https://gallery.mailchimp.com/dba6dcbab0612aed4b4d71cb3/files/PERSIMMON_book.pdf.

This project has been funded by Horticulture Innovation Australia Limited using the Persimmon Industry levy and funds from the Australian Government. The Queensland Government has also co-funded the project through the Department of Agriculture and Fisheries.

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