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Extension of citrus practices to maximise marketable fruit size and economic returns through on-farm trials

Steven Falivene
NSW Department of Primary Industries

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December 2015 final report

Steven Falivene & Karen Connolly
(NSW Department of Primary Industries)

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Introduction

In the past decade many new products and production practices have been promoted within the citrus industry, however for many of them little is known about their performance under a variety of Australian conditions. Sometimes promotional brochures only display favourable results, do not indicate constancy of performance or provide information on where they did not perform. Some of these products and practices have been tried by growers and the performance of some of them has been highly variable. The variability could be due to differences in site, equipment or management. This variability and lack of experience is causing confusion in the industry and limiting adoption.

The key aim of this project is to extend to industry production practices that increase the yield of marketable fruit and to identify non-profitable practices. This will improve the profitability, knowledge and skills of growers. It will also give growers confidence to evaluate and adopt improved technologies.

The secondary aim is to investigate and develop a suitable and efficient methodology to evaluate new technologies through on-farm trials.

To achieve these aims, numerous on-farm trials were conducted on grower properties in the Sunraysia region from 2010 to 2013 that examined various products and practices. The results of these trials were extended to industry through annual field days, seminars and conference presentations.

Media summary

A project to extend citrus production practices that increase the yield of marketable fruit and to identify non-profitable practices was conducted from September 2010 to September 2013. The project conducted 22 replicated citrus (mainly navel orange) demonstration trials on grower's properties. Products and practices trialled include potassium (ground and foliar applied), 2,4-D fruit sizing spray (Corasil®), winter gibberellic acid (GA, Ralex®), hand thinning, hand pruning, summer urea fruit sizing spray, GA flower fruit setting spray, young tree growth bio stimulant enhancing sprays, kaolin clay foliar sprays and wind blemish assessment. The project helped to improve the profitability, knowledge and skills of growers and encouraged them to work collaboratively with science officers to evaluate, refine and adopt new technologies.

Trials on potassium nutrition indicated that cost savings and improved rind quality can occur if foliar potassium sprays are targeted only when fruit size is below the acceptable size range or possibly in high demand situations. In most cases an annual maintenance ground applied potassium program should be sufficient for tree and crop needs.

A cost benefit analysis model was developed by the project to assess the financial benefit or loss of practices. The model used typical fruit box prices for quality and size grade. Sometimes a minor increase in productivity was overshadowed by the cost of implementation. The cost benefit analysis identified the potential benefit of cheap fruit size and yield enhancement practices such as winter GA, flower GA, 2,4-D and summer urea. The cost benefit analysis model can be used to analyse other current and potential production practices in the future to help improve the efficiency and competitiveness of the citrus industry.

2,4-D (Corasil®) trials demonstrated increased fruit size and grower returns. There is opportunity for increased industry adoption of Corasil® in targeted situations. Medium crop load years provided the best results for Corasil® application, no significant results were detected in high or low crop load years.

No benefit in the application of soil conditioners and tree growth bio stimulants were detected. Trials were conducted over two years and it is possible that benefits may not be achieved after a number of years.

The project developed a computerised on-tree fruit size measurement method that improves the efficiency of conducting replicated on-farm demonstration trials. A digital caliper was connected to a small netbook that could measure up to 2000 fruit per day by a single operator. Special MS Excel based software was developed to store and organise digital caliper and yield data. The software was also able to automatically graph, cost benefit analyse and statistically analyse the data. The software can be used in future trials.

Technical summary

A project to extend citrus production practices that increase the yield of marketable fruit and to identify non-profitable practices was conducted from September 2010 to September 2013. The project conducted 22 replicated citrus (mainly navel orange) demonstration trials on grower's properties. Products and practices trialled include potassium (ground and foliar applied), 2,4-D fruit sizing spray (Corasil®), winter GA (Ralex®), hand thinning, hand pruning, summer urea fruit sizing spray, GA flower fruit setting spray, young tree growth bio stimulant enhancing sprays, kaolin clay foliar sprays and wind blemish assessment.

Foliar potassium was trialled on four sites and ground application on two sites. An approximate 2 mm increase in fruit size was detected only on one site which had no previous history of potassium application for over 10 years. The use of foliar potassium sprays is questionable if fruit size is large and/or an annual maintenance program of approximately 50 kg/ha of potassium is applied. The block which demonstrated a response had leaf potassium levels at approximately1% whilst blocks providing no responses were at 1.2 to 1.4%

No fruit size increase was detected for summer urea. Large fruit size throughout the whole block occurred when it was trialled and it is suspected that this masked possible differences. Trials need to be repeated in blocks with district average fruit size.

The use of products and practices that enhance fruit size is questionable in a low cropping year when fruit size will be large and/or in blocks that naturally produce large fruit. Enhancing fruit size of large fruit may increase rind coarseness that can downgrade fruit quality and prices.

Kaolin clay products Surround® and Screen® significantly reduced the incidence of fruit sunburn. The trial occurred for two years and Surround® provided significant results in both years whilst Screen® for one year. Surround® had significantly higher levels of sooty mould on fruit caused by an increase in Red scale and Mealybug infestation of fruit and canopy.

Tree growth bio stimulants Brotomax® and Branch-It® did not increase growth of young navel and Imperial mandarin trees. Navel trees used in the trial may have been water stressed during their establishment phase and this may have affected results.

Soil conditioning products did not provide a response. Organic matter can take time to break down and impact on soil biological and physical properties. Possible beneficial effects might occur after a number of years.

Wind blemish is a significant factor downgrading fruit. The project developed a method to assess wind blemish on-tree which was used to demonstrate the benefits of permanent netting at the 2015 Citrus Technical Forum, Mildura.

Recommendations

Summary

1. Targeted use of potassium foliar sprays to reduce wastage and improve efficiency.
2. Fruit size and yield monitoring to improve nutrition and crop regulation .
3. Further on farm trailing is conducted on winter GA, flowering GA, 2,4-D, kaolin clay, summer urea, 356-TPA, late fruit set thinning sprays, reduce blemish to increase first grade packout, smooth rind practices and sweeter citrus practices.
4. Adoption of on-farm trials within the framework of a National Development officer project.
5. Cost benefit analysis is conducted on all current and potential practices.

Details

1. **Targeted use of potassium foliar sprays to reduce wastage and improve efficiency.**
    a. In low crop load situations and/or when trees have high leaf potassium levels (consistently above 1.2% K), foliar potassium sprays may not provide a fruit size response. In such situations if potassium is applied it may increase rind coarseness. In most years an annual ground application program of approximately 50 kg/ha of potassium might be optimal for fruit size.
2. **Fruit size and yield monitoring to improve nutrition and crop regulation practices.**
    a. Adoption of monthly fruit size and yield monitoring beginning in the first week of December can help growers identify excessive crop loads (trigger for crop regulation) and low fruit size (trigger for fruit size enhancement practices). Crop monitoring will also help growers modify nutrition practices to current crop conditions (i.e. reduce/increase potassium and nitrogen). Refining nutrition practices to crop load will help reduce coarse rind texture.
3. **Further on farm trailing is conducted on winter GA, flowering GA, 2,4-D, kaolin clay, summer urea, 356-TPA, late fruit set thinning sprays, reduce blemish to increase first grade packout, smooth rind practices and sweeter citrus practices.**
    a. <u>Winter GA (Ralex®):</u> The Ralex® trial showed potential, more work needs to be conducted to improve its consistency and a cheaper form of winter GA should be investigated.

b. Flowering GA: Although a result could not be achieve, this was only one trial, trailing on other sites might identify benefits. Increasing the consistency of good yields, especially for late navels, can significantly improve the profitability of production.
c. 2,4-D (Corasil®): There is opportunity for wider adoption of the 2,4-D fruit sizing spray, especially for some early season navels that have small fruit size issues. During the end of the project the use of 2,4-D to reduce the navel end size was identified (Verreynne and Mupambi, 2010). This can help to reduce quarantine pest issues.
d. Kaolin clay for thrips control: Thrips are a major problem and costly to control in terms of chemical cost and disruption to beneficial insects. Kaolin clay could be less disruptive to beneficial insects than chemical control and improve the efficacy of IPM programs.
e. Summer urea: Fruit size in the project summer urea trial was naturally large and this may have possibly masked a response. The trial needs to be repeated on a block with district average sized fruit.
f. 3,5,6-TPA(Tops®): The project conducted row trials and data was too variable to draw a conclusion and present in this report. On-farm replicated adoption trials need to be conducted to better understand its performance.
g. Reduce blemish to increase first grade packout: Various cost benefit analysis presented in this report demonstrated how minor increases in first grade fruit can significantly improve grower returns. Practices that can reduce blemish such as wind breaks and netting need to be further explored. Current information does not provide enough detailed case study information to conduct a realistic cost benefit analysis (i.e. loss of yield from tree wind break competition, realistic reductions in wind blemish etc.).
h. Late fruit set thinning sprays: Most thinning sprays target the early stages of fruit set (October - early November). Often fruit set is not completed until early December and applying crop thinning practices before this stage caries a risk. Adapting current thinning technology to the early December period will provide a more viable option that can improve adoption. Work can focus on early season navels that have a higher tendency to set excessive crop loads.
i. Smoother rind and sweeter citrus practices: This issue was identified at the end of the project. Trialling strategies to make rinds smoother and fruit slightly sweeter can significantly benefit the export program.

4. **Adoption of on-farm trials within the framework of a National Development officer project**
   - The future success of the citrus industry will be driven by the efficient and competitive production of high quality fruit. Market access has been

developed for all countries. Industry needs to focus on production based research and development to improve the technical expertise and technology of Australian production in a cost effective manner. An annual on-farms trial program conducted by industry Development Officers (DO) in partnership with research institutions will invest in the capacity of the industry. One to three replicated on-farm trials per year could be a component of a funded DO program.

    - The experience, techniques and software developed by this project could be used in a future on-farms trials project.

  - On-farm trials will be launch pads to inspire and encourage grower innovation, engagement and the sharing of knowledge within industry. Trials will facilitate field days, workshops, technical publications and other dissemination products (TAFE courses, online learning, videos etc.). The trials can also be presented at the biannual Citrus Technical forum.
  - On farm trials complement detailed research studies as a mechanism to investigate/scope the practical and economic issues of adopting and fine tuning production practices.
    - On-farm trials could scope new practices and if encouraging results occur then better targeted research projects can be developed.
    - On-farm trials can facilitate adoption by raising grower awareness and providing greater confidence in the performance of practices in various farm situations and seasons.
    - If practical adoption problems are detected (i.e. spray application, timing etc.), it can either be solved within the on-farm trial framework or referred on for further detailed research.

5. **Cost benefit analysis is conducted on all current and potential practices and new research**
    a. Research might demonstrate gains in production, but the gain needs to be financially assessed in a realistic model that incorporates box prices and inputs costs. Practical adoption barriers also need to be considered (i.e. new machinery or training).

Material and Methods

Grower collaboration

The project evaluated products and practices promoted to industry through on-farm demonstration trials and the information was extended to industry with farm walks, industry forums and written material.

To achieve the project aims it was necessary to gain grower participation and ownership of the project. This was achieved by conducting a workshop held on 3/08/10 at the Murray Valley Citrus Board (MVCB) Office. The workshop explained the concept of the project and asked growers to suggest products/practices that they would like trialled. Growers were also asked if they wished to volunteer or participate in a trial for a nominated product/practice. The workshop identified numerous practices to investigate. A tick sheet was developed for participants to prioritise proposed trials. Tick sheet results were used to identify the trial treatments and sites. This process enhanced motivation and interest by the participating growers to conduct and manage the trials.

Trial design and analysis

Most demonstration trials included a minimum amount of replication to increase the confidence of interpreting results. Replicated trials used randomised complete block design (RCBD) with up to four treatments. Twenty-four to thirty single tree plots with buffers (where applicable) were used (aiming for a statistical 12 degrees of freedom for RCBD). Increasing the amount of trees per plot and replication would have increased the robustness of the trial design, however this would have also required a much higher level of funds beyond the allocated budget. In some trials the buffers between same treatments were removed to fit a trial within a designated area. The RCBD was chosen because of its simplicity to implement and statistically analyse. Analysis of trial results were conducted using an analysis of variance (ANOVA) for both block and treatment effects (RCBD) at the 5% significance level. Analysis was conducted under the guidance and consultation of NSW DPI Biometrics unit using Genstat® and MS Excel.

Some growers did not want to use a replicated trial design because it was difficult for them to manage, or the site was not suitable for a replicated design, so row/block demonstration trials were implemented. Although it is difficult to derive confident conclusions from row/block demonstration trials, they are still useful for:

- Providing a better understanding of the practical implementation and management of a new practice,

- Indicating if the practice will make significant/large differences (i.e. differences > 4 mm fruit size),
- A good demonstrative extension tool for field days and help to increase grower enthusiasm and participation in the project.

Data collection

Trial yield and fruit size data was collected to assess results and if differences between controls and treatments were detected a cost benefit analysis was conducted. Where applicable frame counts (50 cm frame to indicating crop load) were collected and where funds permitted soil and leaf analysis was conducted.

Leaf analysis was sampled and results were interpreted according to Reuter and Robinson (1997).

Fruit data for research trials is generally assessed by an electronic sorting machine. The sorting machine can measure individual fruit size (size count) and fruit weight (yield). New South Wales Department of Primary Industries (NSW DPI) Dareton has a small fruit sorting machine, however due to the number of trials conducted and the logistics of transporting fruit to and from the sorting machine, this option was unviable. Another problem was that the fruit passing through the sorting machine would be unviable for first grade export because it would have had extra handling (fruit injury) and not have fungicides applied within the appropriate time frame.

Another data collection option was the use of a commercial packing house electronic sorting machine. Many commercial packing houses are very busy during harvest and numerous individual bins of fruit are very inconvenient to measure. Some packing machines are unable to accurately determine when the fruit of one bin stops and another begins. To overcome this, field bin scales were developed by the project that placed straps around the bin and weighed it with the aid of a forklift (Figure 1). However this became impractical mainly because it was too time-consuming and some farm tractors did not have enough forklift height to raise bins off the ground, even with the shortest straps. Straps also became very dirty and difficult to handle in muddy conditions.

Figure 1 : In field bin weighing system in operation. This method was eventually abandoned.

Commercial packing houses prefer at least four bins per treatment plot to improve the accuracy of packing line fruit measurement. This would require at least 20 mature trees. Many blocks would not be large enough to implement adequate replication with 20 tree plots and in most cases row demonstration trials would be implemented. As previously discussed it is difficult to conclusively determine minor treatment differences using row trials, however large differences are observable. Other problems with large trials are the risk of pickers accidentally harvesting wrong trees, bins becoming mixed up during transport or sorting and the increased cost of harvesting.

To overcome the limitations of collecting harvest data through a packing house a more controllable in-field data collection method for fruit size and yield was developed that used single tree plots for on-tree fruit size and field scales yield measurement.

Fruit size measurements were taken electronically using a computerised measurement method developed by the project. Fruit size was measured by a digital caliper that transmitted data to a netbook computer via a USB cable (Figure 2). A button on the digital caliper transmitted data to the computer. A special visual basic MS Excel computer program was developed to accept the data and provide audio cues to the user on the number of fruit sampled. The program also automatically generated graphs and analysed the data. One hundred fruit were measured on each plot. It took 7 to 10 minutes to measure 100 fruit and most trial sites were measured by one person within a full working day.

Figure 2: Demonstration of the automated digital caliper fruit size measurement system.

Visually selecting random fruit for fruit size measurement would have a high degree of bias. It is very easy for the operator to subconsciously select fruit of a desired size. To overcome this problem the operator stood at one of the four corners of a tree and sampled all the fruit within their reach. They made no decision on which fruit to select for sampling. When approximately 25 fruit were sampled the operator moved to the next corner of the tree and continued sampling.

Yield was measured by harvesting individual trees into buckets and weighing each bucket using digital field scales (Figure 3). Project staff would supervise the harvest to ensure the correct trees were harvested and measured.

Figure 3 : Harvest of a replicated trial. Fruit are harvest into buckets and weighed.

Fruit numbers were not counted in the field but calculated using yield and fruit size data. There were a number of steps in this calculation Step 1: 70 to 100 fruit were collected at harvest and each fruit was measured for weight and diameter. A graph and equation was derived that described the relationship between fruit size and weight (Figure 4). Step 2: The equation was used to estimate the weight of fruit for each individual fruit size measurement. Step 3: The total tree fruit weight (tree yield) was divided by the distribution of fruit weight. The division was interpolation of total fruit numbers until it corresponded to the total fruit weight data of the tree.

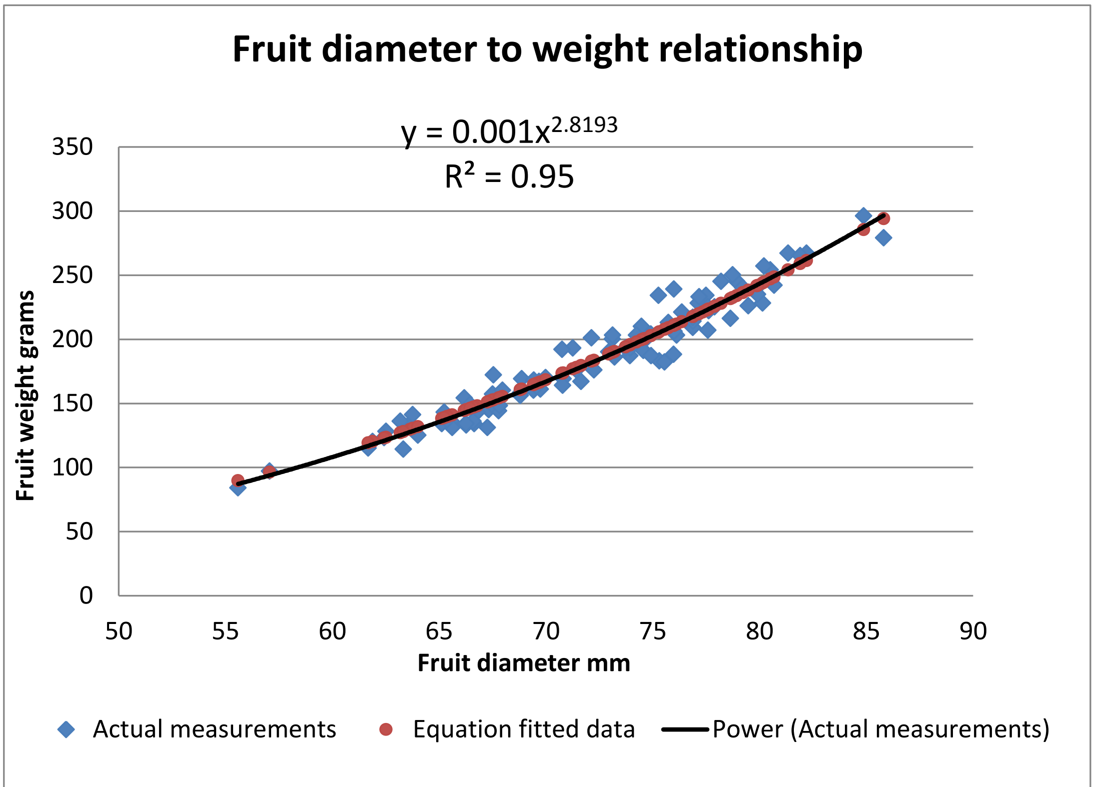

Figure 4: Example of a fruit diameter to weight relationship graph and equation developed for a Washington navel trial site.

The target fruit size for optimum pricing is 75 mm and above. This information is an important indicator used by industry to determine fruit size and was included in trial results.

Cost benefit analysis

Providing results to growers in terms of yield and fruit size is helpful however it does not indicate profitability. Sometimes small gains in fruit size and yield are outweighed by increased costs. To assess profitability a cost benefit analysis was conducted on data showing significant differences between treatments. The cost benefit analysis calculates the amount of money gained or lost by implementing a practice (treated) as compared to not implementing the practice (control). The cost benefit analysis includes the cost of the treatment, application costs and harvest costs.

Citrus prices have fluctuated widely over the past few years and it was difficult to allocate a single nominal fruit price. Therefore data has been presented using a sensitivity analysis for three price scenarios, growers can assess which situation best fits their circumstance and price conditions. The low price scenario could represent a high fruit supply season (on year) and/or low demand season (high exchange rate) and the high price scenario could represent a low fruit supply season (off year) and/or high demand season (lower exchange rate).

Prices were allocated to boxes in a range of fruit size categories (Figure 5). Box prices were chosen in consultation with major export packinghouses. An estimate of farm gate returns for each treatment was calculated using this box pricing assumption. Packing charges and export charges were excluded from the dollar per box assumptions.

Central costs & returns input table

Returns
Note: $/Box excludes packing & export charge

	Scenario 1 Low			Scenario 2 Med			Scenario 3 High		
Box size	16 kg			16 kg			16 kg		
	1st grade $/Box	2nd grade $/Box	3rd grade $/T	1st grade $/Box	2nd grade $/Box	3rd grade $/T	1st grade $/Box	2nd grade $/Box	3rd grade $/T
0-65 mm	$0.8	$0.8	$50	$1.0	$1.0	$60	$1.3	$1.3	$80
60-65 mm	$0.8	$0.8	$50	$4.0	$2.4	$60	$5.8	$3.2	$80
65-70 mm	$1.3	$0.8	$50	$1.6	$3.9	$60	$6.6	$5.6	$80
70-75 mm	$2.6	$1.6	$50	$7.0	$5.1	$60	$9.0	$7.2	$80
75-85 mm	$4.5	$1.9	$50	$9.7	$5.1	$60	$14.0	$8.5	$80
85+ mm	$5.8	$2.5	$50	$11.9	$5.1	$60	$13.6	$8.5	$80

Costs

	Scenario 1 Low	Scenario 2 Med	Scenario 3 High
Picking cost $/T	$75	$75	$75
Harvest freight $/T	$10	$10	$10
Levies $/T	$5	$5	$5
Total $/T	$90	$90	$90
Est. $/T returns only	$144	$333	$486

Figure 5 : Navel cost:benefit analyser box price input table. The prices are used to calculate net returns and cost benefit analysis for trial treatments.

Fruit prices are often provided to growers on a per bin or equivalent per ton basis and some growers may be unfamiliar with box pricing. To help growers better understand the price assumptions used in the cost benefit analysis, box prices were converted into an approximate per ton price. Per ton pricing is only a guide because blemish (Table 2) and fruit size packout's assumptions (Table 3) were used to develop the per ton price. Pricing scenarios were also developed for Afourer mandarin (Figure 6, Table 5 and Table 6).

The approximate navel dollar per ton price for the three scenarios are; $144/T low price, $333/T medium price and $486/T high price. The approximate Afourer mandarin dollar per ton price for the three scenarios are; $580/T low price, $1,131/T medium price and $1,595/T high price.

$/box to $/T conversion

	Low		Med		High	
	1st grade $/T	2nd grade $/T	1st grade $/T	2nd grade $/T	1st grade $/T	2nd grade $/T
0-65 mm	$50	$50	$60	$60	$80	$80
60-65 mm	$50	$50	$250	$150	$360	$200
65-70 mm	$81	$50	$100	$244	$410	$350
70-75 mm	$163	$100	$438	$319	$563	$450
75-85 mm	$281	$119	$606	$319	$875	$531
85+ mm	$363	$156	$744	$319	$850	$531

Table 1 : Summary of navel fruit price $/T applied to fruit size categories.

1st	55.0%
2nd	30.0%
3rd	15%

Table 2: The % blemish grade distribution for all size categories indicates used to estimate per ton pricing.

Count C31		Estimate % packout
Factory	0-65 mm	3%
138	60-65 mm	7%
113	65-70 mm	20%
88	70-75 mm	30%
72	75-85 mm	25%
56	85+ mm	15%

Table 3: Navel fruit size distribution (by weight) that was used to estimate per ton pricing.

Central costs & returns input table

Returns

Note: $/Box excludes packing

	Scenario 1 Low (Box size 10 kg)			Scenario 2 Med (Box size 10 kg)			Scenario 3 High (Box size 10 kg)		
	1st grade	2nd grade	3rd grade	1st grade	2nd grade	3rd grade	1st grade	2nd grade	3rd grade
	$/Box	$/Box	$/T	$/Box	$/Box	$/T	$/Box	$/Box	$/T
0-55 mm	$2.0	$1.0	$10	$4.0	$3.0	$50	$8.0	$4.0	$100
55-60 mm	$6.0	$3.0	$10	$8.0	$9.0	$50	$12.0	$10.0	$100
60-65 mm	$8.0	$6.0	$10	$16.0	$14.0	$50	$24.0	$18.0	$100
65-70 mm	$10.0	$8.0	$10	$20.0	$18.0	$50	$28.0	$20.0	$100
70+ mm	$11.0	$9.0	$10	$20.0	$18.0	$50	$28.0	$22.0	$100

Costs

	Scenario 1 Low	Scenario 2 Med	Scenario 3 High
Picking cost $/T	$220	$220	$220
Freight $/T	$13	$13	$13
Levies $/T	$5	$5	$5
Total $/T	$238	$238	$238
Est. $/T returns only	$580	$1,131	$1,595

Figure 6: Afourer mandarin cost:benefit analyser box price input table. The prices are used to calculate net returns and cost benefit analysis for trial treatments.

$/box to $/T conversion

	Low		Med		High	
	1st grade	2nd grade	1st grade	2nd grade	1st grade	2nd grade
	$/T	$/T	$/T	$/T	$/T	$/T
0-55 mm	$200	$100	$400	$300	$800	$400
55-60 mm	$600	$300	$800	$900	$1,200	$1,000
60-65 mm	$800	$600	$1,600	$1,400	$2,400	$1,800
65-70 mm	$1,000	$800	$2,000	$1,800	$2,800	$2,000
70+ mm	$1,100	$900	$2,000	$1,800	$2,800	$2,200

Table 4: Summary of Afourer mandarin fruit price $/T applied to fruit size categories

1st	65.0%
2nd	25.0%
3rd	10%

Table 5: The % Afourer mandarin estimate blemish grade distribution for all size categories used to estimate per ton pricing.

Fruit size	Estimate % packout
0-55 mm	5%
55-60 mm	13%
60-65 mm	40%
65-70 mm	22%
70+ mm	20%

Table 6: Afourer mandarin fruit size distribution (by weight) that was used to estimate per ton pricing.

Results

Trial results are grouped into sections of similar treatments, these groupings are:

1. Potassium
2. Pruning and crop regulation
3. Tree growth enhancement sprays
4. Soil conditioner
5. Fruit manipulation

1. Potassium

Introduction

Potassium (K) is known to be important for water regulation in trees and fruit size (Ferguson et al. 2014). Research from around the world report significant increases in fruit size form potassium application (Erner et al. 1993; Alva et.al., 2006; Calvert and Smith, 1972). Potassium use in the Sunraysia region is increasing however an assessment of its impact on fruit size in navel oranges has never been conducted.

Potassium was trialled at six sites;

1. Ground potassium: Deakin Estate
2. Ground potassium: Minter Magic
3. Foliar potassium - Pot. Nitrate: Cottrell Nominees
4. Foliar potassium - Nutrivant® & Pot. Nitrate: Deakin Estate
5. Foliar potassium - Pot. Nitrate: Ellerslie North Citrus
6. Foliar potassium – K-Carb®: Manna Farms

.

1.1 Ground potassium: Deakin Estate

Background

Property managers: Craig Thornton & Justin McFee

The trial site was a block of 28 year old Washington navels on Citrange rootstock planted at 446 trees/ha and watered by overhead irrigation (Figure 7). The trial site had not received any potassium fertiliser for at least 10 years (known records). The trial was conducted over two seasons; 2010-11 and 2011-12.

Figure 7: Ground applied potassium trial site trees

Method

The trial was a randomised complete block design with 15 replicates, two trees per replicate with a buffer tree in between treatment plots. Two hundred kg per hectare (units) of K in the form of potassium sulphate was ground applied by hand underneath the canopy of treated plots on the 9/12/10. One hundred units of K were applied on 20/12/11.

Fruit size data was collected on the 27/6/11 and 22/5/12. Harvest occurred at 30/6/11 and 24/5/12. Leaf samples for leaf analysis were taken on the 16/3/11 and soil samples taken on the 23/7/11.

Results

There was no significant difference in yield between treatments over the two seasons. There was a significant difference for fruit size. As seen in Table 7 average fruit size was approximately 1 to 2 mm larger in the potassium treatment than control (5% significance). Average yield for 2011 was 43.7 T/ha and for 2012 T/ha was 62.5 T/ha.

	Fruit size	
Year	Control	Potassium
2011	75.1 a	77.6 b
2012	74.2 a	75.4 b

Table 7: Average fruit size. (Different letters on columns indicate a statistical difference at the 5% level)

As seen in Table 8 there was 5-10% less fruit in the below 75 mm fruit size and similarly more fruit in the above 75 mm category for the potassium treatment. Results for both categories were significant at the 5% level.

Percent fruit size distribution fruit calliper measurement results			
Year	Fruit size	Control	Potassium
2011	0-75 mm	45.9% a	35% b
	75+ mm	54.1% a	65% b
2012	0-75 mm	52.8% a	46.5% b
	75+ mm	47.3% a	53.5% b

Table 8: Percent fruit size distribution above and below 75 mm fruit diameter. (Different letters on columns indicate a statistical difference at the 5% level)

Leaf analysis results from sampling in autumn 2011 indicate that most nutrients were in adequate levels (Table 9). The only significant difference was detected for sulphur. This is understandable since potassium sulphate was applied.

		Control	Potassium	Control	Potassium
Nitrogen	%	2.68	2.74	Adequate	High
Phosphorus	%	0.16	0.16	Adequate	Adequate
Potassium	%	1.06	1.12	Adequate	Adequate
Calcium	%	4.7	4.5	Adequate	Adequate
Magnesium	%	0.39	0.38	Adequate	Adequate
Sodium	%	0.05	0.05	Adequate	Adequate
Chloride	%	0.14	0.14	Adequate	Adequate
Zinc	mg/kg	16	15	Low	Low
Manganese(c)	mg/kg	26	24	Adequate	Low
Boron	mg/kg	83	84	Adequate	Adequate
Copper	mg/kg	205	223	Excessive	Excessive
Iron	mg/kg	214	224	Excessive	Excessive
Sulphur	%	0.25 a	0.26 b	Adequate	Adequate

Table 9: 2011 leaf analysis results and interpretation. (Different letters on columns indicate a statistical difference at the 5% level)

	Control	Potassium
EC dS/m	0.035 b**	0.026 a**
pH (CaCl2) pH units	6.5	6.0
Colwell Phosphorus mg/kg	11.8	16.7
KCl extractable Ammonium-N mg/L	0.72	0.66
KCl extractable Nitrate-N mg/L	1.43 b*	0.95 a*
Calcium cmol(+)/kg	3.4	3.4
Potassium cmol(+)/kg	0.38 b**	0.73 a**
Magnesium cmol(+)/kg	1.3	1.3
Sodium cmol(+)/kg	0.09	0.11
Cation Exchange Capacity cmol(+)/kg	5.2	5.5
Calcium/Magnesium ratio	2.7	2.7
Exch. Calcium %	65.5 b**	61.1 a**
Exch. Potassium %	7.4 b**	13.5 a**
Exch. Magnesium %	25.1 b*	23.2 a*

Table 10: 2011 soil test results. (Different letters on columns indicate a statistical difference; * = 5% and ** = 1%)

The 2011 soil test results indicated a number of significant differences in data (Table 10). Soil potassium levels were significantly higher and this understandably affected the exchangeable percentage of calcium, potassium and magnesium. It is difficult to explain the lower soil EC levels in the potassium treatment. Higher EC levels are expected due to the application of extra fertiliser. Extractable nitrate was also lower in the potassium treatment. Although EC and extractable nitrate were different, the differences were not of practical significance.

A 100 fruit sample was taken from each treatment and assessed for albedo breakdown. The percentage of fruit with albedo breakdown greater than 1 cm is provided in Table 11. There was no significant difference.

	Control	Potassium
% fruit with albedo	23.8%	26%

Table 11: 2011 harvest albedo breakdown assessment results. Fruit with albedo breakdown greater than 1 cm. (Different letters on columns indicate a statistical difference at the 5% level)

2012 leaf analysis results (Table 12) showed a significant increase in sulphur levels as was observed in the 2011 results (Table 10). The percent potassium levels were significantly higher in the potassium treatment.

	Units	Control	Potassium	Control	Potassium
Nitrogen	%	2.9	2.8	High	High
Phosphorus	%	0.15	0.15	Adequate	Adequate
Potassium	%	0.98 a**	1.09 b**	Adequate	Adequate
Calcium	%	4.5	4.5	Adequate	Adequate
Magnesium	%	0.38	0.35	Adequate	Adequate
Sodium	%	0.04	0.04	Adequate	Adequate
Chloride	%	0.11	0.11	Adequate	Adequate
Zinc	mg/kg	46	33	Adequate	Adequate
Manganese(c)	mg/kg	66	65	Adequate	Adequate
Boron	mg/kg	80	84	Adequate	Adequate
Copper	mg/kg	5	6	Adequate	Adequate
Iron	mg/kg	198	209	High	Excessive
Sulphur	%	0.28 a**	0.3 b**	Adequate	Adequate

Table 12: 2012 leaf analysis results and interpretation. (Different letters on columns indicate a statistical difference at the 5% level)

Figure 8 presents the cost benefit analysis of applying 200 kg per hectare of potassium for the 2010-11 season and 100kg per hectare for the 2011-12 season based on the data collected from the trial. The analysis includes the cost of applying potassium sulphate which was $370 per hectare (fertiliser cost $362 plus $8 for fertigation costs). In other words in a low price year a net return (profit) of approximately $500 per hectare was achieved in 2012 by applying 100 kg of potassium.

A positive cost benefit was achieved at all pricing levels however a higher return was achieved for the medium and high price scenarios.

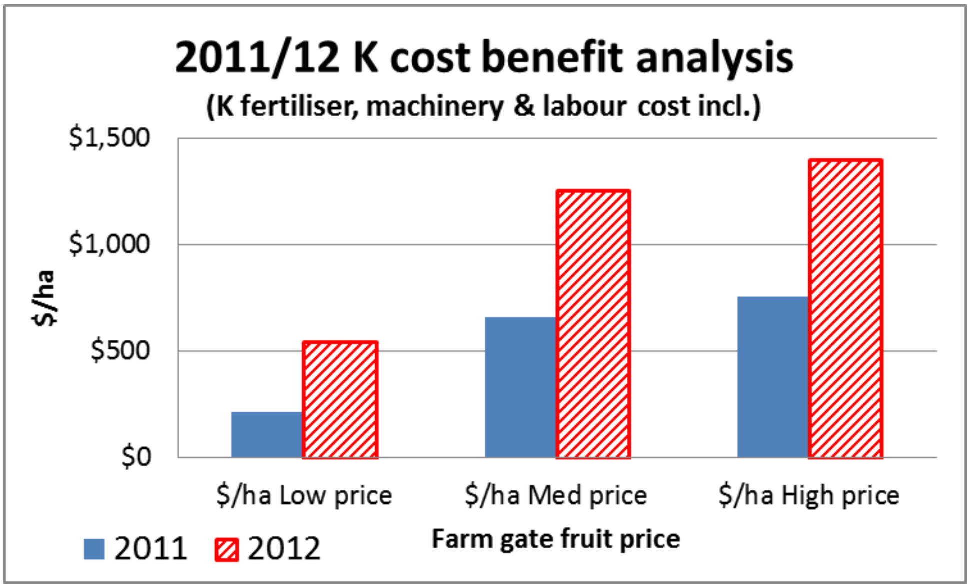

Figure 8: Cost:benefit analysis of applying potassium including the cost of potassium fertiliser, harvest, fertigation and labour.

1.2 Ground potassium: Minter Magic

Background

Property manager: Darren Minter

The trial site was a block of Whitley Washington navels on Citrange rootstock planted in 1990 at 452 trees/ha and irrigated by drip irrigation (Figure 9). The trial was conducted over 2 seasons; 2011-12 and 2012-13.

Figure 9: Minter Magic potassium trial site trees.

Method

Fifty kg/ha of potassium in the form of potassium nitrate was applied by the grower to the entire block in early December 2011 and 2012. Three treatments were implemented

1) 50 kg/ha K: grower applied 50 kg/ha to the entire block.
2) 100 kg/ha K: 50 kg per ha applied on 23/12/11 and 19/12/12.
3) 150 kg/ha K: 50 kg per ha applied on 23/12/11 and 19/12/12; 50 kg per ha applied on 10/1/12 and 10 /1/13.

Eight single tree replicates were implemented and the potassium fertiliser applied to treatments was SprayGro K blast® liquid potassium fertiliser. The fertiliser was applied by injecting a measured amount under each dripper of a treated tree using a sheep drench gun (Figure 10).

Figure 10: Injecting liquid potassium fertiliser (SprayGro K blast®) under each dripper of a treated tree.

Leaf analysis was sampled in March 2012. Fruit was harvested 4/6/12 and 12/6/13.

Results

There was no significant difference in yield or fruit size for the 2012 and 2013 trial at the 5% level of significance (Table 13 and Table 14). Average yield for 2012 was 57 T/ha and 2013 56 T/ha.

2012 fruit size results			
Category	Kg/ha of K applied		
	50	100	150
Average fruit size mm	76.9	78.5	76.9
% fruit 0-75 mm	35.2%	24.3%	34.3%
% fruit 75+ mm	64.8%	75.7%	65.7%

Table 13: 2012 Minter Magic K trial average fruit size and percentage fruit size distribution above and below 75 mm fruit diameter. (Different letters on columns indicate a statistical difference at the 5% level)

2013 fruit size results			
Category	Kg/ha of K applied		
	50	100	150
Average fruit size mm	85.2	83.8	87.6
% fruit 0-75 mm	4.7%	11.7%	3.0%
% fruit 75+ mm	95.3%	88.3%	97.0%

Table 14: 2013 Minter Magic K trial average fruit size and percentage fruit size distribution above and below 75 mm fruit diameter. (Different letters on columns indicate a statistical difference at the 5% level)

In the 2012 leaf analysis tests (Table 15) there was a significance difference at the 5% level of lower zinc and manganese levels for the 100 and 150 unit treatment rates as compared to the 50 unit treatment rate. There were no significant differences for all other nutrients.

2012 leaf analysis results							
Element	**Unit**	**Treatments kg/ha of K**					
		50	**100**	**150**	**50**	**100**	**150**
Nitrogen	%	2.8	2.8	2.7	High	High	Adequate
Phosphorus	%	0.14	0.13	0.14	Adequate	Adequate	Adequate
Potassium	%	1.35	1.43	1.29	High	High	Adequate
Calcium	%	5	5.3	5	Adequate	Adequate	Adequate
Magnesium	%	0.34	0.36	0.36	Adequate	Adequate	Adequate
Sodium	%	0.02	0.02	0.02	Adequate	Adequate	Adequate
Chloride	%	0.2	0.22	0.19	Adequate	Adequate	Adequate
Sulphur	%	0.25	0.25	0.25	Adequate	Adequate	Adequate
Zinc	mg/kg	30 a**	19 b**	22 b**	Adequate	Low	Low
Manganese	mg/kg	26 a**	17 b**	18 b**	Adequate	Low	Low
Boron	mg/kg	135	138	143	High	High	High
Copper	mg/kg	12	10	11	Adequate	Adequate	Adequate
Iron	mg/kg	104	92	101	Adequate	Adequate	Adequate

Table 15: 2012 Minter Magic K trial leaf analysis results and interpretation. (Different letters on columns indicate a statistical difference at the 5% level)

1.3 Foliar potassium – Pot. nitrate: Ellerslie North Citrus

Background

Property manager: David Stevens

The trial site was a block of Lane Late navels on trifoliata rootstock planted in 2000 at 357 trees/ha and irrigated by sprinkler irrigation (Figure 11). The trial was conducted over 2 seasons; 2011-12 and 2012-13.

Method

Potassium nitrate was sprayed onto trees at two rates: 5% and 10%. Deluge® was used as an adjuvant wetter at a rate of 10 ml per 100L. Trees were sprayed on 10/2/12 and 17/12/12 to the point of run-off (approximately 5 L per tree). Leaf analysis samples were collected on 21/3/12. Fruit was harvested 21/8/12 and 7/8/13. Approximately 80 kg/ha of potassium was fertigated by the grower to all trees each season.

Figure 11: Ellerslie North Citrus foliar potassium spray trial site

Results

There was no significant difference in yield or fruit size for the 2012 and 2013 trial at the 5% level of significance (Table 16 and Table 17). Average yield for 2012 was 40 T/ha and 2013 28 T/ha.

2012 Ellerslie North Citrus fruit size trial results			
Category	% of foliar potassium nitrate		
	Control	5%	10%
Average fruit size mm	82.8	84.7	82.8
% fruit 0-75 mm	12.1%	6.1%	12.4%
% fruit 75+ mm	87.9%	94.0%	87.6%

Table 16: 2012 Ellerslie North Citrus foliar K trial average fruit size and percentage fruit size distribution above and below 75 mm fruit diameter.
(Different letters on columns indicate a statistical difference at the 5% level)

2013 Ellerslie North Citrus fruit size trial results			
Category	% of foliar potassium nitrate		
	Control	5%	10%
Average fruit size mm	79.5	80.5	81.5
% fruit 0-75 mm	24.7%	18.9%	17.3%
% fruit 75+ mm	75.4%	81.1%	82.7%

Table 17: 2013 Ellerslie North Citrus foliar K trial average fruit size and percentage fruit size distribution above and below 75 mm fruit diameter.
(Different letters on columns indicate a statistical difference at the 5% level)

No significant differences for any of the elements were detected in the 2012 leaf analysis tests. Chloride levels were slightly high, but this is typical of Trifoliatia rootstock for this region.

2012 Ellerslie North Citrus leaf analysis results							
Element	**units**	**Treatments: % of foliar potassium nitrate**					
		Control	**5%**	**10%**	**Control**	**5%**	**10%**
Nitrogen	%	2.9	2.8	2.8	High	High	High
Phosphorus	%	0.14	0.14	0.13	Adequate	Adequate	Adequate
Potassium	%	1.4	1.4	1.51	High	High	High
Calcium	%	4.4	4.5	4.3	Adequate	Adequate	Adequate
Magnesium	%	0.35	0.37	0.38	Adequate	Adequate	Adequate
Sodium	%	0.01	0.02	0.02	Adequate	Adequate	Adequate
Chloride	%	0.43	0.5	0.44	High	High	High
Sulphur	%	0.24	0.24	0.23	Adequate	Adequate	Adequate
Zinc	mg/kg	53	43	29	Adequate	Adequate	Adequate
Manganese(c)	mg/kg	29	31	31	Adequate	Adequate	Adequate
Boron	mg/kg	133	139	133	High	High	High
Copper	mg/kg	4.9	5.3	4.7	Low	Adequate	Low
Iron	mg/kg	86	85	91	Adequate	Adequate	Adequate

Table 18: 2012 Ellerslie North Citrus foliar K trial leaf analysis results and interpretation. (Different letters on columns indicate a statistical difference at the 5% level)

1.4 Foliar potassium – Pot. Nitrate: Cottrell Nominees

Background

Property managers: Mathew Cottrell and Andrew Donaldson

The trial site was a block of Lane Late navels on Citrange rootstock planted in 2004 at 800 trees/ha and irrigated by drip irrigation (Figure 12). The trial was conducted over 2 seasons; 2011-12 and 2012-13.

Figure 12: Cottrell Nominees foliar potassium spray trial site

Method

The trial was a RCBD with three treatments, nine replicates and single tree plots.

Cottrell Foliar Potassium trial treatments		
	2011-12	2012-13
Level 1	1.5% : 23/12/12	2.5% : 18/12/12
Level 2	3.5% (level 1 plus 2% 1/1/12)	5% : 18/12/12

Table 19 Cottrell Farms foliar K treatments

The potassium rates for each treatment were increased for 2012-13 because of the lack of differences from the 2011-12 season (Table 19). Deluge® was used as an adjuvant wetter at a rate of 10 ml per 100L. Trees were sprayed to the point of run-off (approximately 5 L per tree). Approximately 70 kg/ha of potassium is fertigated to all trees each season. Leaf analysis samples were collected March 2012. Fruit was harvested 13/9/12 and 13/8/13.

Results

There was no significant difference in yield or fruit size for the 2012 and 2013 trial at the 5% level of significance (Table 16 and Table 17). Average yield for 2012 was 41 T/ha and 2013 23 T/ha.

2012 Cottrell Farms fruit size trial results			
Category	% of foliar potassium nitrate		
	Control	1.5%	1.5+2%
Average fruit size mm	81.8	82.6	81.0
% fruit 0-75 mm	12.8%	13.4%	14.8%
% fruit 75+ mm	87.3%	86.6%	85.3%

Table 20: 2012 Cottrell Nominees foliar K trial average fruit size and percentage fruit size distribution above and below 75 mm fruit diameter. (Different letters on columns indicate a statistical difference at the 5% level)

2013 Cottrell Farms fruit size trial results			
Category	% of foliar potassium nitrate		
	Control	3.5%	5%
Average fruit size mm	87.8	86.6	85.9
% fruit 0-75 mm	3.6%	4.2%	4.0%
% fruit 75+ mm	96.4%	95.8%	96.0%

Table 21: 2013 Cottrell Nominees foliar K trial average fruit size and percentage fruit size distribution above and below 75 mm fruit diameter. (Different letters on columns indicate a statistical difference at the 5% level)

In the 2012 leaf analysis tests there was a significance difference at the 5% level of higher zinc and manganese levels (Table 22) for the 1.5% and 1.5+2% treatments as compared to the control. Leaf potassium levels were higher at the 5% level of significance for the 1.5% and 1.5+2% treatments as compared to the control. Leaf sodium levels were higher at the 5% level of significance for the 1.5% treatment as compared to control and 1.5+2%. The sodium result is unexplainable. There were no significant differences for all other nutrients.

2012 Cottrell Nominees leaf analysis results							
Element	**Unit**	**Treatments: % of foliar potassium nitrate**					
		Control	**1.5%**	**1.5+2%**	**Control**	**1.5%**	**1.5+2%**
Nitrogen	**%**	2.6	2.6	2.6	Adequate	Adequate	Adequate
Phosphorus	**%**	0.13	0.14	0.12	Adequate	Adequate	Low
Potassium	**%**	1.22 a*	1.32 b*	1.38 b*	Adequate	High	High
Calcium	**%**	5.4	5	5	Adequate	Adequate	Adequate
Magnesium	**%**	0.28	0.26	0.27	Low	Low	Low
Sodium	**%**	0.012 a**	0.023 b**	0.011 a **	Adequate	Adequate	Adequate
Chloride	**%**	0.03	0.04	0.04	Adequate	Adequate	Adequate
Sulphur	**%**	0.26	0.26	0.26	Adequate	Adequate	Adequate
Zinc	**mg/kg**	38 a*	63 b*	46 b*	Adequate	Adequate	Adequate
Manganese	**mg/kg**	72 a*	100 b*	83 b*	Adequate	High	Adequate
Boron	**mg/kg**	57	50	52	Adequate	Adequate	Adequate
Copper	**mg/kg**	3	3	3	Deficient	Deficient	Deficient
Iron	**mg/kg**	88	87	86	Adequate	Adequate	Adequate

Table 22: 2012 Cottrell Nominees foliar K trial leaf analysis results and interpretation. (Different letters on columns indicate a statistical difference at the 5% level)

1.5 Foliar potassium – Nutrivant® & Pot. Nitrate: Deakin Estate

Background

Property manager: Craig Thornton & Justin McFee

The trial site was a block of Thompson navels on Citrange rootstock planted in 1994 at 274 trees/ha and irrigated by drip irrigation (Figure 13). The trial was conducted over the 2011-12 season. No potassium fertiliser has been applied to the site for a number of seasons.

Figure 13: Deakin Estate foliar potassium spray trial site

Method

The trial was an RCBD with three treatments, nine replicates and single tree plots. The treatments were a Nutrivant® and potassium nitrate foliar spray. A 3% mixture of each nutrient was applied to trees and a water volume rate of approximately 3500 L/ha. This equates to approximately 35 to 40 kg per hectare of potassium per application. The first application was on 20/12/11 and the second application on 11/1/12. The percentage concentration of nutrients used in the treatment foliar sprays are presented in Table 23.

	Element		
Fertiliser	%N	%P	%K
Potassium nitrate	13	0	38
Nutrivant®	8	7	33

Table 23: Concentration of nutrients in Deakin Estate foliar potassium treatments.

Results

There was no significant difference in yield or fruit size for the trial at the 5% level of significance (Table 24). Average yield was 86 T/ha.

2012 Deakin Estate Citrus foliar K fruit size trial results			
Category	Foliar potassium treatment		
	Control	Nutrivant®	Pot. Nit.
Average fruit size mm	75.8	75.9	76.8
% fruit 0-75 mm	44.1%	41.8%	36.5%
% fruit 75+ mm	56.2%	58.3%	63.6%

Table 24: 2013 Deakin Estate foliar K trial average fruit size and percentage fruit size distribution above and below 75 mm fruit diameter. (Different letters on columns indicate a statistical difference at the 5% level)

Leaf analysis results presented in Table 25 are from non-replicated sampling. Results indicate that nitrogen and phosphorus levels were generally low. All other nutrients were in the adequate range. There were expectations that the foliar application of potassium and nitrogen on trees with below average levels of leaf nutrients would have produced a response in leaf analysis results. Possible explanations for the lack of response are there was poor uptake of nutrients at the time of application and/or much higher rates or frequency of foliar nutrients are required to evoke a change in leaf analysis results.

2012 Deakin Estate foliar K trial leaf analysis results							
Element	Units	Treatments					
		Control	**KNO_3**	**Nutrivant®**	**Control**	**KNO_3**	**Nutrivant®**
Nitrogen	%	**2.3**	**2.3**	**2.4**	Low	Low	Adequate
P	%	**0.10**	**0.11**	**0.12**	Low	Low	Low
K	%	**0.96**	**0.97**	**0.95**	Adequate	Adequate	Adequate
Ca	%	**6.2**	**5.7**	**5.8**	High	High	High
Mg	%	**0.39**	**0.41**	**0.40**	Adequate	Adequate	Adequate
Na	%	**0.016**	**0.059**	**0.024**	Adequate	Adequate	Adequate
Chloride	%	**0.10**	**0.10**	**0.10**	Adequate	Adequate	Adequate
S	%	**0.22**	**0.20**	**0.23**	Adequate	Adequate	Adequate
Zn	mg/kg	**34**	**32**	**31**	Adequate	Adequate	Adequate
Mn	mg/kg	**61**	**54**	**60**	Adequate	Adequate	Adequate
Fe	mg/kg	**160**	**170**	**160**	High	High	High
B	mg/kg	**120**	**110**	**94**	Adequate	Adequate	Adequate
Cu	mg/kg	**320**	**330**	**280**	Excessive	Excessive	Excessive

Table 25: 2012 Deakin Estate foliar K trial leaf analysis results and interpretation. Non-replicated sampling. Leaf samples from each treatment were bulked together.

1.5 Foliar potassium – K-Carb®: Manna Farms

Background

Property manager: David Keens

The trial site was a block of Washington navels on rootstock of unknown origin (probably sweet orange) planted in 1928 at 204 trees/ha and irrigated by drip irrigation (Figure 14). The trial was conducted over the 2011-12 season. No potassium fertiliser has been applied to the site for a number of seasons. The site is a registered organic farm.

Figure 14: Manna Farms foliar potassium spray trial site.

Method

The trial was a RCBD with two treatments, eight replicates and single tree plots. K-Carb 35® was sprayed onto treated trees at 1% mixing rate with a water volume of approximately 3500 L per hectare. Trees were sprayed twice; 9/1/12 and 14/2/12. K-Carb 35® contains approximately 35% potassium in the form of citrate. K-Carb 35® is an acceptable fertiliser for organic registered farms.

Results

There was no significant difference in yield or fruit size for the trial at the 5% level of significance (Table 26). Average yield was 30.3 T/ha.

2012 Manna Farms fruit size trial results		
Category	Foliar potassium treatment	
	Control	K-Carb®
Average fruit size mm	79.3	81.0
% fruit 0-75 mm	25.4%	19.5%
% fruit 75+ mm	74.7%	80.5%

Table 26: 2012 Manna Farms foliar K trial average fruit size and percentage fruit size distribution above and below 75 mm fruit diameter. (Different letters on columns indicate a statistical difference at the 5% level)

2012 leaf analysis results indicate that most nutrients were within adequate levels (Table 27). Phosphorus leaf analysis levels were higher than typical of conventionally grown citrus. This might be a reflection of the application of organic fertilisers (i.e. blood and bone and manure) as compared to conventional chemical fertilisers. The fruit did have a smooth rind, this could be a reflection of the nutrition program (high phosphorus - medium nitrogen) or other factors related to organic production. The nitrogen to phosphorus ratio for trial trees was approximately 15, whilst conventionally grown citrus is typically approximately 20.

2012 Manna Farms Potassium trial leaf analysis results					
Element	**Unit**	**Treatment**			
		Control	**K-Carb®**	**Control**	**K-Carb®**
Nitrogen	**%**	2.6	2.6	Adequate	Adequate
Phosphorus	**%**	0.19	0.17	High	Adequate
Potassium	**%**	1.15	1	Adequate	Adequate
Calcium	**%**	3.8	4	Adequate	Adequate
Magnesium	**%**	0.25	0.25	Low	Low
Sodium	**%**	0.03	0.04	Adequate	Adequate
Chloride	**%**	0.05	0.07	Adequate	Adequate
Sulphur	**%**	0.25	0.27	Adequate	Adequate
Zinc	**mg/kg**	28	25	Adequate	Adequate
Manganese(c)	**mg/kg**	33	29	Adequate	Adequate
Boron	**mg/kg**	80	76	Adequate	Adequate
Copper	**mg/kg**	5	5	Adequate	Adequate
Iron	**mg/kg**	288	268	Excessive	Excessive

Table 27: 2012 Manna Farms foliar K trial leaf analysis results and interpretation. Non replicated sampling. Leaf samples from each treatment were bulked together.

Figure 15: Smooth rind texture of Manna Farms trial fruit.

Discussion: potassium

Foliar potassium sprays are extensively used throughout the region and trials were expected to demonstrate a positive response. None of the four foliar spray trial sites provided a response.

Two ground potassium trials were implemented, Deakin and Minter, and the Deakin site demonstrated a response in fruit size and cost benefit analysis. One of the factors that distinguish the Deakin site from all others was that no potassium fertiliser had been applied to the site for over 10 years. Soil and leaf test analysis indicated that the Deakin site was not low in percentage leaf potassium, however its levels were lower than all other sites (Table 28). Leaf potassium levels in the Deakin site was approximately 1% whilst other trial sites that showed no response to potassium treatments were approximately 1.2 to 1.4%.

Site	Year	Application	Yield T/ha	Fruit diameter mm	Leaf %K
Cotrell	2013	Foliar	23	86.8	
Ellerslie	2013	Foliar	28	80.5	
Manna	2012	Foliar	30.3	80.2	1.08
Ellerslie	2012	Foliar	40	83.4	1.44
Cotrell	2012	Foliar	41	81.8	1.31
Deakin	2011	Ground	43.7	76.4	1.09
Minter	2012	Ground	56	85.5	
Minter	2011	Ground	57	77.4	1.36
Deakin	2012	Ground	62.5	74.8	1.04
Deakin	2012	Foliar	86	76.2	0.96

Table 28: Summary of potassium trials

Yield has an important influence on fruit size (Khurshid and Bevington, 2002). Young trees and low crop load situations generally produce large fruit. Table 28 has been sorted from lowest to highest yield and there is a trend of highest fruit size associated with the lowest yields.

Interpretations of the results are:

1. Sandy loams of the Sunraysia region have reasonable soil potassium levels to grow a tree and produce a reasonable crop of fruit. Annual maintenance applications of approximately 50 kg/ha of potassium may produce a fruit size response of approximately 2 mm. A 2 mm fruit size increase provides a positive cost benefit analysis in low to high fruit price years. Seasonal fertiliser rates should be adjusted to suit crop levels and site specific circumstances.

2. The use of foliar potassium sprays is questionable if there is adequate ground application. A school of thought suggests that potassium sprays are best targeted on high yielding years where there is a high fruit demand for potassium. However the Deakin foliar site had a yield of 86 T/ha and no response was detected. All other foliar potassium sites had low to moderate yields. More trials conducted on high yield scenarios would be required to provide a greater insight.
3. The use of foliar potassium is probably unnecessary in a low yielding year when fruit size will naturally be large. It can also increase the degree of rind coarseness in a low yielding year. In most seasons a low crop yield can be detected in early December with ample opportunity to reduce or eliminate potassium and adjust other fertiliser inputs accordingly.

2. Hand pruning and crop regulation

Introduction

Hand Pruning

Pruning is promoted as a cultural practice to obtain larger and cleaner fruit. (Krajewski, 1996; Morales, et al. 2000). Although widely adopted, research is not extensive in navel oranges. Some research reports indicate no benefits of hand pruning (Kallsen, 2005) whilst others report benefits (Bevington et al. 2000). Pruning is also expensive and no information is available on its cost benefit.

Flower GA

The use of Gibberelic acid (GA) at flowering has been tested since the 1950's in Florida to increase fruit set (Hield et al. 1958). This early work was unable to achieve a consistent response in Valencia and navel oranges (Davies, 1997), however responses were achieved when a potassium form of GA was applied at 250ppm (up to 1000ppm) onto isolated branches. Krezdorn (1973) reported that when GA was applied at high rates at flowering to whole trees, no responses were detected. Some trees were also damaged by the high rates of GA. The maximum rate of GA application in Australia is 20 ppm, a 250 ppm rate would be cost inhibitive. Agusti et al, (1982) reported no response when spraying GA at flowering on late Navel oranges. Eman et al. (2007) reported a significant response when applying GA at 10-20 ppm at flowering and at the end of early summer fruit set to Washington Navel orange trees and a similar response when applying chelated Zinc alone or with GA. Recent studies indicate that an increase in yield and fruit size can be achieved when Valencia trees are sprayed with a 15 or 25 ppm rate of GA (Bagdady et al. 2014).

Other varieties have reported a response with flowering GA. A flowering GA trial conducted in the Riverina, Australia, on midnight Valencia have reported a significant response (unpublished: A.Creek NSW DPI) and similar reports are received from South African growers.

Hand thinning

Hand thinning is commonly practised in Queensland on selected mandarin varieties but rarely used for navel oranges. Crop thinning has been extensively studied around the world, mainly focussing on chemical thinning of mandarins (Gardiola and Garcia-Luis, 1998; Gardiola and Garcia-Luis, 2000). Bevington and Khurshid (2002) demonstrated that thinning navel oranges down to 6 fruit per 50 cm quadrat increased net income. Thinning is generally recommended when a high crop load occurs (Falivene and Hardy, 2008). One reason why thinning, and other crop regulation practices, are uncommon for navels in Australia is that in most years mid and late season navels set under 6 fruit per 50 cm quadrat, however some early navel varieties are more prone the biennial bearing and may benefit from crop regulation (Chislett developments, 2015).

Winter GA

The application of gibberellic acid (GA) during winter can affect the flowering of citrus (Gardiola et al. 1982). It can reduce the level of flowering and most importantly increase the ratio of leafy inflorescence (inflorescence with few flowers and numerous leaves) that bear good quality large fruit to white blossom or leafless inflorescence (many flowers and no or very few leaves) that bear small fruit. Trials conducted in Australia have demonstrated a good response in Navelina, however a mixed response with Washington navel orange (Khurshid, 2005).

Trials occurred at six sites;

1. Ethrel® thinning & Corasil® fruit size: Grant & Carmel Carey
2. Hand pruning: Simonetta Farms
3. Afourer hand thinning and pruning trial: Seven Fields
4. Hand pruning: Ellerslie Citrus
5. Hand thinning & winter GA: Keenan Partners
6. GA flower set spray: Cross Farms

2.1 Ethrel® thinning & Corasil® fruit size: Grant & Carmel Carey

Background

Property managers: Grant & Carmel Carey

The trial site is a block of Barnfield navel oranges reworked in 2005 from Murcott mandarins on citrange rootstock at a planting density of 1196 trees/ha and irrigated by drip irrigation.

Figure 16: Grant & Carmel Carey Corasil® and Ethrel® spray trial site.

Method

The trial was a randomised complete block design (RCBD) with 4 replicates and 4 treatments. Each treatment comprised of twelve trees with two buffer trees in between treatments.

The treatments were:

1. Control
2. One application of Corasil® : Fruit size enhancing growth regulator
3. One application of Ethrel® : Crop thinning growth regulator
4. One application of Corasil® and Ethrel®

Ethrel® was sprayed on the morning of the 22 of November 2010 when the average fruit size was approximately 13mm at a rate of 50ml/100L of water. The trees were sprayed to the commencement of leaf drip.

The Corasil® treated trees were sprayed on the morning of the 10th of December when fruit size was 28mm at a rate of 200ml/100L with Li700® wetter at a rate of 30ml/100L. The trees were sprayed with an airblast spray machine.

Results

There was no significant difference in fruit size and yield (Table 29) at the 5% level of significance.

2011 G & C Carey Corasil® and Ethrel® spray trial results				
Category	**Treatments**			
	Control	**Corasil®**	**Ethrel®**	**Corasil® & Ethrel®**
Average fruit size mm	82.7	83.9	81.4	83.1
% fruit 0-75 mm	11.6%	9.1%	16.0%	11.4%
% fruit 75+ mm	88.4%	91.0%	84.1%	88.6%
Yield T/ha	51.6	43.6	45.9	51.3

Table 29: 2011 G & C Carey Corasil® and Ethrel® spray trial average fruit size, percentage fruit size distribution above and below 75 mm fruit diameter and yield. (Different letters on columns indicate a statistical difference at the 5% level)

2.2 Hand pruning: Simonetta Farms

Background

Property managers: Tony Simonetta & Geoff Brown

The trial site is a block of Barnfield navel oranges planted in 1991 on citrange rootstock at a planting density of 539 trees/ha irrigated by drip irrigation. The trees were approximately 2 m tall, previously had very minor pruning and had a significant amount of dead wood within the canopy. The pruning trial was conducted over three seasons; 2010 to 2013.

Method

The trial was a randomised complete block design (RCBD) with 12 single tree replicates and a buffer tree between plots. The trees were pruned after harvest on the 15/12/10, 16/9/11 and 15/11/12. Trials were harvested on 16/9/11, 5/11/12 and 22/8/13

Pruning targeted deadwood and unproductive branches using Electrocoup electric shears. Pruning conducted in 2010 took an average of 3.3 min/ tree, in 2012 1.21 min/tree and 1.6 min/ tree in 2013. In 2010, 10 to 12 cuts were made to each tree. In following season 5-6 cuts were made per tree.

The cost of pruning assumed a labour rate of $25 /hour, electric shears at $5 /hr and the time was increased by 25% to account for breaks and fatigue. The 2012 season pruning cost was $337 /ha or $0.63 /tree. Mulching prunings was estimated to take 3 hours per ha with a medium PTO mulching implement (wood up to 40 mm diameter) at a cost of $195 /ha or $0.36 per tree (labour @ $25 /hr and machinery @ $40 /hr). Total cost of pruning was $532 /ha or $0.99 /tree.

Figure 16: Pruning trees with Electrocoup electric shears.

Figure 17: Simonetta Farms pruning trial site.

Results

There was no significant difference in fruit size or yield for 2011 (Table 30). The lack of results in the first season is expected because pruning normally takes a season or more to produce results. Pruning promotes the production of new shoots that produces higher quality larger fruit in the following season. There was a significant difference (1% level of significance) in fruit size in 2012, but no significant difference in yield (Table 31). There was no significant difference in fruit size or yield for 2013 (Table 32). 2013 had a very low yield (5T/ha) across all treatments and fruit size for control and treated was naturally very large.

2011 Simonetta Farms pruning trial results		
Category	**Treatment**	
	Control	**Prune**
Average fruit size mm	75.1	75.5
% fruit 0-75 mm	48.7%	46.8%
% fruit 75+ mm	51.4%	53.2%
Yield T/ha	38.1	33.1

Table 30: 2011 Simonetta Farms pruning trial average fruit size, percentage fruit size distribution above and below 75 mm fruit diameter and yield. (Different letters on columns indicate a statistical difference at the 5% level)

2012 Simonetta Farms pruning trial results		
Category	**Treatment**	
	Control	**Prune**
Average fruit size mm	77.8 a	81.5 b
% fruit 0-75 mm	35.6% a	15.4% b
% fruit 75+ mm	64.4% a	84.7% b
Yield T/ha	30.5	25.9

Table 31: 2012 Simonetta Farms pruning trial average fruit size, percentage fruit size distribution above and below 75 mm fruit diameter and yield. (Different letters on columns indicate a statistical difference at the 5% level)

2013 Simonetta Farms pruning trial results		
Category	**Treatment**	
	Control	**Prune**
Average fruit size mm	88.7	87.2
% fruit 0-75 mm	4.5%	3.1%
% fruit 75+ mm	95.5%	96.9%
Yield T/ha	4.9	4.5

Table 32: 2013 Simonetta Farms pruning trial average fruit size, percentage fruit size distribution above and below 75 mm fruit diameter and yield. (Different letters on columns indicate a statistical difference at the 5% level)

The 2012 cost benefit analysis demonstrates a net gain of approximately $520 for medium and high price scenarios whilst the low price scenario was approximately $150 (Figure 18). This cost benefit analysis assumed there was no yield difference between control and prune treatments.

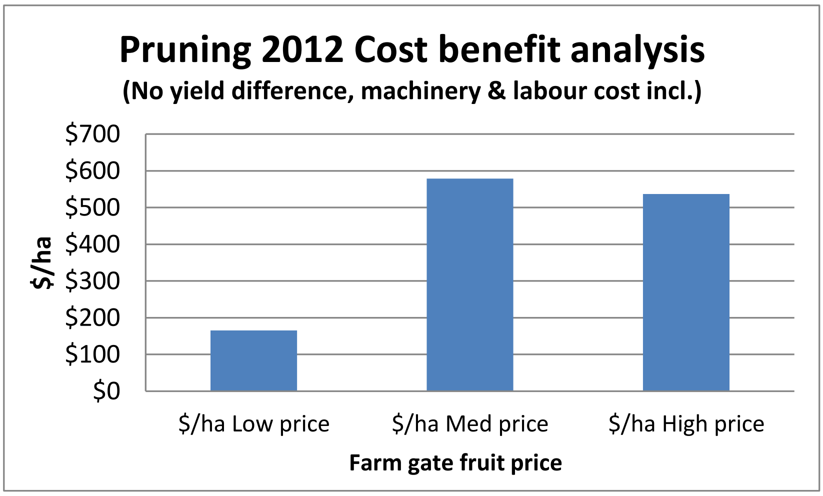

Figure 18 : 2012 Simonetta Farms pruning trial cost:benefit analysis of applying pruning including the cost of product, harvest, machinery and labour. Same yield for control and pruned treatments.

The 2012 data indicated a 16% yield reduction trend in the pruning treatment, however this was not statistically different. The slight yield reduction concurs with the reduction of flower sites from pruning. For demonstrative purposes the cost benefit analysis has been recalculated with the 16% decrease in yield for the 2012 pruning treatment. A net loss occurs at all fruit price scenarios with the highest loss occurring at the highest fruit price (Figure 19).

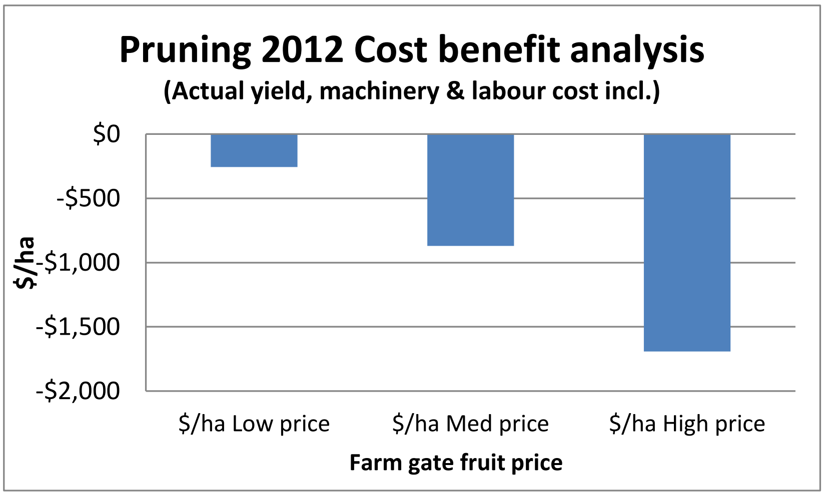

Figure 19 : 2012 Simonetta Farms pruning trial cost:benefit analysis of pruning including the cost of product, harvest, machinery and labour and a 16% decrease in yield.

District observations suggest that pruning reduces fruit blemish by approximately 10% and thereby increases the packout of first grade fruit. For demonstrative purposes the percentage first grade packout was increased from 55% to 65% to the previous cost benefit analysis scenario (16% yield reduction included). The 10% increase first grade packout scenario results

(Figure 20) indicate a $300-$430 net gain for the low to medium fruit price scenario whilst a breakeven for the high fruit price scenario.

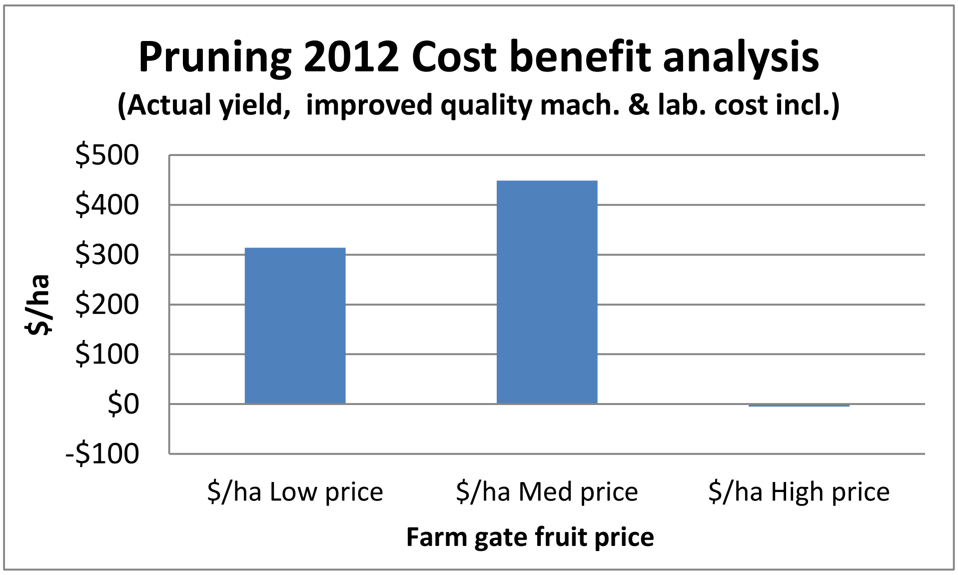

Figure 20 : 2012 Simonetta Farms pruning trial cost:benefit analysis of pruning including the cost of product, harvest, machinery and labour, a 16% decrease in yield and a 10% increase in first grade packout.

District observations suggest that yield recovers after a number of years so the following cost benefit analysis assumes that there is no difference in yield between control and pruned and a 10% increase of first grade packout. The results (Figure 21) indicate a positive net gain over all fruit price scenarios.

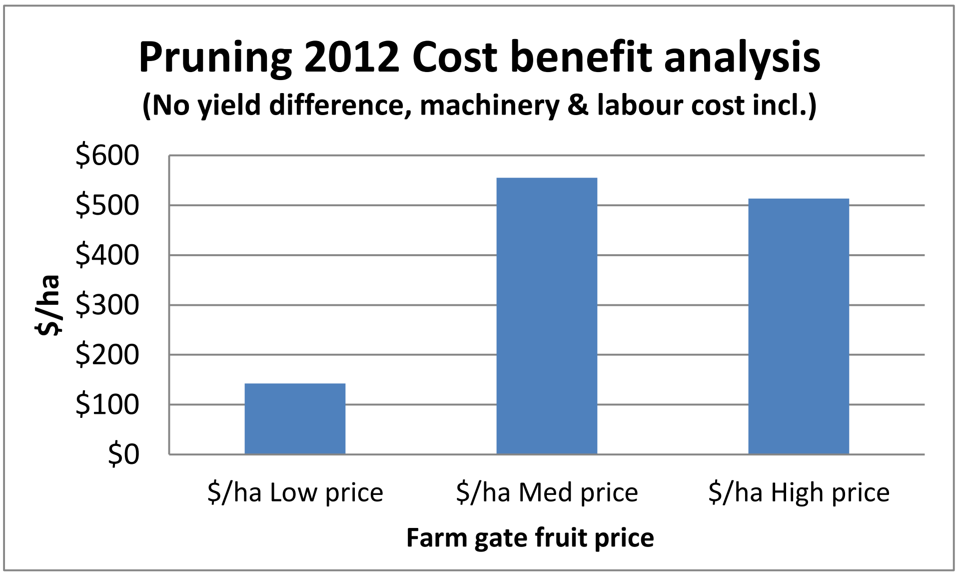

Figure 21 : 2012 Simonetta Farms pruning trial cost:benefit analysis of pruning including the cost of product, harvest, machinery and labour, no yield difference and a 10% increase in first grade packout.

2.3 Hand thinning and hand pruning trial - Afourer: Seven Fields

Background

Property managers: Richard Byllaardt, Thomas Braybrook and David Stevens

The trial site is a block of Afourer mandarins planted in 2005 on mounds on Cleopatra rootstock at a planting density of 539 trees/ha and irrigated by drip irrigation (Figure 22). A thinning and pruning trial was conducted over two seasons 2011 - 2013.

Figure 22: Seven Fields thinning and pruning trial site.

Method

The trial was a randomised complete block design (RCBD) with three treatments and 10 single tree replicates per treatment. Thinning and pruning dates, average times and average fruit numbers removed are presented in Table 33.

2012-12 Seven Fields thinning and pruning trial						
	Thin (per tree)		**Prune (per tree)**		**Av. Fruit size**	**Av. yield T/ha**
Date	**Av. time Min**	**Av. fruit No. removed**	**Av. time Min**	**Av. fruit No. removed**		
31/01/12	6.2	152	2.2	147	32	47
7/01/13	9.2	229	2.9	271	24.8	66

Table 33: 2012 Seven Fields per tree pruning & thinning time taken to implement treatments, fruit removed, average fruit size at implementing treatment and final average yield at harvest of all treatments.

Trials were harvested on 14/8/12 and 8/8/13.The block had an annual pruning program that targeted major limbs and branches. The supplementary pruning conducted in the trial targeted small branches up to 10 mm in diameter carrying clusters of fruit as a method to quickly remove large numbers of fruit. Pruning was conducted using Electrocoup electric shears (Figure 23).

Figure 23: Prunings from a 2012 pruned Afourer tree at the Seven Fields thinning and pruning trial site.

Hand thinning targeted blemished and small fruit (Figure 24). Fruit was also spaced at approximately a hand span apart. However small clusters of 2-3 fruit were often not thinned if they had good size, no blemish and the remaining branch did not have an excessive number of fruit.

Figure 24: Sample of thinned fruit in 2012 from the Seven Fields Afourer thinning and pruning trial site. Two fruit on the left are blemished and two fruit on the right are too small.

The cost of pruning and thinning assumed a labour rate of $25 /hour, electric shears at $5 /hr and the time was increased by 25% to account for breaks and fatigue. For the 2012 season the cost of pruning was $765 /ha or $1.38 /tree. Mulching prunings was estimated to take 2 hours per ha with a slashing or light mulching implement (wood 10 mm diameter) at a cost of $110 /ha or $0.36 per tree (labour @ $25 /hr and machinery @ $30 /hr). Total cost of pruning was $875 /ha or $1.62 /tree. For the 2012 season the cost of thinning was $2,155 /ha or $4 /tree.

Results

There was a significant difference in fruit size 2012 at 1% level of significance, but no significant difference in yield at the 5% level of significance. There was no significant difference in fruit size and yield in 2013 at 5%.

2012 Seven Fields Afourer pruning & thinning trial results			
Category	Treatments		
	Control	Thin	Prune
Average fruit size mm	60.7 a	63.1 b	61.9 a
% fruit 0-60 mm	45.5% a	29.1% b	38.8% a
% fruit 60+ mm	54.7% a	71.1% b	61.2% a
Yield T/ha	49.3	44.8	46.8
Est. fruit numbers per tree	753	622	689

Table 34: 2012 Seven Fields pruning & thinning trial average fruit size, percentage fruit size distribution above and below 60 mm fruit diameter, yield and estimated fruit numbers at harvest. (Different letters on columns indicate a statistical difference at the 1% level)

2013 Seven Fields Afourer pruning & thinning trial results			
Category	Treatments		
	Control	Thin	Prune
Average fruit size mm	59.3	59.5	60.5
% fruit 0-60 mm	53.4%	55.5%	48.7%
% fruit 60+ mm	46.7%	44.6%	51.4%
Yield T/ha	68.9	69.3	59.9
Est. fruit numbers per tree	1166	1126	911

Table 35: 2013 Seven Fields pruning & thinning trial average fruit size, percentage fruit size distribution above and below 60 mm fruit diameter, yield and estimated fruit numbers at harvest. (Different letters on columns indicate a statistical difference at the 5% level)

Significant differences in fruit size occurred in 2012, but not in 2013. Twenty percent of fruit were hand thinned in 2012 and 17% in 2013, similar amounts.

However yield in 2012 was moderate at approximately 47 T/ha (621 fruit/tree) whilst higher in 2013 at approximately 67 T/ha (1126 fruit/tree). Thinning and pruning to reduce crop load is commonly recommended for high crop load situations. Possibly a higher degree of thinning was required for the higher yield situation of 2013, but this probably would have been at the expense of yield.

Crop thinning is reported to increase yield in the following season of a high yield year because the tree has less crop load stress. Unfortunately the projects ceased at the end of 2013 and no data is available for the 2014 harvest. There could be other unknown factors (i.e. varietal, climatic or physiological) that influence the success of thinning or pruning practices.

A cost benefit analysis of 2012 results demonstrates a significant net gain for both pruning and thinning treatments (Figure 25). However this data allocates the average yield of 47 T/ha to all treatments.

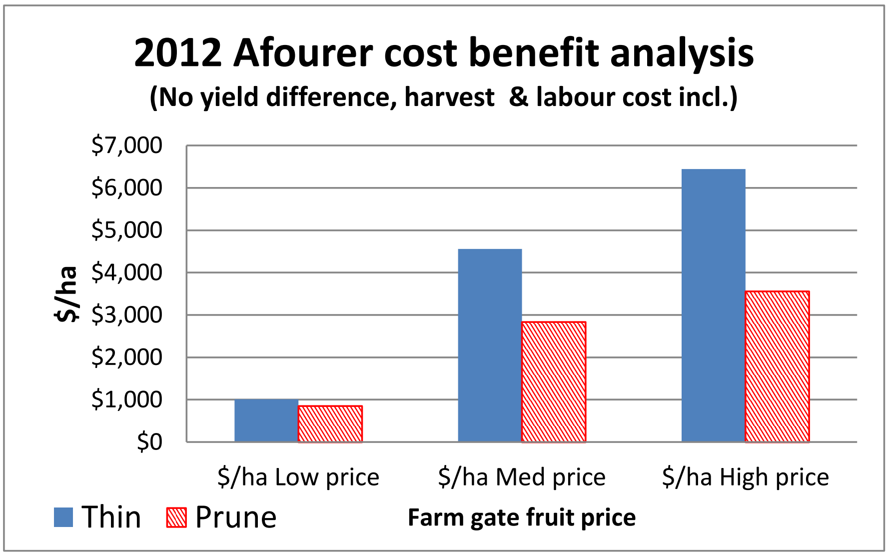

Figure 25 : 2012 Seven Fields pruning & thinning trial cost:benefit analysis including the cost of product, harvest, machinery and labour. The scenario assumes no difference in yield across all treatment.

For demonstrative purposes a cost benefit analysis was conducted using actual yield data from the trial (Figure 26). Yield reductions were approximately 10% for thinning treatments and 7% for pruning treatments. It is interesting to note that in 2012 fruit numbers were reduced by approximately 17% in the hand thinning treatment and yet it reduced yield only by 9%. An increase in fruit size would increase the weight of fruit and subsequent yield. The cost benefit analysis indicates that all pruning treatments would provide a net loss and thinning treatments indicated a marginal net gain for medium and high price scenarios.

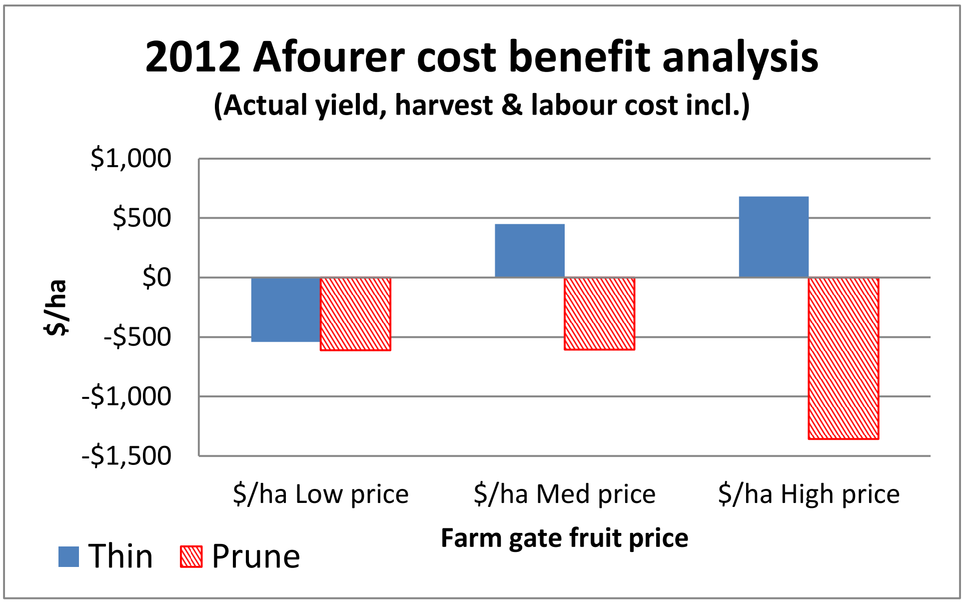

Figure 26 : 2012 Seven Fields pruning & thinning trial cost:benefit analysis including the cost of product, harvest, machinery and labour. The scenario uses actual yield data for all treatments.

Thinning increases the percentage of first-grade fruit because highly blemished fruit is targeted for removal. Another cost benefit analysis is presented that uses actual yield and increases the percentage of first-grade fruit by 5% (Figure 27). This slight change provides a very positive net return for high and medium priced fruit scenarios.

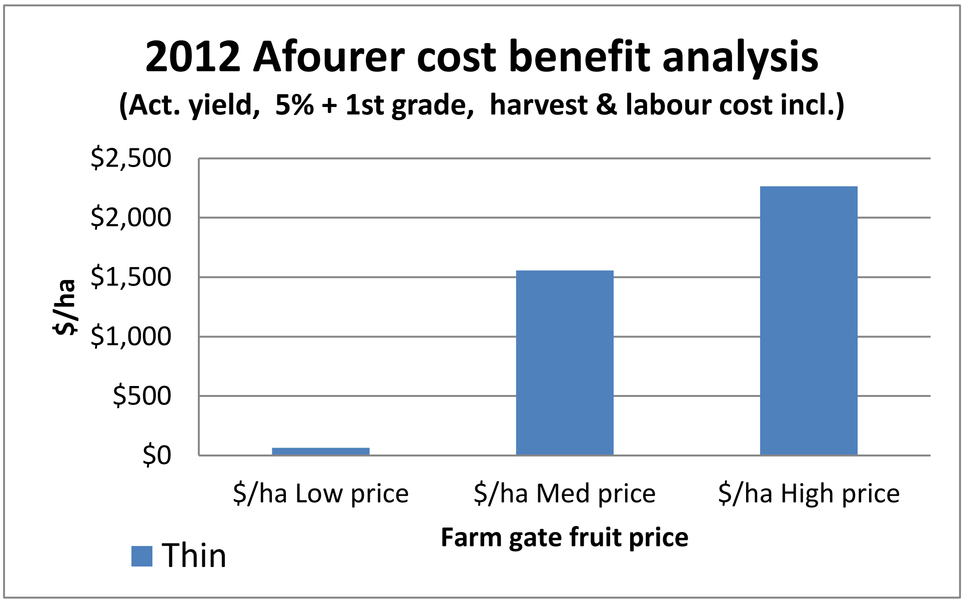

Figure 27 : 2012 Seven Fields pruning & thinning trial cost:benefit analysis including the cost of product, harvest, machinery and labour. Only thinning is presented. The scenario uses actual yield data and increased first-grade fruit packout by 5%.

2.4 Hand pruning: Ellerslie North Citrus

Background

Property manager: David Stevens

The trial site was a block of Scopoletti navel oranges planted in the1950's on sweet orange rootstock at a planting density of 253 trees/ha irrigated by sprinkler irrigation. A pruning trial was conducted over the 2010-11 season.

Figure 28: Prunings from a 2010 pruned Scopoletti navel tree at the Ellerslie Citrus pruning trial site.

Method

The trial was a randomised complete block design (RCBD) with two treatments, 13 replicates and single tree plots. The trees had a history of pruning however they had not been pruned for approximately 3 years and had a congestion of large branches.

The trees were pruned after harvest on the 17/12/10. Pruning aimed to open up the canopy with multiple cuts of large branches using Electrocoup electric saw (Figure 28). Pruning took an average of 4.1 min/ tree.

The cost of pruning assumed a labour rate of $25 /hour, electric shears at $5 /hr and the time was increased by 25% to account for breaks and fatigue. The cost of pruning was $648 /ha or $2.56 /tree. Mulching prunings was estimated to take 3 hours per ha with a medium mulching PTO implement (wood up to 40 mm diameter) at a cost of $195 /ha or $0.77 per tree (labour @ $25 /hr and machinery @ $40 /hr). Total cost of pruning was $843 /ha or $3.33 /tree.

The trial was harvested on 26/7/11.

Results

There was no significant difference in fruit size and yield at the 5% level of significance (Table 36). Unfortunately due to farm restructuring, the trees were removed in the following season.

2010 Ellerslie Citrus pruning trial results		
Category	**Treatment**	
	Control	**Prune**
Average fruit size mm	72.8	73.7
% fruit 0-75 mm	64.3%	60.6%
% fruit 75+ mm	35.7%	39.5%
Yield T/ha	23.1	24.1

Table 36: 2010 Ellerslie Citrus pruning trial average fruit size, percentage fruit size distribution above and below 75 mm fruit diameter and yield. (Different letters on columns indicate a statistical difference at the 5% level)

2.5 Hand thinning and winter GA flower thinning: Keenan Partners

Background

Property manager: Michael Keenan

The trial site is a block of Keenan Valencia planted in 1962 on sweet orange rootstock that were reworked in 2001 to Cupper Navels. The planting density was 452 trees/ha and it was irrigated by under tree sprinkler irrigation (Figure 29). A hand thinning and winter GA flower thinning trial was conducted over the 2012-13 season.

Figure 29: Hand thinning at the Keenan crop regulation trial site.

Method

The trial was a randomised complete block design (RCBD) with three treatments, seven replicates and single tree plots. The trees were pruned and thinned after harvest.

Ralex® is a registered form of gibberellic acid used for flower manipulation of citrus. Ralex® was sprayed onto trees on 2/8/12 a rate of 150 ml / 100L and a water volume of approximately 3500 L/ha. The cost of Ralex® and its application (labour and machinery) was approximately $673/ha. At the time of spraying the top 3 to 4 terminal buds of shoots had already sprouted. The lower buds were in the early stages of bud break (Figure 30). Research indicates that buds that have expanded more than 1.5 mm are no longer sensitive to the flower manipulation effects of GA (Gardiola et al. 1982). At least 50% of buds (top of shoot) had a ready past the 1.5 mm stage and there were concerns that the spray timing was too late.

Figure 30: An example of the bud break stage of shoots at the Keenan crop regulation trial site at the time of Ralex® application. Left: whole shoot, middle: top/terminal bud, Right: lower buds.

Hand thinning occurred on 29/01/13 and targeted blemished and small fruit. Average fruit diameter at thinning was 49.3 mm. On average 73 fruit per tree were removed at an average time of 4.4 min/tree. The control trees were estimated to be carrying approximately 530 fruit per tree. Fruit was also spaced at approximately a hand span apart. However small clusters of 2-3 fruit were often not thinned if they had good size, no blemish and the remaining branch did not have an excessive number of fruit (Figure 31).

Figure 31 : A sample of fruit thinned on the 29/01/12 in the 2012 Keenan crop regulation trial.

The cost of thinning assumed a labour rate of $25 /hour and the time was increased by 25% to account for breaks and fatigue. For the 2012 season the cost of thinning was $1,036 /ha or $2.29 /tree.

The trial plot was accidently harvested in July prior to yield measurements being taken. Prior to harvest (24/5/13) six frame counts per tree (50 cm frame) were measured for the purpose of conducting a preliminary yield assessment. This frame count data was used to estimate yield to calculate the demonstrative cost benefit analysis. Estimated yield (kg/ha) reductions for the Ralex® and thinning treatments were reduced by 50% to account for the effect of larger size fruit increasing the fruit weight and yield.

Results

There was no significant difference in fruit size and yield at the 5% level of significance (Table 37). However the level of significance for the average fruit size data was very close to significance at 5.9%. Ralex® and hand thinning demonstrated a trend of approximately a 3 mm increase in fruit size.

2013 Keenan crop regulation trial results			
Category	Treatments		
	Control	Ralex®	Hand thin
Average fruit size mm	70.7	73.7	73.0
% fruit 0-75 mm	77.0%	59.0%	67.0%
% fruit 75+ mm	23.1%	41.1%	33.4%
Frame counts (May 2013)	5.6	4.6	4.2
Estimated yield T/ha	40.0	35.8	34.3
Est. fruit numbers per tree	527	418	416

Table 37: 2013 Keenan crop regulation trial average fruit size, percentage fruit size distribution above and below 75 mm fruit diameter, yield and estimated fruit numbers at harvest. Yield and fruit numbers are extrapolated from frame count data. (Different letters on columns indicate a statistical difference at the 5% level)

Although the data was not statistically different it presented a plausible scenario. For demonstrative purposes a cost benefit analysis was conducted using this data. The cost benefit analysis presented in Figure 32 assumes the same yield of 40 T/ha for all treatments. A net financial gain of $1000 to $2000 is achieved for the medium and high price scenarios for both treatments. At the low price scenario Ralex® provides a $490 gain whilst hand thinning provides minor loss.

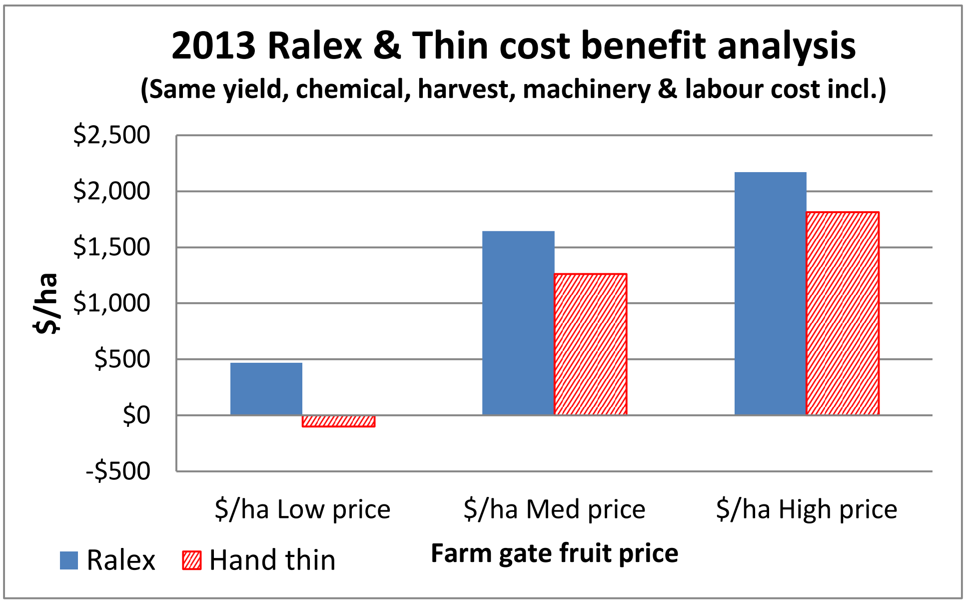

Figure 32 : 2013 Keenan crop regulation trial cost:benefit analysis including the cost of product, harvest, machinery and labour. The scenario assumes the same yield for all treatments.

Yield loss would be expected in the treatments so the cost benefit analysis was repeated using the estimated yield data (Figure 33). This cost benefit analysis presents a net loss for hand thinning at all price scenarios. Ralex® provides an approximate $200, $400 and $600 net gain respectively for the low, medium and high price scenarios.

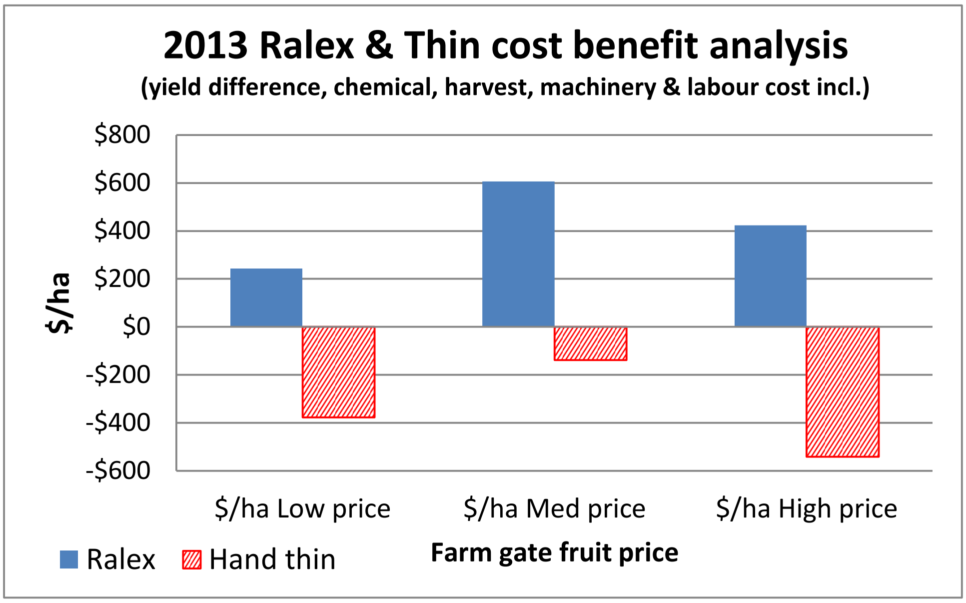

Figure 33 : 2013 Keenan crop regulation trial cost:benefit analysis including the cost of product, harvest, machinery and labour. The scenario uses yield data extrapolated from frame count data.

2.6 GA Flower set spray: Cross Farms

Background

Property managers: Sam Cross and Justin Kasulke

The trial site was a block of Chislet navels planted in 1999 on trifoliata rootstock (Figure 34). The planting density was 429 trees/ha and it was irrigated by drip irrigation. A gibberellic acid (GA) flower setting trial was conducted over the 2011-12 season.

Figure 34: Cross Farms GA flower set spray trial site at full bloom.

Method

A 10 ppm mixture of GA was applied to trees at full bloom (Figure 35) on the 4/10/11 and also at approximately 95% petal fall (Figure 36) on the 17/10/11. Trees were sprayed to leaf drip, and an average of 3.75 L of spray mixture was applied to each treated tree. Four frame count (50 cm frame) measurements per tree (a measurement at each quadrant of the tree) were conducted on 12/04/12. The trial was a randomised complete block design (RCBD) with two treatments, sixteen replicates and single tree plots.

Figure 35: Full bloom (4/10/11) at Cross Farms GA flower set spray trial site.

Figure 36: Ninety five percent petal fall (17/10/11) at Cross Farms GA flower set spray trial site.

Results

There was no significant difference in fruit size and yield at the 5% (Table 37).

2012 Cross Farms GA flower set spray trial results		
Category	Treatments	
	Control	GA
Average fruit size mm	77.5	76.9
% fruit 0-75 mm	34.8%	37.9%
% fruit 75+ mm	65.3%	62.4%
Yield T/ha	31.3	29.8

Table 38: 2012 Cross Farms GA flower set spray trial average fruit size, percentage fruit size distribution above and below 75 mm fruit diameter and yield. (Different letters on columns indicate a statistical difference at the 5% level)

Discussion: hand pruning and crop regulation

Navel pruning

The hand pruning results are consistent with grower field observations. No differences were detected in the first year because pruned trees need at least a season to grow new shoots that will bear larger and less blemished fruit. Differences in fruit size were observed in the second year. Differences were not observed in the third year and this is due to the extremely low yield in all treatments. In low yield situations all fruit regardless of treatments will be large.

The cost benefit analysis indicated that yield and blemish/packout can have a major impact on net profit. Incorporating a 16% yield loss provided negative net returns however incorporating a 10% increase in packout provided positive net returns. District observations suggest that after 3 to 4 seasons of annual pruning the yield recovers and sometimes increases. In a no yield loss cost benefit scenario, there is considerable gain in net returns across all fruit price scenarios and this is possibly why there is good adoption of pruning in the southern regions of Australia.

The cost of pruning is an important factor and the trial implemented pruning strategies to maintain cost at industry levels of approximately one dollar per tree (maintenance pruning). It is best to conduct pruning trials for at least five years to better balance seasonal effects on yield.

Afourer supplementary hand pruning

The pruning conducted in the Afourer mandarin pruning trial was not regular structural pruning, but supplementary crop thinning pruning. This type of pruning is not used by industry. The data indicated it had no beneficial effect within the two seasons of trials.

Hand thinning

Hand thinning navels is a very rare practice because district experience has not been able to demonstrate a profitable result. Mid to late season navels set medium to low crop loads in most seasons. They only occasionally set excessive crop loads that may require crop manipulation. It is also often very difficult to predict yield of navels because of the effect that climate and other unknown factors can have on fruit set during spring and early summer. The yield of the navel hand thinning trial was approximately 40 T/ha, this is an average yield. The hand thinning trial cost benefit analysis demonstrated a net loss in returns.

Hand thinning is commonly used on a number of mandarin varieties. Reasons for hand thinning some mandarin varieties include:

- Some mandarin varieties set high crop loads each season and thinning is required to produce fruit in the desired size range. If thinning is not conducted the majority of the crop will be too small returning very poor prices and/or unmarketable fruit.
- Mandarins are a high value crop and producing high-quality blemish free fruit significantly elevates prices. The cost of throwing blemished unmarketable fruit to the ground can be cheaper than harvesting and processing fruit in the packing house. Unfortunately the cost of processing unmarketable fruit in the packing house is generally not fully reflected in farm gate prices. The returns of high quality fruit are sometimes used to buffer the prices of lower quality fruit. In principle unmarketable fruit should incur a penalty. This could be adopted by charging growers a per ton fruit processing fee and a fee to dump unmarketable fruit. This fee is offset by sale of packed fruit. Growers that packed their own fruit fully account for the costs of unmarketable fruit. If the cost of unmarketable fruit is better reflected in both navel and mandarin prices this could drive improved production practices that can improve fruit quality.

Hand thinning of Afourer mandarin is generally not conducted in the southern growing regions because it is perceived that Afourer mandarin consistently produces fruit within a marketable size range, even in high crop load years. Surprisingly trial results indicate a gain in net returns. The trial was conducted over two years and further investigations are required to validate if the positive results experienced in the trial can be repeated over a number of years.

Ethrel®

It is difficult to interpret results of the Carey crop regulation trial because there were a couple of problems with the trial. When fruit size is naturally large it is difficult to obtain further increases in fruit size from improved production practices. The young trees and light crop load contributed to the large fruit size experienced in the trial. The trial had four replicates per treatment and 12 trees per plot. Natural variation may have masked a response, in hindsight reducing the tree plot numbers and increasing replication might have provided a better result. This trial layout was originally chosen so fruit could be harvested into commercial bins and assessed through the packing house. As discussed in the methodology, the packing house assessment of trial fruit is complicated and risky. The experience from this trial instigated the use of single tree plots with a higher level of replication in all future trials.

Winter GA

Although the trial did not produce a statistically significant result at the 5% level of significance, a trend of larger fruit size was detected at the 5.9% level of significance. This trend was consistent with previous research (Khurshid, 2005). The positive trend was surprising because it was thought that the spray timing was too late. Further work needs to be conducted on bud break spray timing.

There is significant industry benefit in the use of winter gibberellic acid (GA) for targeted situations. Growers are hesitant to use Ralex® because of the cost and lack of local experience. The cost could be reduced by examining cheaper forms of GA and the lack of local experience could be overcome by conducting more on-farm trials (build industry capacity of winter GA use technology).

GA fruit setting spray

The lack of response supports previous work (Hield et al. 1958; Davies, 1997) indicating the inconsistency and/or ineffectiveness of gibberellic acid (GA) as a fruit setting spray for Washington navel. However recent research from Eman et al. (2007) and Bagdady et al. (2014) demonstrate great promise. A single trial in one season is not sufficient to disregard the use of GA as a fruit setting spray for mid and late season navel oranges. More trials need to be conducted in different situations.

3. Tree growth enhancement sprays

Introduction

Bio stimulant sprays

Branch-it® (Spray Gro) and Brotomax® (Agrometodos) are classified as nutrient sprays however their raw materials include organic extracts (i.e. Kelp). Some claim that these organic raw materials contain a variety of natural hormones, growth stimulants and stress reducing compounds that improve the growth of plants.

Kaolin clay

Kaolin clay products have been promoted as enhancing tree growth (Agnova, 2015). Trial work and photos from research conducted in Florida is sometimes used in presentations that show large differences in tree size between treated and untreated trees (Lapointe, et. Al., 2006 and Agnova., 2015).

Four trials were conducted at two sites;

1. Nutrient tree growth enhancing spray – M7 and blood orange: Keenan Partners
2. Kaolin tree growth enhancing spray- Navel and Imperial mandarins: Keenan Partners

3.1 Nutrient tree growth enhancing spray: Keenan Partners

Background

Property manager: Michael Keenan

The trial was implemented on young non-bearing M7 navels and Blood oranges that were planted in 2009 and 2008 respectively. Both sites were planted on Citrange rootstock at a planting density of 556 trees/ha (Figure 37 and Figure 38). The sites were irrigated by under tree sprinkler irrigation. A young tree growth enhancing spray trial was conducted over two seasons; 2010/11 and 2011/12.

Figure 37: Keenan Partners M7 tree growth enhancement trial January 2012.

Figure 38: Keenan Partners Blood orange tree growth enhancement trial January 2012.

Method

The trial was a randomised complete block design (RCBD) with four treatments, single tree plots and seven replicates for the Blood orange site and eight replicates for the M7 Navel site.

The three spray treatments were Branch-It®, Brotomax® and a custom mixture of nutrients in similar proportions to Branch-It®. The custom mixture was made by mixing 220 g urea, 24 g zinc sulphate, 24 g manganese sulphate, 70 g copper sulphate into one litre of water. This mixture was applied at the same rate as Branch-It® and Brotomax® at 300 ml per 100 L.

Four applications of treatment sprays occurred in both years

- 2010/2011 - 14/12/10; 30/12/10; 24/01/11; 16/02/11
- 2011/2012 - 4/11/11; 30/11/11; 30/12/2011;7/03/12

Tree height measurements were taken on 05/03/12. It was difficult to determine tree height because some trees had single shoots growing above the main canopy. These single shoots were ignored and measurements were taken to the top of the main canopy.

Tree butt diameter measurements were taken on the 22/12/10 and 05/03/12 as a method to better quantify possible differences in tree growth than tree height measurements. A faster and larger growing tree will have a larger tree butt.

The property owner, Michael Keenan, also assessed the general size of each trial tree on 13/1/12 using a rating system; 1 =small, 2 = small/medium tree, 3 = medium, 4 = medium/large and 5 = large. Before the trees were rated the smallest and largest trees in the trial were identified to provide a point of reference.

Initially there was some variation in tree size within the block. The trees may have experienced some occasional mild water stress during the drought in their first season which may have contributed to this variability. Therefore trees of a similar size were chosen for the trial.

Results

There was no significant difference for the Blood orange and M7 trials in butt diameter differences, tree height and grower tree growth assessment at 5% level of significance (Table 39 and Table 40).

2010-12 Keenan Partners Blood orange tree growth spray trial results				
Category	Treatments			
	Control	Brotomax®	Branch-It®	Custom
Butt diameter difference mm	20.3	17.8	19.5	20.4
Tree height m	2.1	1.8	2.1	1.8
Grower tree growth assessment	2.9	2.1	2.3	2.6

Table 39: 2010-12 Keenan Partners Blood orange tree growth spray trial butt diameter differences (22/12/2010 to 05/03/2012), tree height and grower tree growth assessment. (Different letters on columns indicate a statistical difference at the 5% level)

2010-12 Keenan Partners M7 navel tree growth spray trial results				
Category	Treatments			
	Control	Brotomax®	Branch-It®	Custom
Butt diameter difference mm	14.3	14.1	15.0	17.0
Tree height m	1.1	1.2	1.1	1.2
Grower tree growth assessment	1.9	2.3	1.6	2.5

Table 40: 2010-12 Keenan Partners M7 navel tree growth spray trial butt diameter differences (22/12/2010 to 05/03/2012), tree height and grower tree growth assessment. (Different letters on columns indicate a statistical difference at the 5% level)

3.2 Kaolin tree growth enhancing spray- Navel & Imp. mandarins: Keenan Partners

Background

Property managers: Michael Keenan

The trial was implemented on young non-bearing Fisher navels and Imperial mandarins that were planted in 2008 on Citrange rootstock at a planting density of 556 and 769 trees/ha respectively (Figure 39 and Figure 40). The sites were irrigated by under tree sprinkler irrigation. A young tree kaolin clay growth enhancing trial was conducted over two seasons; 2010/11 and 2011/12.

Figure 39: Keenan Partners Fisher navel Kaolin clay tree growth enhancement trial January 2012. The first tree is a Kaolin clay treated tree.

Method

The trial was a randomised complete block design (RCBD) with four treatments, 10 replicates and single tree plots.

The two spray treatments were Screen® and Surround®. All spray treatments were applied to runoff and Duwett® silicon spreader was added to all mixtures at a rate of 20 ml per 100 L. Screen® was applied at 2.5 kg per 100 L. Surround® was applied at 5 kg per 100 L for the first application of the season and then at 2.5 kg per 100 L thereafter.

Figure 40: Keenan Partners Imperial mandarin Kaolin clay tree growth enhancement trial January 2012. The far right tree is a Surround® treated tree and the tree to its left was treated by Screen®. Surround® treated trees looked whiter than Screen®. Screen® treated trees were a less prominent sandy beige colour.

Four applications of treatment sprays occurred in both years

- 2010/2011 - 14/12/10; 30/12/10; 18/01/11; 14/02/11
- 2011/12 - 12/12/11; 29/12/11; 12/01/11; 13/03/12

Tree height measurements were taken on 05/03/12. It was difficult to determine tree height because some trees had single shoots growing above the main canopy. These single shoots were ignored and measurements were taken to the top of the main canopy.

Tree butt diameter measurements were taken on the 22/12/10 and 05/03/12 as a method to better quantify possible differences in tree growth than tree height measurements. A faster and larger growing tree will have a larger tree butt.

The property owner, Michael Keenan, also assessed the general size of each trial tree on 13/1/12 using a rating system; 1 =small, 2 = small/medium tree, 3 = medium, 4 = medium/large and 5 = large. Before the trees were rated the smallest and largest trees in the trial were identified to provide a point of reference.

Initially there was some variation in tree size within the block. The trees may have experienced some occasional mild water stress during the drought in their first season which may have contributed to this variability. Therefore trees of a similar size were chosen for the trial.

Results

There was no significant difference for the Fisher navel and Imperial mandarin trials in butt diameter differences, tree height and grower tree growth assessment at 5% level of significance (Table 41 and Table 42).

2010-12 Keenan Partners Fisher navel Kaolin tree growth spray trial results			
Category	Treatments		
	Control	Screen®	Surround®
Butt diameter difference mm	16.9	17.4	17.3
Tree height m	1.92	1.96	1.79
Grower tree growth assessment	3.1	3.2	2.6

Table 41: 2010-12 Keenan Partners Fisher navel kaolin tree growth spray trial butt diameter differences (22/12/2010 to 05/03/2012), tree height and grower tree growth assessment. (Different letters on columns indicate a statistical difference at the 5% level)

2010-12 Keenan Partners Imperial mandarin Kaolin tree growth spray trial results			
Category	Treatments		
	Control	Screen®	Surround®
Butt diameter difference mm	25.0	22.6	21.9
Tree height m	2.48	2.5	2.51
Grower tree growth assessment	4.3	4.1	4.3

Table 42: 2010-12 Keenan Partners Imperial mandarin kaolin tree growth spray trial butt diameter differences (22/12/2010 to 05/03/2012), tree height and grower tree growth assessment. (Different letters on columns indicate a statistical difference at the 5% level)

Discussion: Tree growth enhancement sprays

Bio stimulant sprays

Growers have been reporting significant responses from using products like Branch-it® and Brotomax® to accelerate the growth of young trees and it is disappointing that none of the trials demonstrated a response. Some growers have tried these products and indicated that differences were visually obvious between sprayed and under sprayed rows.

Kaolin clay

The positive results from research conducted in Florida provided great hope and incentive for adoption in Australia (Lapointe et.al. 2006; Agnova 2015). Unfortunately project trials were not able to achieve a response. It is possible that the climate or other site specific circumstances (i.e. variety, rootstock, rainfall etc.) in Florida was conducive to a response, but not in the Sunraysia region.

Although there was no response with a bio stimulants or Kaolin clay products, growers are encouraged to continue trialling these products and contacting appropriate science-based development officers to observe, make notes and take photographs whether a response is detected or not. Recording a trial that has not provided a response is just as important as one that has.

4. Soil conditioner

Introduction

The benefits of increasing soil organic levels are widely publicised throughout literature (Lines-Kelly, 2001). A study by Crisp and Baker (2011) demonstrated that the application of organic soil amendments increased yield in citrus. The group were studying the effect of soil amendments on Thrip population; its effect on yield was an unintentional secondary outcome. A brochure was published indicating they were able to achieve 5-7 mm increases in fruit size and an increase of $4000 per hectare (Crisp and Baker, 2011). Crisp and Baker (2011) results generated grower interest for similar trials to be included in the project.

sleep

4.1 Moorello soil conditioner: Dougal Plumber

Background

Property managers: Dougal & Teresa Plumber

The trial was implemented on young Fisher navels planted in 2004 on Citrange rootstock at a planting density of 417 trees/ha (Figure 41). The site was irrigated by drip irrigation. A young tree soil conditioning trial was conducted over two seasons; 2011/12 and 2012/13.

Figure 41: Jeffries organic compost soil conditioner recently spread along the tree row at a rate of 10 T/ha at the Dougal Plumber trial site.

Method

Jeffries organic compost, provided by David Morello (Figure 42), was applied on 8/12/11 at a rate of 10 T/ha along the tree row, no compost was applied in the inter row (Figure 43). The cost of the compost in 2010 was $52 /T. Harvest occurred on the 7/6/12 and 17/6/13.

The trial was a randomised complete block design (RCBD) with two treatments, 12 replicates and single tree plots.

Figure 42: Close up of the Jeffries organic compost soil.

Figure 43: Close up of Jeffries organic compost soil conditioner recently spread along the tree row at a rate of 10 T/ha.

Results

There was no significant difference in fruit size and yield at 5% in 2012 (Table 43) and 2013 (Table 44).

2012 Dougal Plumber soil conditioner trial results		
Category	Treatments	
	Control	Conditioner
Average fruit size mm	74.4	75.5
% fruit 0-75 mm	51.5%	47.3%
% fruit 75+ mm	48.5%	52.7%
Yield T/ha	25.1	24.9

Table 43: 2012 Dougal Plumber soil conditioner trial average fruit size, percentage fruit size distribution above and below 75 mm fruit diameter and yield. (Different letters on columns indicate a statistical difference at the 5% level)

2013 Dougal Plumber soil conditioner trial results		
Category	Treatments	
	Control	Conditioner
Average fruit size mm	78.8	80.9
% fruit 0-75 mm	26.0%	17.7%
% fruit 75+ mm	74.0%	82.5%
Yield T/ha	10.1	7.9

Table 44: 2013 Dougal Plumber soil conditioner trial average fruit size, percentage fruit size distribution above and below 75 mm fruit diameter and yield. (Different letters on columns indicate a statistical difference at the 5% level)

4.2 Mangan soil conditioner: R & J Bertalli

Background

Property managers: Richard and Judy Bertalli

The trial was implemented on young Chislett navels planted in 1996 on Citrange rootstock at a planting density of 436 trees/ha (Figure 44). The site was irrigated by drip irrigation. A soil conditioning trial was conducted over two seasons; 2011/12 and 2012/13.

Figure 44: Bertalli trial site near harvest , July 2012.

Method

The trial was a randomised complete block design (RCBD) with two treatments, 12 replicates and single tree plots.

Mangan composted cow manure (Figure 45), was applied on 16/12/11 at a rate of 10 T/ha along the tree row, no compost was applied in the inter row. Harvest occurred on the 25/09/12 and 27/09/13.

Figure 45: Residue of Mangan composted cow manure at the Bertalli trial site eight months after application.

Results

There was no significant difference in fruit size and yield at 5% in 2012 (Table 45) and 2013 (Table 46).

2012 Bertalli soil conditioner trial results		
Category	Treatments	
	Control	Conditioner
Average fruit size mm	78.4	77.7
% fruit 0-75 mm	29.1%	31.7%
% fruit 75+ mm	70.9%	68.3%
Yield T/ha	45.5	42.6

Table 45: 2012 Bertalli soil conditioner trial average fruit size, percentage fruit size distribution above and below 75 mm fruit diameter and yield. (Different letters on columns indicate a statistical difference at the 5% level)

2013 Bertalli soil conditioner trial results		
Category	Treatments	
	Control	Conditioner
Average fruit size mm	86.7	86.3
% fruit 0-75 mm	3.8%	3.5%
% fruit 75+ mm	96.2%	96.5%
Yield T/ha	11.4	11.3

Table 46: 2013 Bertalli soil conditioner trial average fruit size, percentage fruit size distribution above and below 75 mm fruit diameter and yield. (Different letters on columns indicate a statistical difference at the 5% level)

4.3 Morello grape marc soil conditioner: Cross Farms

Background

Property managers: Sam Cross and Justin Kassulke

The trial was implemented on Summer Gold navels planted in 1996 on Trifoliata rootstock at a planting density of 661 trees/ha (Figure 46). The site was irrigated by drip irrigation. A young tree grape marc soil conditioning trial was conducted over the 2011-12 season.

Figure 46: Cross Farms Morello's Tarac Tech. Berri grape marc trial site near harvest.

Method

The trial was a randomised complete block design (RCBD) with two treatments, 16 replicates and single tree plots.

Morello's Tarac Tech. Berri grape marc (Figure 47), was applied on 19/12/11 at a rate of 10 T/ha along the tree row, no compost was applied in the inter row. The cost of the grape marc in 2011 was $33 /T. Harvest occurred on the 18/7/12.

Figure 47: Residue of Morello's Tarac Tech. Berri grape marc at the Cross Farms trial site eight months after application.

Results

There was no significant difference in fruit size and yield at the 5% level of significance in 2012 (Table 47).

2012 Cross Farms grape marc soil conditioner trial results		
Category	Treatments	
	Control	Conditioner
Average fruit size mm	76.5	75.6
% fruit 0-75 mm	37.7%	43.6%
% fruit 75+ mm	62.4%	56.4%
Yield T/ha	39.3	36.7

Table 47: 2012 Cross Farms grape marc soil conditioner trial average fruit size, percentage fruit size distribution above and below 75 mm fruit diameter and yield. (Different letters on columns indicate a statistical difference at the 5% level)

Discussion: Soil conditioner

Measurements for soil conditioner trials were conducted over two years and the grape marc for one year. The Crisp and Baker (2011) trials presented results for two years. No improvements in yield or fruit size were detected for all trials.

The project trial sites had a good level of management and ample nutrition application. It is possible that the Crisp and Baker (2011) trial site may have been slightly nutritionally deficient and any form of extra nutrient application, whether chemical or organic, produced a response.

Organic amendments can take time to impact on production. Organic matter takes time to breakdown and gradually improve the soil physical, chemical and biological properties. Further years of data collection would be required to assess these longer term impacts.

5. Fruit manipulation

Introduction

Summer Urea

Trials in California (Lovatt, 1999) indicate that an increase in fruit size can be achieved by spraying a low biuret form of urea at the beginning of fruit cell expansion (mid December). The urea spray is relatively inexpensive and can potentially provide significant financial gain.

Corasil®

Corasil® is a growth regulator used to increase citrus fruit size (Nufarm, 2007a). Corasil® is a form of 2,4-D and the fruit size effects of 2,4-D have been known for many years (Stewart and Hield, 1949). Corasil® is the only registered form of 2,4-D as a fruit sizing spray in Australia. In United States the common form is registered (Lovatt, 2010). Extensive research has been conducted around the world demonstrating the fruit size response of 2,4-D (Agusti et al. 1996; Davies, 1997; Erner et al. 1993; Greenberg et al. 2006; Guardiola, 1997; Guardiola and García-Luis, 1998; Vanniere and Arcust 1994). The manufacturers of Corasil®, Nufarm, have conducted demonstration trials in Sunraysia and published results and technical information in a very well compiled and presented fact sheet and technical manual (Nufarm, 2007a; Nufarm, 2007b). Cost benefit information is presented in the fact sheet. The product has not been extensively adopted, growers are still not confident with its use. The trials were conducted to re-expose Corasil® to industry and further build industry knowledge and confidence in its use.

Kaolin clay

Research indicates there are various benefits in the foliar application kaolin clay. Its main benefit is the reduction of sunburnt fruit (Agnova., 2015; Lolicato and VIC DPI. 2011). Florida research has demonstrated improvements in tree growth (Lapointe, et. Al., 2006; Agnova., 2015). Research from Arizona has demonstrated its effectiveness in reducing infestations of thrips on lemons (Kerns and Wright, 2000) and other research presents its benefits on tree physiology (Jifon and Syvertsen, 2003; Rosati et al. 2006).

5.1 Summer urea fruit size spray: NSW DPI

Background

Property managers: Douglas Camin, Brad Bowes and Darren Howard

The trial was implemented on Fukomoto navels planted in 2001 on Citrange rootstock at a planting density of 645 trees/ha (Figure 48). The site was irrigated by drip irrigation. A summer urea trial was conducted over two seasons; 2011/12 and 2012/13.

Method

The trial was a randomised complete block design (RCBD) with two treatments, 16 replicates and single tree plots.

Low biuret urea was applied on 13/12/11 at a rate of 3.3 kg/100L and a water volume of 1700 L/ha. Harvest occurred on the 20/6/12 and 20/6/13.

Figure 48: NSW DPI summer urea trial site near harvest.

Results

There was no significant difference in fruit size and yield at the 5% level of significance in 2012 (Table 48) and 2013 (Table 49).

2012 NSW DPI summer urea trial results		
Category	Treatments	
	Control	Urea
Average fruit size mm	80.9	82.0
% fruit 0-75 mm	1.5%	1.1%
% fruit 75+ mm	98.5%	98.9%
Yield T/ha	58.3	57.5

Table 48: 2012 NSW DPI summer urea trial average fruit size, percentage fruit size distribution above and below 75 mm fruit diameter and yield. (Different letters on columns indicate a statistical difference at the 5% level)

2013 NSW DPI summer urea trial results		
Category	Treatments	
	Control	Urea
Average fruit size mm	84.9	84.5
% fruit 0-75 mm	9.5%	7.7%
% fruit 75+ mm	90.5%	92.4%
Yield T/ha	25.9	21.8

Table 49: 2013 NSW DPI summer urea trial average fruit size, percentage fruit size distribution above and below 75 mm fruit diameter and yield. (Different letters on columns indicate a statistical difference at the 5% level)

Fruit size was extremely large in both years and this may have masked any possible responses. The trial should be repeated on blocks producing fruit near district average fruit size

5.1 Corasil® fruit size spray: Colin Nankivell

Background

Property manager: Colin Nankivell

The trial site was a block of Washington navels on sweet orange rootstock planted in 1965 at 409 trees/ha and irrigated by drip irrigation (Figure 49). The trees had been hedged on the eastern side in 2006. A Corasil® trial was conducted over three seasons; 2010/11, 2011/12 and 2012/13.

Figure 49: Nankivell Corasil® spray trial site.

Method

The trial was a randomised complete block design with two treatments, 13 replicates and single tree plots.

Corasil® was applied on 23/11/10 at 16 mm average fruit size, 25/11/12 at 24 mm average fruit size and 28/11/13 at 29mm average fruit size. Corasil® was applied at a rate of 200ml/100L with Li700® wetter at 100 ml/100L with a spray volume of approximately 3500 L/ha.

Harvest was on 21st July 2011.

Results

There was a significant difference in fruit size for the 2011 trial, but there was no significant difference in the yield at the 5% level of significance (Table 50). There was no significant difference in fruit size and yield for the 2012 and

2013 trials (Table 51 and Table 52). However the 2012 data did show a trend of a 2 mm increase in fruit size with Corasil® application which is consistent with 2011 data and other grower experiences. Yield in 2013 was extremely low (6 T/ha) and a lack of response at low yields with large fruit size was expected.

2011 Nankivell Corasil® trial fruit size results		
Category	Treatment	
	Control	Corasil®
Average fruit size mm	75.2 a	76.9 b
% fruit 0-75 mm	50.9% a	37.8% b
% fruit 75+ mm	49.1% a	62.5% b
Yield T/ha	46.5	49.4

Table 50: 2011 Nankivell Corasil® trial average fruit size, percentage fruit size distribution above and below 75 mm fruit diameter and yield. (Different letters on columns indicate a statistical difference at the 5% level)

2012 Nankivell Corasil® trial fruit size results		
Category	Treatment	
	Control	Corasil®
Average fruit size mm	78.0	80.2
% fruit 0-75 mm	37.3%	27.3%
% fruit 75+ mm	62.8%	72.7%
Yield T/ha	84.5	78.1

Table 51: 2012 Nankivell Corasil® trial average fruit size, percentage fruit size distribution above and below 75 mm fruit diameter and yield. (Different letters on columns indicate a statistical difference at the 5% level)

2013 Nankaville Corasil® trial fruit size results		
Category	Treatment	
	Control	Corasil®
Average fruit size mm	84.8	85.1
% fruit 0-75 mm	13.5%	7.2%
% fruit 75+ mm	86.5%	92.8%
Yield T/ha	5.5	6.6

Table 52: 2013 Nankivell Corasil® trial average fruit size, percentage fruit size distribution above and below 75 mm fruit diameter and yield. (Different letters on columns indicate a statistical difference at the 5% level)

The 2 mm increase in fruit size provided a cost benefit analysis positive net financial benefit at all price scenarios (Figure 50).

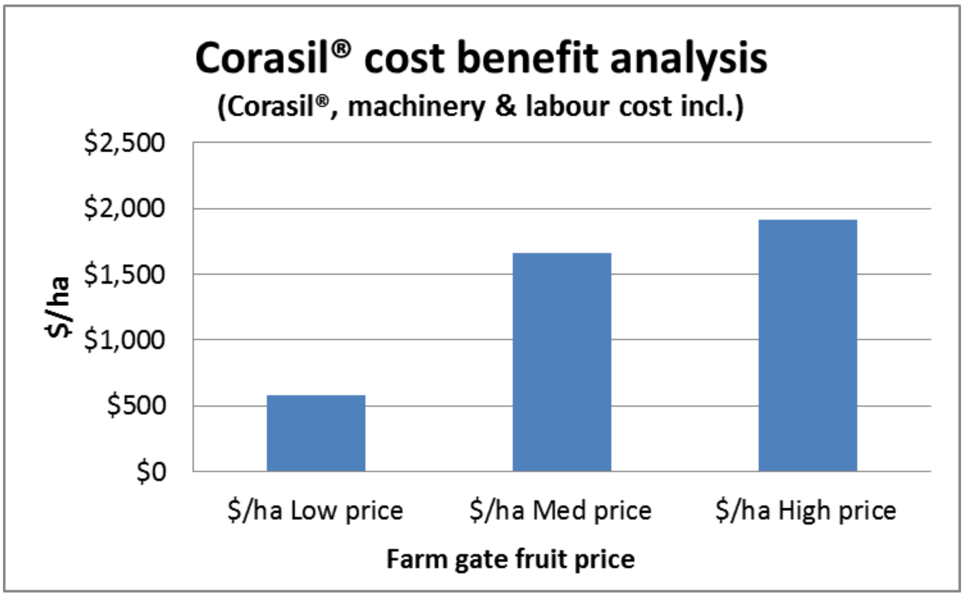

Figure 50 : 2011 Nankivell Corasil® trial cost:benefit analysis of applying Corasil® including the cost of product, harvest, machinery and labour.

5.3 Kaolin sunburn reduction spray: NSW DPI

Background

Property managers: Douglas Camin, Brad Bowes and Darren Howard

The trial was implemented on Cara Cara navels planted in 2005 on Citrange rootstock at a planting density of 589 trees/ha (Figure 51). The site was irrigated by drip irrigation. Harvest occurred on the 12/8/11 and 26/7/12. A kaolin clay sunburn prevention spray trial was conducted over two seasons; 2010/11 and 2011/12.

Figure 51: NSW DPI kaolin clay sunburn trial site January 2012. The white coloured trees are the Surround® treatments.

Method

The trial was a randomised complete block design (RCBD) with three treatments, seven replicates and single tree plots. The three spray treatments were Screen Duo®, Raynox® and Surround®.

Four applications of treatment sprays occurred in both seasons.

- 2010/2011 - 14/12/10; 30/12/10; 18/01/11; 14/02/11
- 2011/2012 - 12/12/11; 29/12/11; 12/01/11;13/03/12

All spray treatments were applied to runoff and Duwett® silicon spreader was added to all mixtures at a rate of 20 ml per 100L. Raynox® was applied at 2.5 L per 100L with water softener added. Screen Duo® was applied at 2.5 kg

/100L. Surround® was applied at 5 kg /100L for the first application of the season and then at 2.5 kg /100L thereafter.

Fruit was assessed for sunburn on the 8/07/11 and 7/07/12. Only fruit with sunburn greater than 3 cm^2 (~ 10c coin) were counted (Figure 52 and Figure 53). The percent sunburn results presented might be slightly elevated than actual because of the difficulty of checking fruit deep within the canopy.

Figure 52: An example of fruit with acceptable levels of sunburn

Figure 53: An example of fruit with unacceptable levels of sunburn

The surface temperature of fruit in direct contact with sunlight was measured with an infrared dual laser thermometer on 25/01/11, 31/01/11 and 24/02/12.

Results

There was a significant difference in fruit size and yield at the 5% level of significance in 2011 (Table 53). Fruit size was larger in Surround® than control and Raynox®, but not different to Screen Duo®. There was no significant difference in yield at the 5%, but its level of significance was close at 6.6%. On first appraisal the results look promising for Surround®. However the yield data indicates it had approximately 18% less yield than all other treatments. It is well established that as yield decreases fruit size increases (Khurshid, 2002). There is a possibility that the increase in fruit size for Surround® was influenced by its lower yield than other treatments. It is suspected that its lower yield was not caused by the application of Surround®, but by coincidently selecting trees that were going to naturally have a lower yield.

Repeatability of results in following seasons provides confidence in the data. In 2012 season no significant differences were detected for fruit size or yield at the 5% level of significance (Table 54). It is interesting to note that the trend in the 2012 data indicated that Surround® treatment had one of the highest yields and smallest fruit size. The Surround® treated trees seem to be demonstrating a biannual bearing pattern that was out of sync from the rest of the treatments.

2011 NSW DPI Kaolin sunburn reduction trial results				
Category	Treatments			
	Control	Screen Duo®	Raynox®	Surround®
Average fruit size mm	79.8 a	80.8 ab	79.7 a	82.3 bc
% fruit 0-75 mm	21.9% a	20.2% a	23.2% a	11.1% b
% fruit 75+ mm	78.1% a	79.8% a	77.0% a	88.9% b
Yield T/ha	50.7	52.2	49.7	41.3

Table 53: 2011 NSW DPI Kaolin sunburn reduction trial average fruit size, percentage fruit size distribution above and below 75 mm fruit diameter and yield. (Different letters on columns indicate a statistical difference at the 5% level)

2012 NSW DPI Kaolin sunburn reduction trial results				
Category	Treatments			
	Control	Screen Duo®	Raynox®	Surround®
Average fruit size mm	87.0	87.8	88.4	85.7
% fruit 0-75 mm	3.3%	0.9%	2.6%	5.0%
% fruit 75+ mm	96.7%	99.1%	97.4%	95.0%
Yield T/ha	38.6	41.2	38.3	41.3

Table 54: 2012 NSW DPI Kaolin sunburn reduction trial average fruit size, percentage fruit size distribution above and below 75 mm fruit diameter and yield. (Different letters on columns indicate a statistical difference at the 5% level)

There was a significant difference in the fruit surface temperature measured in 2011 and 2012 at the 5% level of significance. The data has been presented in a graph (Figure 54) and a table (Table 55). The graph provides a visual appraisal of data trends over the 5 measurements, whilst the table includes statistical difference information to separate treatment differences.

The Surround® treatment fruit surface temperature was statistically different (5% level) by 1 to 2°C less than other treatments for four of the five measurements. The Screen Duo® treatment was approximately 1°C less than control in the first reading (25/01/11- 9:30) and then in the second reading (25/01/11 – 13:00) it was not statistically different (5% level) from Surround® and control.

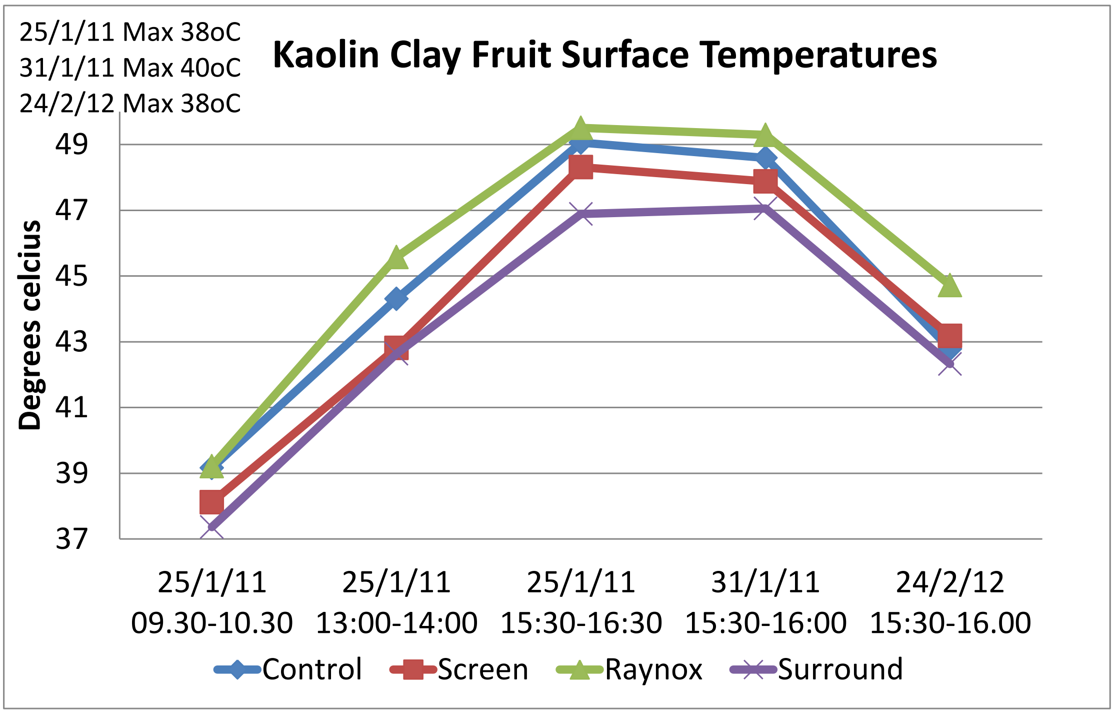

Figure 54: 2012 NSW DPI Kaolin sunburn reduction trial fruit surface temperatures.

NSW DPI Kaolin sunburn reduction trial fruit surface temperatures °C				
Dates & times	Treatments			
	Control	Screen Duo®	Raynox®	Surround®
25/1/11 09.30-10.30	39.2 a	38.1 b	39.2 a	37.4 b
25/1/11 13:00-14:00	44.3 a	42.8 a	45.6 b	42.6 a
25/1/11 15:30-16:30	49.1a	48.3 a	49.5 a	46.9 b
31/1/11 5:30-16:00	48.6 a	47.9 a	49.3 a	47.1 b
24/2/12 15:30-16.00	42.8	43.2	44.7	42.3

Table 55: 2011-12 NSW DPI Kaolin sunburn reduction trial fruit surface temperatures. (Different letters on columns indicate a statistical difference at the 1% level)

There was a significant difference in the fruit sunburn measurements in 2011 and 2012 at 1% level of significance (Figure 55). Surround® had 4.5% and 7.7% less sunburned fruit than control in 2011 and 2012 respectively. Screen Duo® had 5.5% less sunburned fruit (1% level of significance) than control in 2011, but not in 2012.

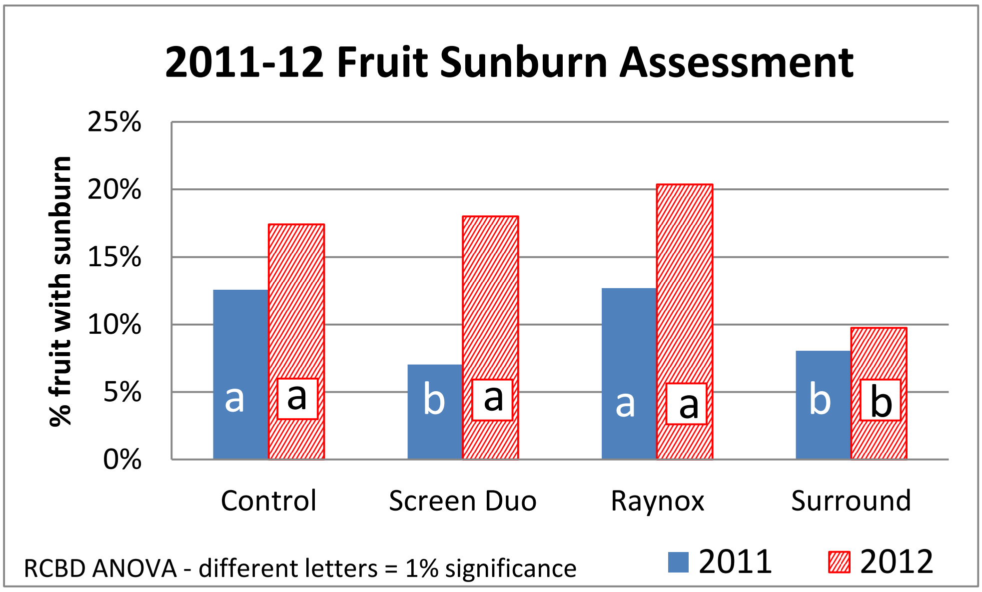

Figure 55: 2012 NSW DPI Kaolin sunburn reduction trial fruit sunburn assessment.

The sunburn data indicates that there was a higher level of fruit sunburn in 2012 than in 2011. Maximum temperature data from the Bureau of

Meteorology Mildura airport weather station is presented in Table 56. It indicates that the number of days over 40°C in 2012 was only different by one day to 2011, however 2012 had 10 more days over 35°C than in 2011. This might imply that Cara Cara navels more sensitive to sunburn when hot temperatures (i.e. above 35°C) are experienced over an extended period rather than single extreme high temperature events (i.e. above 40°C). More detailed research is required to better understand possible relationships between sunburn and temperatures.

Mildura Dec. to Mar. days exceeding 35 °C & 40 °C		
Year	> 35 °C	> 40 °C
2010/11	16	2
2011/12	26	1

Table 56: The number of days greater than 35°C and greater than 40°C at Mildura airport (~ 32km south of Dareton NSW DPI) from December to March 2010 to 2012.

The Surround® treatments visibly had higher levels of sooty mould than other treatments (Figure 56). Sooty mould was most visible when the fruit began to colour. Sooty mould is a product of scale and mealybug infestation. The insects exude sugar as they feed on tree sap, the sugar coats leaves, shoots and fruit, then a black coloured fungus (sooty mould) grows on the sugar.

Figure 56: Sooty mould on a Surround® treated tree.

On 8/7/2011 fruit were assessed for the percentage of fruit with sooty mould. The assessment recorded both minor (around the neck of fruit) or major (Figure 56) growths of sooty mould on fruit as an infestation. Results indicate that Surround® had approximately 45% extra fruit with sooty mould than other treatments at the 1% level of significance (Figure 57). In most cases sooty mould can be washed off fruit at the packing house, but in circumstances of high sooty mould levels some residues remain that can downgrade its quality.

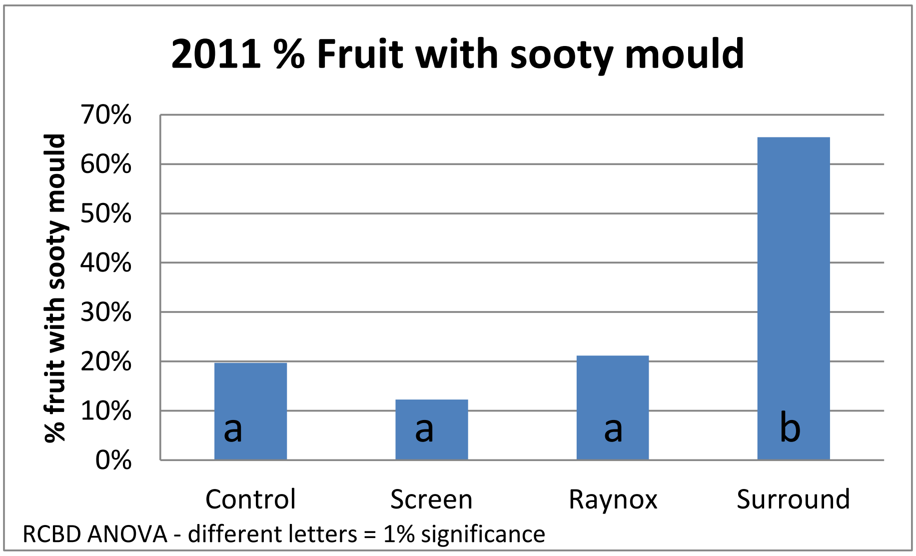

Figure 57: 2011 NSW DPI Kaolin sunburn reduction trial percentage of fruit with sooty mould.

For demonstrative purposes a cost benefit analysis was conducted on Surround® and Screen Duo® assuming that fruit size and yield remained constant for all treatments (Figure 58). The analysis assumed that Surround® and Screen Duo® treatments would decrease sunburn by 2.5% and thereby increasing first grade packout by the 2.5 %. The cost benefit analysis demonstrated a net loss for the low fruit price scenario, but a $200-$400 net gain per hectare for the medium to high fruit price scenario.

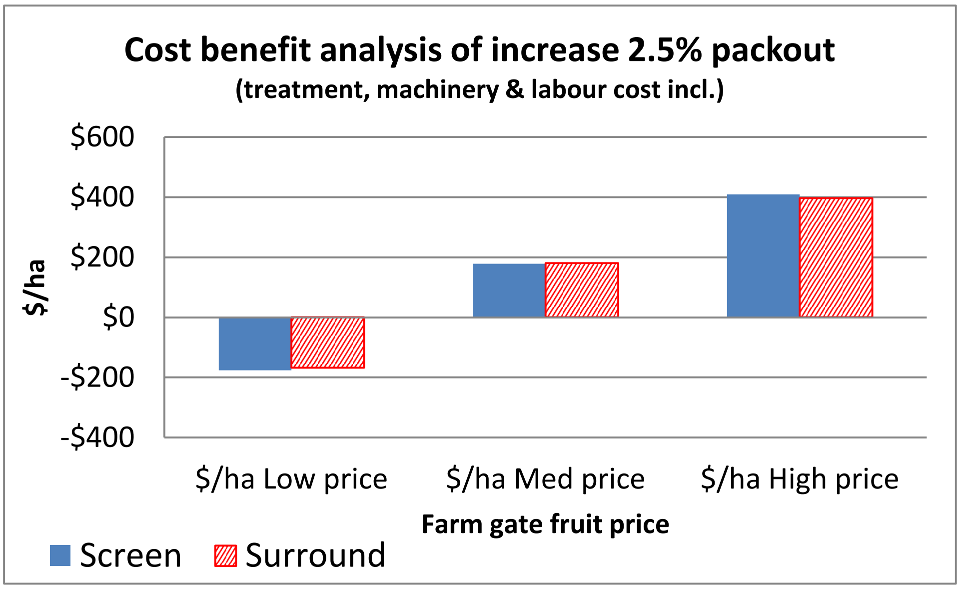

Figure 58: Cost benefit analysis of the effect of increasing first grade packout by 2.5% for Surround® and Screen Duo® assuming a constant yield and fruit size for all treatments.

5.4 Wind break assessment: Geoff Rix

Background

Property manager: Geoff Rix

A block of Navels was assessed for the effect of windbreaks on rind blemish. The block was Lane late navels planted in 2006 on Trifoliata rootstock at a planting density of 384 trees/ha (Figure 59). Casuarinas were planted on the western end of the block at 4 m apart and they were approximately 3 m in height.

Figure 59: Geoff Rix wind blemish assessment site.

Method

The site was not optimal for conducting a wind blemish assessment because the windbreak trees were not fully mature. However the assessment proceeded for the purpose of testing the technique. Three rows of trees were selected and approximately every fifteenth tree was assessed for on-tree wind blemish.

Fruit were assessed according to blemish grade specifications commonly used in packinghouses. These specifications were developed by visiting a packinghouse to obtain a first-hand understanding of in-line grading and also reviewing fruit grading literature (Revelant et al. 1997).

An example of grade classification used in the assessment is provided in Figure 60. The examples are the maximum blemish allowed to be classified within the specified grade.

Figure 60: Pictorial representation of maximum acceptable levels of blemish within the specified grade. Left: 1st grade fruit. Middle: Second grade. Right: Third grade.

Results

Unfortunately data from the fifteenth tree became corrupted and is not presented. The data indicates a trend of lower first grade packout for the first few trees (Table 57). This infers that the immature casuarina windbreak was not very effective and the first few trees of the row partially provided some wind protection for the rest of the trees down the row.

2012 Geoff Rix wind blemish assessment results			
Tree	**Percentage of fruit within a grade**		
	1st	**2nd**	**3rd**
1	41%	40%	19%
3	55%	38%	7%
30	61%	33%	5%
60	63%	29%	8%

Table 57: 2012 Geoff Rix wind blemish assessment results.

The data was variable and more sampled plots are required to improve the reliability of data. For future assessments at least six rows should be selected and at least 10 trees sampled down the row (or more).

Intentions were to conduct more detailed wind blemish assessments, but the project was already overcommitted with trials and was unable to conduct more assessments.

The wind blemish assessment technique was used in 2015 to compare wind protection products for the National Technical Forum, Mildura. On-tree “drape” netting used for bee exclusion to create seedless fruit in mandarins and permanent structure hail netting was assessed. The data presented in the field day handout (Appendix 1) indicated that tree “drape netting” did not reduce wind blemish. It was draped over trees in mid-November with the theory that insect sprays will be required in early November and the net might reduce spray penetration and efficacy. There is a possibility that wind blemish damage occurred prior to the installation of the netting. It is recommended to repeat the trial applying the drape net at an earlier time. Permanent structure hail netting was also assessed and it demonstrated a 22% increase in first grade packout. This is consistent with feedback from property managers that packout results provide a 20 to 25% increase in first grade fruit as compared to open field.

The technique was very successful and can be used to conduct further wind blemish assessments studies.

Discussion; Fruit manipulation

Summer Urea

No significant differences were detected. Fruit size in both years was extremely large and this may have masked possible effects. It would be valuable to repeat the trials on trees that bear district average fruit size.

Corasil®

In all three seasons of trials Corasil® produced larger fruit size, however a statistical difference was only present in the first year. In the second year a very high crop load occurred followed by a very low crop load in the following year. This might infer that Corasil® works best on medium crop loads rather than very low or high crop loads. The cost benefit analysis for the first season indicated substantial gains in net returns from $500-$1900 per hectare. An important factor in the use of Corasil not investigated in this project is its minor effect on reducing juice levels. This should not be a problem for varieties that naturally have juice levels above market standards, however this could be an issue for varieties that have juice levels close to market standards.

Kaolin clay

Surround® was able to demonstrate a significant reduction in sunburn for two seasons and Screen Duo® for one season. A cost benefit analysis demonstrated a net gain in returns based on the assumption it increased first grade packout by 2.5%. The kaolin clay products vary significantly in the way they are manufactured and perform. Surround® treated trees where much whiter that Screen Duo® or Raynox® treated trees. Unfortunately Surround® increased the infestation of scale and mealybug insects which caused a proliferation of sooty mould. It is speculated that the clay interferes with beneficial insects that feed or parasitise the scale. Growers have also been reporting increased insect infestation from the use of kaolin clay products.

Four sprays per annum of kaolin clay was used in the trials, opportunity exists to investigate if fewer sprays can provide similar beneficial results in reducing sunburn and also minimise insect infestation.

Wind blemish assessment

The assessment on the young tree orchard with an immature windbreak indicated that the windbreak did not have a significant effect. The exercise helped to develop the assessment technique which was used to conduct an assessment for the 2015 Citrus Technical Forum, Mildura. This data demonstrated that permanent structure hail netting provided a 22% increase in first grade packout. It is proposed to use this and other data in a future DPI economic assessment on wind protection publication.

Outputs & Outcomes: Technology transfer

Outcomes

The project helped to improve the profitability, knowledge and skills of growers by identifying profitable and non-profitable practices.

The project;

- helped some growers make cost savings by reducing potassium application to more moderate levels and eliminating unnecessary foliar potassium sprays. Reduction in excessive potassium also improves rind quality and fruit price. The project also demonstrated an increase in fruit size and returns for growers not applying enough potassium,
- developed a methodology that can be used in future trials conducted on-farms, and
- identified practices for future trials that have potential to make significant improvements to production (see recommendations).

Outputs

Development of an on-farm trial methodology and tools

The project developed a computerised on-tree fruit size measurement method that improves the efficiency of conducting replicated on-farm demonstration trials. A digital caliper was connected to a small netbook that could measure up to 2000 fruit per day by a single operator. Special MS Excel based software was developed to store and organise digital caliper and yield data. The software was also able to automatically graph, cost benefit analyse and statistically analyse the data (see methodology section for more details). The software can be used in future trials. An on-tree wind blemish assessment methodology was also developed.

Field days and seminars

<u>Summary (Date, topic & attendance)</u>

1. 11/05/11: Corasil, wind shelters & potassium : 40
2. 08/06/11: Corasil & Pruning : 40
3. 16/06/11: Pruning & chemical thinning : 30
4. 29/09/11: National extension forum : 15
5. 04/04/12: Summer urea, growth enhancing & kaolin : 40
6. 25/07/12: Fruit set & soil conditioning : 30
7. 31/05/12 : Foliar and ground potassium application : 30
8. 21/10/12: Leeton National Citrus Growers Conference : 70
9. 18/11/12: International Citrus Congress in Spain : 90
10. 29/05/13: Crop regulation trial : 25

11. 27/06/13: Citrus Technical Conference 190
12. 25/07/13: Crop regulation trial and potassium : 25
13. 15/09/15: Riverina: Project overview & potassium
14. 16/09/15: Project overview & potassium

Details

The key focus of the project was to obtain trial participation and field day attendance by growers so information can be exchanged and disseminated. The project was successfully able to generate a good level of grower interest as demonstrated by the participation, field day attendance and feedback throughout the project.

2011

Three field days were conducted in the Sunraysia region in 2011. Approximately 110 participants attended the field days. Growers provided very positive feedback indicating that this kind of work has practical relevance and impact on their operations. The field days were conducted on:

1. 11th May 2011 : Corasil on Mandarins, artificial wind shelters & ground potassium
2. 8th June 2011 : Corasil & Pruning
3. 16th June 2011: Pruning and chemical thinning

A selection of photographs from the 2011 field days is shown in Figure 61.

Figure 61: Field day photos from 2011 On-Farms Trials field days.

A National Crop Regulation and On Farms Trials meeting was held 29/09/11 at Dareton Research Station. The meeting brought together 16 industry representatives from around Australia to discuss research and extension priorities. A presentation was conducted that overviewed the On-Farms Trial project. The concept of on-farms trials was determined as a priority method to help extend crop regulation and other fruit size practices to industry.

Figure 62: Steven Falivene presenting at the National Crop Regulation and On Farms Trials meeting on 29/09/11.

2012

Three field days were conducted in 2012 in the Sunraysia region. Approximately 100 participants attended the field days. The Murray Valley Citrus Board (MVCB) considered the field days to be very successful and growers provided positive feedback indicating that this kind of work has practical relevance and impact on their operations. The field days were conducted on:

1. 4/04/12: Summer urea spray, young tree growth enhancing sprays and kaolin clay.
2. 25/07/12: Fruit set enhancing spray and soil conditioning
3. 31/05/12: Foliar and ground potassium application

A poster was presented at the Leeton National Citrus Growers Conference on the 21/10/12 (Appendix 2). A five minute verbal presentation was provided to approximately 70 delegates. Delegates were split up into four groups and the presentation was repeated.

A verbal presentation that overviewed the concept and methodology of on-farms trials was delivered at the International Citrus Congress in Spain on 18/11/12 (Figure 63 and Figure 64). The conference paper was published in a refereed journal (see scientific refereed publication section).

Figure 63: Steven Falivene presenting at the International Citrus conference, Spain 2012.

Figure 64: Delegate view of Steven Falivene presenting at the International Citrus conference, Spain 2012.

2013

Two field days and a presentation at a Technical Field day were conducted in 2013 in the Sunraysia region. Attendances across all field days were very good, approximately 50 attending field days and 140 attending the Technical Field day field session. The first was a farm walk held on the 29/05/13 presented the crop regulation trial. Twenty five participants attended the farm walk. The trial compared hand thinning to flower regulation sprays. A local grower was also invited to present his experience of crop regulation (Figure 65).

Figure 65: Mr Michael Keenan discusses the crop regulation trial site with farm walk participants (29th May 2013)

The second field presentation occurred at the Murray Valley Citrus Board Citrus Technical Field Day held at Dareton Research Station on 27/06/13. Approximately 190 participants attended the Technical Field Day with approximately 140 attending the field session. The participants were split into four groups and presentation was repeated (Figure 66).

Figure 66: Conference participants listening to Steven Falivene presenting information about the on-farms trials.

The third field session occurred on the 25/07/13 and presented information from the Washington navel crop regulation and potassium spray trials (Figure 67). Twenty five participants attended the farm walk.

Figure 67: Steven Falivene discusses the results of the potassium foliar spray fertiliser trial to field day participants.

2015

An On-Farms Trials presentation was made to Riverina growers on 15/09/15 (Griffith, NSW) and to Sunraysia growers on 16/09/15 Sunraysia presentation. About forty growers attended each presentation. The presentation focused on discussing the potassium trial. The South Australian On-Farms Trials presentation will occur at the CASAR growers meeting scheduled for 08/02/16.

Scientific refereed publications, keywords & glossary

Scientific refereed publications

Steven G. Falivene, Karen Connolly and Mary Cannard (2015). On-farm citrus trials in Australia: effective extension for commercial assessment. Acta Hortic. 1065, 1839-1844 http://www.actahort.org/books/1065/1065_235.htm

Keywords

Citrus, navel, crop regulation, hand thinning, hand pruning, gibberellic acid, GA, Kaolin clay, Corasil, Surround, Screen, Raynox, Branch IT, Brotomax, bio stimulants, potassium nitrate, potassium, nutrition, foliar sprays and 2,4-D, fruit size, Afourer mandarin, wind blemish and soil conditioning.

Glossary

Crop regulation:	Conducting actions to change the numbers of fruit on the tree. Fruit reduction can occur by pruning, hand thinning or chemical thinning. Setting more fruit could occur by flower GA (gibberellic acid) or winter urea sprays.
Flower GA spray:	The spray application of gibberellic acid (GA) during the stages of flowering through to petal fall to increase fruit set and subsequent numbers of fruit on the tree (yield).
Gibberellic acid:	A plant hormone that can be sprayed onto trees to manipulate tree and fruit physiology.
Hand thinning:	The removal of fruit by hand to reduce the crop load. Small or blemished fruit are targeted for removal.
Kaolin clay spray:	A general term to describe the spray application of a kaolin clay based products to mainly act as a sun screen. Products vary significantly in the way they are manufactured and perform.
Winter GA spray:	The spray application of gibberellic acid (GA) either at early winter or at bud break (late winter) to reduce the level of flowering in spring.
Winter Urea spray:	The spray application of low biuret urea in winter to increase the numbers of fruit and yield.
Summer Urea spray:	The spray application of low biuret urea at approximately the end of the fruit cell division stage (mid December) to fruit improve fruit size.

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Mrs Karen Connolly (formerly NSW DPI) is thanked for field, technical and editorial assistance and support throughout the project.

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- Ashley Constandine (EJT)
- Mathew Cottrell and Andrew Donaldson (Cottrell Nominees)
- Sam Cross and Justin Kassulke (Cross Farms)
- Michael Keenan (Keenan Partners)
- David Keens (Manna Farms)
- Rohan & Kirrily McMahon
- Darren Minter & Leonard Keating (Minter Magic)
- Colin Nankivell
- Dougal & Teresa Plumber
- Tony Simmonetta and Geoff Brown (Simonetta Farms)
- Craig Thornton and Justin McFee (Deakin Estate)
- Trevor Radloff
- Geoff Rix

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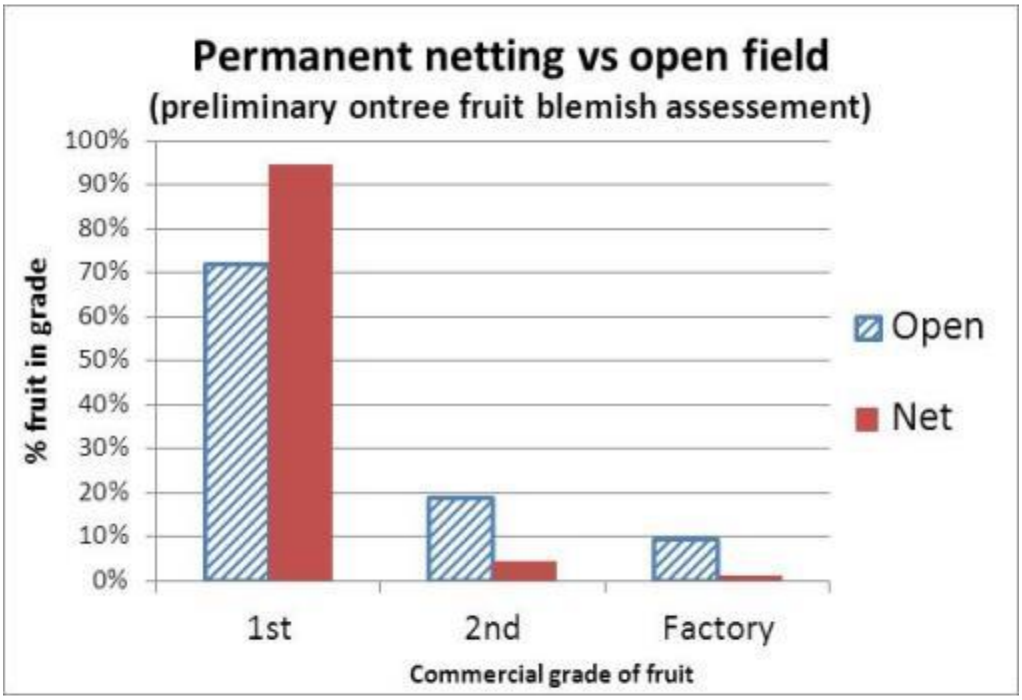
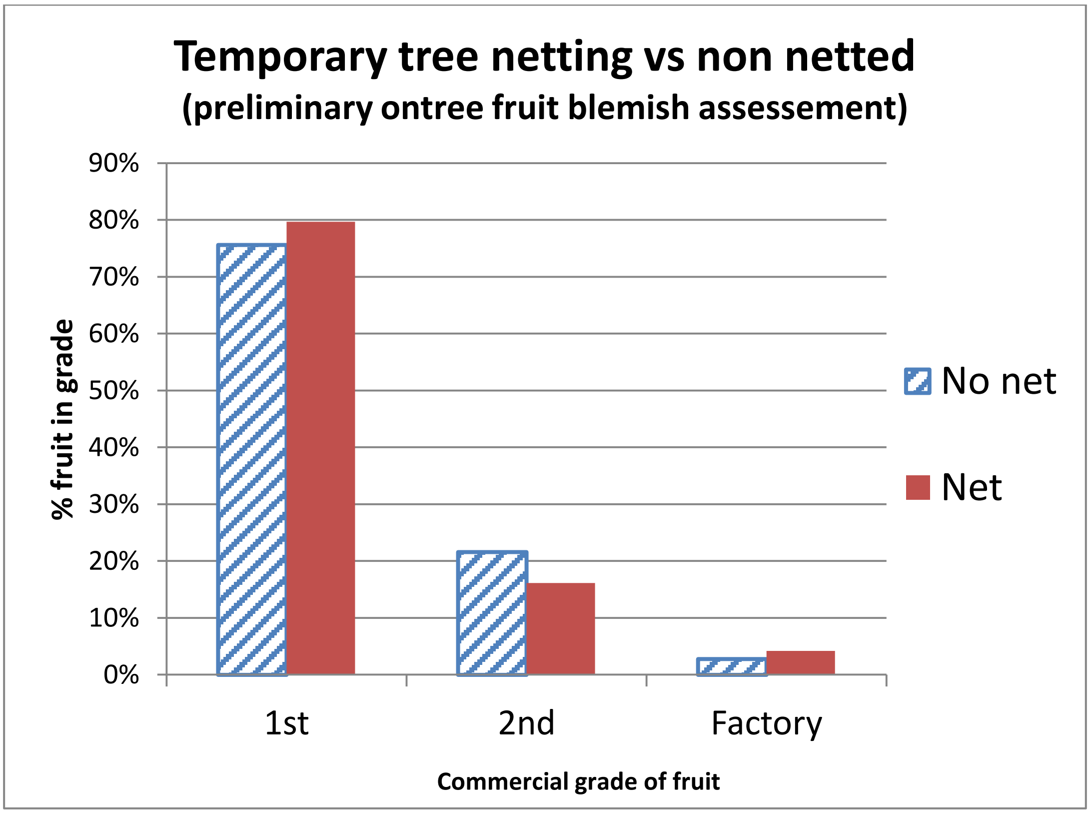
Netting in citrus to reduce wind blemish
Preliminary results March 2015

Assessment 1
Site: Seven Fields Sun West
Site managers: Tom Brayrook and David Stevens
Netting: Permanent netting structure
Assessment: 10th March 2015 by Steven Falivene (NSW DPI) and Clare Li (Seven Fields)
Variety: 2m high Chislet Navels



Discussion: There was an extra 22% more first grade fruit under the netting structure as compared to the open field (about 80m away from the netting structure). Minor light blemishes (up to $1cm^2$) were allowed on 1st grade fruit. The level of first grade fruit in both treatments was higher than district averages. This is probably due to the intensive pruning program that produced canopies with low levels of deadwood and good levels of well-spaced new growth.

Assessment 2
Site: Seven Fields Tarcoola
Site managers: Andy Hancock and David Stevens
Netting: Temporary tree netting applied November 17th (calyx closure)
Assessment: 10th March 2015 by Steven Falivene (NSW DPI) and Clare Li (Seven Fields)
Variety: 1.8m high Navellina Navels



Discussion: There was a small increase in first grade fruit and a small decrease in second grade fruit in the netting treatment. Minor light blemishes (up to $1cm^2$) were allowed on 1st grade fruit. The results are too close to be conclusive but provide a positive trend. The nets were installed in mid November and significant windstorms occurred before the nets were installed. It is possible that the majority of wind damage occurred prior to the application of the nets. Applying nets earlier might provide better results however it is unknown if it may impede the penetrations of insect control sprays up to the time of calix closure (i.e. Katydid, thrips and LBAM).

Appendix 2: 2011 ACG conference poster

MVCB & NSW DPI

Extension of citrus practices to maximise marketable fruit size and economic returns through on-farm trials (CT10030)

Steven Falivene[1] & Karen Connolly[1] (NSW DPI) & Mary Cannard[2] (MVCB)

NSW Primary Industries

I hear and I forget. I see and I remember, I do and I truly understand (Confucius 479BC)

Background

Research

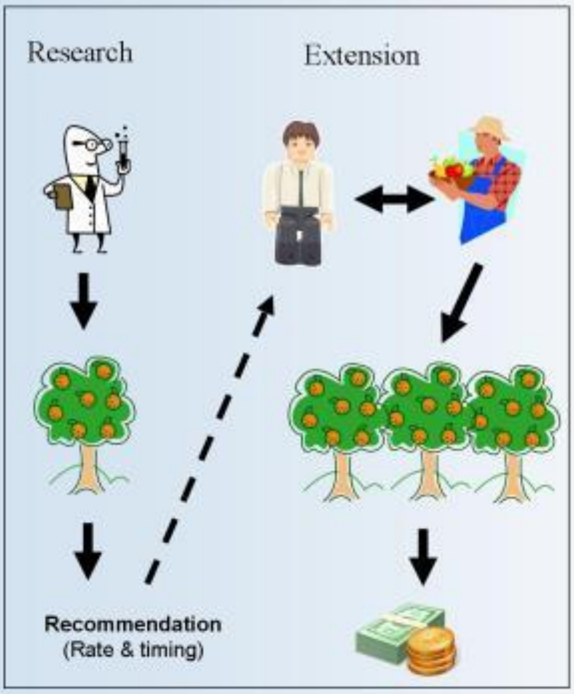
Valuable research has been conducted in Australia and overseas, but adoption has not been universally successful. Research projects focus on the "science" and develop recommendations. This research is very important and the foundation of modern agricultural practices Most of these projects end after the recommendations are communicated to industry, via brochures, seminars and magazine articles.

Adult learning principles

Adults learn via a number of methods;

- Told (*hear & read*) – brochures & seminars
- Visually (*see*) – seeing results in-field
- Participatory (*do*) – experiencing

Research communication generally focuses on the first adult learning principle. The Australian citrus industry is built on the hard work of practically minded growers. Most do not have the time to read through any technical brochures and have to make important decisions on where to spend money and time. A seminar or brochure does not address the important question "how will it work on my property?" Research proves the science, it does not always address its application in commercial orchards in a variety of situations and climates (district, soil type, rootstock, variety, management etc). Doubt and a lack of confidence leads to a lack of acceptance and adoption.



Research works with the crop to develop the science. Extension works with growers that deal with the crop to deliver economic and environmental prosperity and sustainability.

Extension Methodology

Grower focus

This project focuses on the implementation of all adult learning principles. The first step is to gain the respect, motivation, enthusiasm and participation of growers. Research projects focus on scientific methodology and experimental design, extension projects focus on people (growers), learning styles and practice change. Without the growers you have no learning and you have no change!.

Growers are asked to nominate topics that they would like to investigate on their farms. This is achieved through group meetings and/or individual approach. An economic assessment is made on the potential benefit or cost saving. If the topic is seen to be worthwhile and feasible, then a trial is implemented on the grower's property. Some trials are demonstrative, whilst others are single tree replicates. It is important to work in with the growers management system to reduce inconvenience. A satisfied grower will be more inclined to continue participation and encourage others to join.

Project officers collect trial results by measuring fruit size and yield.

Field days are conducted with emphasis on the participating growers discussing their experience and findings. Results are also presented in dollar value.

Citrus grower Rohan McMahon discussing with other growers his experience of using Ethrel® on mandarins

First season achievements

In 2010 eighteen trials were implemented in the Sunraysia district. Trials included; Corasil®, TOPS®, Ethrel®, foliar nutrient sprays, foliar growth enhancing sprays, wind break assessment, pruning & kaolin clay. The 2011 seasons trials will include hand thinning and the application of ground mulch.

Three Sunraysia field days were conducted and were well attended. Feedback from growers indicate a need to continue the project.

Future opportunities

The project (2010-12) is a 2 year pilot and hopefully will be extended. A national meeting was held in late September to discuss implementation in other districts around Australia. The new project will include the extension of crop regulation practices through "best practice" comparison trials conducted and monitored over a number of years.

Fruit size is measure by a computerised calliper. About 3000 fruit per trial are measured.

Project officers work with pickers and growers to measure yield from a replicated trial.

Pruning is a key practice to demonstrate to industry.

A BBQ on the field day facilitates growers socialising and exchanging ideas and experiences, an important extension objective.

ACKNOWLEDGEMENTS

The success of this project is due to the enthusiasm and work of the growers. The project staff wish to thank all participating growers and encourage more growers and districts to join in and learn together.

[1]NSW Department of Industry and Investment,
PO Box 62, Dareton 2717, NSW;
☎+61 3 5019 8400,
steven.falivene@industry.nsw.gov.au

[2]Murray Valley Citrus Board,
58 Pine Ave, Mildura, 3500
☎+61 3 50510500,
mary@mvcitrus.org.au