Horticulture Innovation Australia

Final Report

Total Non-Structural Carbohydrate Testing in Macadamias

Ian Vimpany

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MC13009

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Horticulture Innovation Australia Limited
Level 8, 1 Chifley Square
Sydney NSW 2000
Tel: (02) 8295 2300
Fax: (02) 8295 2399

Content

Summary

Following the commencement of the project a literature survey was completed which showed that TNSC was widely used in both tree crops and forestry to explain cropping behavior.

Nine growers collectively agreed to contribute to the project for a total of 15 sites. The sites were mostly selected by the contributors and management of all sites was controlled by growers. *Following commencement of the project some growers expressed interest in joining and this was facilitated within the project with separate grower contributions. No project funds were used for this work. These sites provided valuable information.* See technical report for site details and TNSC graphs.

Following initial testing of sampling techniques and drawing on experience from the earlier project (Stephenson et al 1987) a sampling procedure was developed and after final site selection of 50 trees sampling commenced in late March 2014. Ten trees were sampled each month for the duration of the project and results collated.

Following purchase of the PAR meter light readings were taken at all sites every half meter from the top of the tree. These were only measured on clear sunny days during December and January between 11am and 1pm EST. (Attachment 2)

The light measurements show that within 1-1.5m of the outside of the canopy there is not enough light for photosynthesis. This is graphically illustrated for a typical site in the technical report.

Since the hours of sunshine received could potentially influence photosynthesis sunshine duration sensors were used to accurately measure sun hours, one located on northern rivers and one in Bundaberg. They are yielding valuable information with Bundaberg receiving significantly more sun hours than the northern rivers. (Attachment 4)

The TNSC results broadly confirm the results of an earlier project with a distinct seasonal pattern but show large differences between the Hawaiian varieties and the Australian A varieties with the A varieties only having approximately half the TNSC levels of the Hawaiian. The detailed data is in attachments 1& 3.

Because the project did not have funds to measure yields it was not possible to relate TNSC measured to yields although all sites were visited annually to try and asses crop load but the data clearly showed the effects of a large industry wide flush which occurred in Autumn 2014 with depletion of reserves. There are also indications of possibly a large deleterious effect of sustained high temperatures on TNSC levels in the final months of the project.

The project has highlighted several deficiencies in our knowledge of the trees physiology.

Twice yearly meetings were held with contributors to communicate results and discuss progress. These meetings provided data for the growers to discuss in detail, with growers stating that the meetings were of great value to them.

Keywords

TNSC – Total nonstructural carbohydrate
PAR – photosynthetically active radiation
Sunlight hours
Macadamia

Introduction

During the 1980s a large industry funded project to study factors influencing macadamia yields measured TNSC as a part of the project. (Stephenson et al, 1987)

That project showed that TNSC increased steeply from nut maturity in late February until flowering and then declined steeply until nuts were mature. This indicated that the tree stored spare carbohydrate during certain times of the crop cycle and used these reserves when demand exceeded supply from photosynthesis.

The varieties used were generally older and not commonly grown today and were more widely spaced.

Since that time industry participants have felt that the result indicated the possibility that this information could be used as a predictor of likely crop load and if treatments were found that could beneficially influence TNSC then this information warranted further work using current varieties and spacing.

The literature survey showed widespread use of TNSC in both fruit crops and forestry supporting further investigation into this area of research.

This project was initiated as a first step to investigate:

- Practical reliable TNSC sampling techniques.
- Assessment of current laboratory methods and their relation to earlier laboratory techniques.
- Establishment of annual patterns of accumulation and depletion.
- Relevance to currently grown varieties.
- Investigate whether differences existed between Hawaiian bred and Australian bred varieties.

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Methodology

Site selection:

At each site 50 uniform trees were selected either in one long row or up to five short rows depending on block layout.

The trees were divided into ten blocks of five trees and at each sampling a tree from each block was sampled. Each tree had multiple samplings spaced around the tree and these generally healed within 6 months.

Sampling procedure:

- The bark of the tree was shaved smooth using a handheld rasp at so that accurate depth measurements could be made and any debris removed.
- A 25mm Spade bit was used to carefully drill through the bark removing any remnants of the vascular tissue (brown in color).
- The wood was drilled out to a depth of 4mm (+_ 0.5mm) using a digital vernier caliper to measure depth.
- The resulting hole was sprayed with a bitumen wound dressing and the drill sterilized in alcohol after each site.
- The sample was collected in an aluminum tray pinned to the tree and the shavings from all 10 trees combined.
- The sample was kept refrigerated until drying at 60°C and then finely ground before dispatch to the laboratory.
- The procedure has also been photographically documented and is attached in attachment 6.

PAR Measurements:

- The meter used had two sensors. One on the instrument used to measure ground level PAR over a distance of one meter and a second sensor connected to the meter by a 18m cable.
- The cable sensor was mounted on one of twelve 1.5m poles that fitted one on top of the other with a sleeve enabling measurements to a height of 18m.
- The first measurement was just clear of the canopy top although this could not always be clearly determined in tall trees with closed canopies and then at 0.5m intervals down the tree until readings were too low for photosynthesis.

- Measurements were only made during December and January between 11am and 1pm (EST) to minimize shading.

- Sunlight hours were recorded on a logger at 30 second intervals and collected each month for tabulation.

Observations:

At each sampling notes were made of flowering, flushing, nut set and crop load, hedging and tree health.

Results were summarized monthly, with reports sent to growers. The reports provided detail for individual orchards over time, as well as comparison against the other orchards.

Outputs

- Literature survey completed.

- Par measurements completed and a new data based understanding of the productive canopy within macadamia trees was determined. (Attachment 2)

- Results of monthly sampling for TNSC tabulated and graphed. (Attachments 1&3)

- Sunlight hours for both production areas documented and graphed. (Attachment 4)

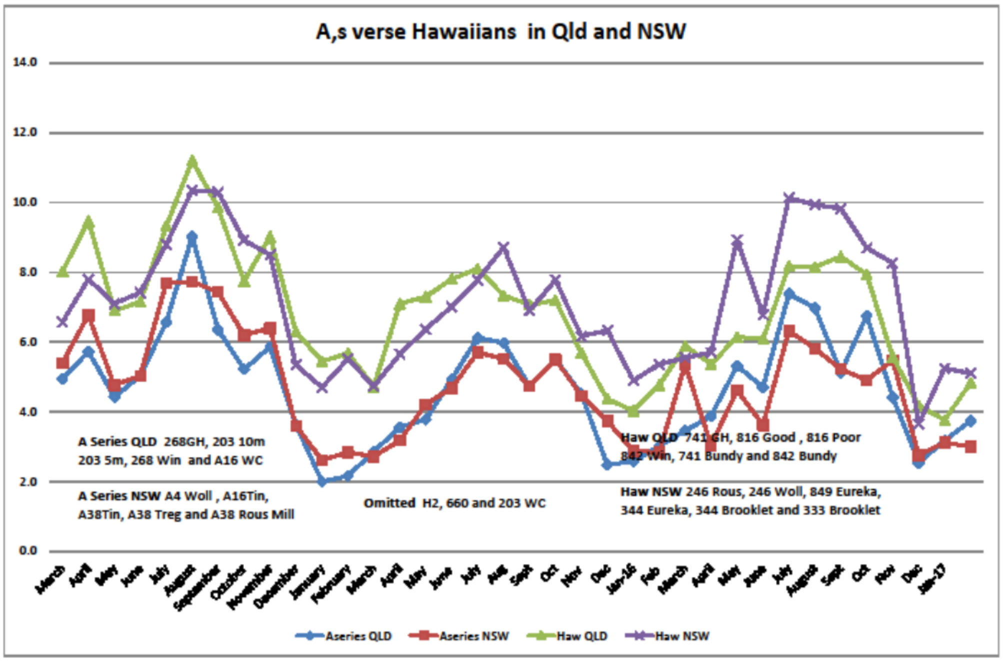
- Easily understood and reproduced sampling procedure established as a documented procedure supported by photographs. (Attachment 6)

- Technical summary report completed. (Attachment 1)

Outcomes

TNSC seasonal trend in Macadamias

The seasonal trend for TNSC found in the earlier project was confirmed for both Hawaiian and A -series varieties with major differences between the two groups for TNSC stored as is illustrated in the graph below.



This data supports the industry concerns over these two groups of varieties needing different management and associated inputs.

TNSC Methodology established

Methodology established for consultants or other central body to collect samples. Although the procedure is relatively simple the need for consistency and the requirement to keep samples refrigerated before drying and grinding probably means that it is not well suited to grower sampling. In addition, sample dispatch should be coordinated as most laboratories prefer not to process single samples.

Productive canopy data

The PAR measurements made have major implications for tree architecture in order to obtain the highest productive canopy relative to unproductive (but energy dependent) canopy with adequate light for photosynthesis not penetrating past about 1.5m into the canopy. (Attachment 2) Modelling of a free standing tree as it grows suggests that at 15-20 years of age the unproductive part of the canopy will exceed the productive canopy. This agrees with reports from the statistics that older orchards were declining in productivity first made 15-20 years ago.

The three orchards which have the smallest trees are also the most consistent croppers with some of the highest yields confirming the findings made after PAR measurement about productive canopy relative to unproductive canopy.

TNSC and Yield

The results suggest that there may be a relationship between TNSC and production since TNSC and crop was high in the

2014 and the crop in 2015 was a record while lower TNSC in 2015 resulted in a smaller crop. TNSC climbed higher than before in Lismore in the last year after sunlight hours (April/Aug) were higher than in the previous year but it appears environmental factors may have resulted in possibly a poorer crop.

The TNSC data indicate four distinct groups with two varieties (741 and 842) having higher peak values, two (H2 and 660) not falling as low or increasing as high, those between the first two and the A varieties having values up to half the Hawaiians and falling very low at crop maturity.

One variety, A38 stands out as producing large crops with much smaller leaf areas than any other and may indicate significantly increased rates of photosynthesis/leaf.

Sun Hours

The measurement of sun hours received for each district has shown that Bundaberg receives significantly more sun than the northern rivers. (Attachment 4)

Greater understanding of key physiological data gaps.

A major outcome would have to be the need for a greater understanding of the macadamias trees physiology;

A) *Do photosynthetic rates for leaves of different varieties decline at different rates as light decreases? – the data suggest this may be the case and there is some data from D. Huett to support this.*
B) *Is there a difference between varieties in heat tolerance before photosynthesis stops?*
C) *Are warmer winters having an adverse effect on factors such as flowering where Lismore had three flowerings in most orchards the past season or was this due to starch build?*
D) *Large flushes such as occurred in the first year had a large negative effect on TNSC but resulted in the big crop the year after indicate the need for management to control flushes.*
E) *There appears to be a biannual effect to the results and there may be other seasonal effects which can override TNSC levels which will only be observed over a longer period of observation. On the northern rivers this observation may be due to increased sunlight in the months March to August as occurred in Lismore in 2016 while sun hours in Bundaberg are greater and crops more even. (Appendix 4&6)*

The project has not established a platform for routine grower use of TNSC due to;

a) *Lack of accurate yield data;*
b) *Major varietal differences in TNSC accumulation and depletion;*
c) *Insufficient time to encompass climatic variations which may override TNSC levels;*
d) *Insufficient control of orchard management.*

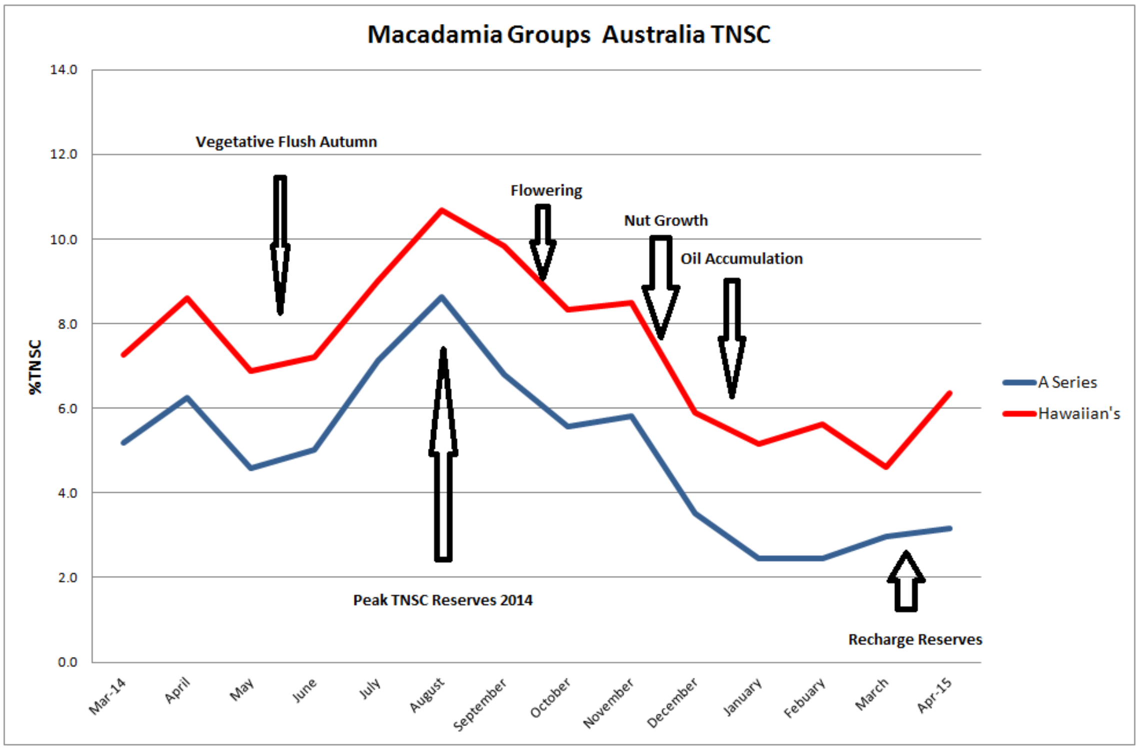
Evaluation and discussion

Timeframes

Working with large trees where changes in management can take up to 5 years before significant change in desired properties is obvious requires research that takes longer than the normal 3 years and this should be kept in mind when any future work is planned.

TNSC trends confirmed

The project has successfully achieved the objective of confirming the general trends found in the earlier project. There are many apparently random falls in TNSC which were also apparent in the data from the earlier project. Monthly observations confirm that these are related to flush events. A very large flush in April/June the first year can be clearly seen in the graph below and in other specific orchard graphs found in attachment 1.



This pattern is suggestive of the fact that a good flush may take more energy than flowering which is contrary to current thinking.

In regards to TNSC there appear to be three groups of varieties within the broad Hawaiian spectrum with the A varieties grouping together resulting in four possible groups within the broader macadamia grouping; (Attachment 6)

a) Those that accumulate higher starch values;
b) Those that are more even through the year, not rising as much or dropping;
c) Those that run at slightly lower levels but still rise and fall.
d) The Australian A varieties that only ever accumulate about half the TNSC levels of the Hawaiians.

The consequence of this is that separate data may be required for many of the currently favored varieties if TNSC is to become a useful tool.

Further to this it is possible that climatic events such as extended period of high temperature, drought or floods and waterlogging may override the benefits of high TNSC levels.

D. Huett has shown that at temperatures above 31^{0}C photosynthesis stops and our data show that in summer 2016/17 TNSC dropped dramatically when there were long periods with temperatures above 35^{O}C.

If this coincides with crop load, then the tree is using reserves to both finish crop and stay alive.

Possible influence on TNSC and possibly yield.

The ability to control the timing and size of large flushes would appear to be an important factor in ensuring large crops as our data suggest this and anecdotal information also suggests this. Flushing which phenologically is supposed to occur twice a year would appear from our observations to occur sporadically during the year and detract from TNSC build or decline depending on timing. They may be in response to events such as good rainfall after a long dry period, fertilizer, hedging etc, but this is not always the case as in late summer 2017 in very dry conditions a large flush developed on the northern rivers possibly in response to a poorer crop. On the northern rivers we had small flushes during flowering in 2016 which would have competed with nut set. Where adequate irrigation is available flushing may be better controlled.

TNSC and sunshine hours

Irrigation management may also play a part in determining total stored TNSC as the volume and distribution of roots is greatly influenced by soil volumes irrigated.

Total sunshine hours appear to be significant in contributing to TNSC accumulation especially on the northern rivers and could be used as a predictive tool if sufficient data is collected. (Attachment 4)

There are some sites such as A 16 at Brooklet which have normal TNSC for As but which produce little or no nut and the reasons for this are not clear.

TNSC and fertiliser

The role of fertilizer in TNSC accumulation cannot be determined from these results as individual orchards had varying management. Measurements were made on a row of 816 receiving no fertilizer and values of TNSC were lowered but the effects of fertilizer timing and quantity are likely to be significant especially if they help to control flushing.

PAR data and observations

The PAR measurements show that no matter what the size of the tree once leaves are more than +_ 1m inside the tree there is unlikely to be enough light for photosynthesis. (Attachment 2)

Modelling of this for a free standing tree as it grows in height and spread has shown that at about 15-20 years of age the unproductive canopy will exceed the productive canopy and yields decrease. This decrease in the production of older orchards was reported in the statistics some 15-20years ago as large numbers of orchards passed the age of 15 but was not recognized as significant.

An important factor which receives little attention is that these large, high and unproductive canopies require large quantities of energy simply to maintain themselves and draw water up to heights not normally seen in producing fruit trees.

If trees are to close in the row the sides of a free standing tree are lost as they grow and once hedged the other side is also lost and only a crown remains, presenting a limitation on the productive canopy.

Observations and conclusions

Because of the large number of varieties, fertilizer regimes, irrigation management and insect and disease control in this project and given the differences between them no clear conclusions on the relationship between TNSC and crop or factors can be made.

However, the following is a conclusion that is plausible when all the information is taken as a whole.

1. The data show that flushing draws down TNSC and if it occurs at the wrong time then TNSC build is interrupted or drawdown increased.
2. This may be the reason the A varieties have lower TNSC as except for A 38 they all tend to flush frequently during the year.
3. We know that trees have large reserves and take a long time to show decline or recovery if they are allowed to go into decline.
4. Current fertilizer recommendations are to split fertilizer into a minimum of four applications coinciding with cropping cycles – flowering, nut sizing, oil formation and recovery. This strategy may be need to be reviewed to take into account management of flushing.
5. Only the outer meter of the canopy receives enough light for active photosynthesis.
6. A large flush in late summer/early autumn will cover the exterior of the tree in freshly hardened foliage capable of producing energy at the critical time for TNSC build coming into the cooler months of the year and there is anecdotal information that this leads to a good crop.
7. Application of a significant proportion of the fertilizer (with water) to generate this flush on an annual basis in March/April may prevent some or all of the small flushes during the year. The old recommendation to apply all the fertilizer just before winter so as not to generate flush suggests that fertilizer timing and quantity may in fact be a tool to generate a reliable flush in late summer autumn when we know bud initiation is also taking place.

Two findings are contrary to current thinking about what part of the annual cycle consume the most energy:

8. Results indicate that flushing consumes more energy than flowering!
9. The early minimums in TNSC in December in many sites suggest that oil formation may not consume as much energy as nut growth! This is earlier than found by Stephenson et al, is climate change playing a role?

If both these findings are correct then our current fertiliser recommendation times will need revision particularly if we also wish to manage flushing.

Significant investment will be required over time to understand all the factors involved in tree physiology but several factors such as temperature effects, light effects on photosynthesis and refinement of tree architecture and influence of fertilizer and water on flushing should be able to be investigated in the short term.

Recommendations

Further funding to address the following issues is recommended

- The potential of TNSC to be a predictor of crop yields will only be determined by long term trials where adequate funding will allow accurate yield assessment (individual tree harvests).
- Trials to test whether treatments are available to influence TNSC either negatively or positively.
- Treatments to determine whether flushing can be influenced as there is anecdotal evidence that large flushes as occurred in 2014 are followed by large crops – large volumes of new growth may boost TNSC.
- Measurements of photosynthetic capacity as light decreases and temperature increases for each variety which will also be useful in the breeding program.
- Differences between cultivars for these parameters.
- Development of pruning techniques to maintain tree architecture as small open tress maximizing productive canopy as has been the case for many other fruit tree crops.
- This project has shown large differences between cultivars in TNSC accumulation but the reasons for this are not clear but may relate to some or all of the above, root volumes or major timber structures and needs to be understood.
- Sun hours appear to be valuable and simple to measure and there continue recording is recommended.
- Effects of irrigation management on root volume on TNSC.

These recommendations require significantly greater funding than the modest grower contributions to this project.

Scientific refereed publications

Nil

Intellectual property/commercialisation

No commercial IP generated.

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Acknowledgement

We gratefully acknowledge the financial contribution from Horticulture Innovation Australia which matched grower contributions that made the project possible.

We gratefully acknowledge the financial contributions made by the cooperating growers who made this project possible and the access to their properties for collection of samples and farm visits by other parties,

We also gratefully acknowledge the contribution by other growers who contributed funds when joining the project after the commencement and those whose orchards were used unfunded to fill perceived gaps.

Financial contributors – HIA matched funding.

- Alloway Macadamias – 1 site.
- Surrey Bogg – 1 site.
- Gray Plantations – 2 sites.
- Hancock Farm Company – 3 sites.
- Macadamia Farm Management – 1 site.
- Steinhart Family Farms -2 sites.
- William Moore – 2 sites.
- MWT Foods – 2 sites.
- Richard Willis – 1 site.
- Other financial contributors.
- Alloway Macadamias – 1 site.
- David Berman – 2 sites.
- Fullerton Family Farms – 1 site.
- Scott Norval – 2 sites
- Keith Frederickson – 1 site.
- Surrey Bogg -1 site.

The work of collecting samples in Bundaberg was done by Ngarie Meyers and we gratefully acknowledge her valuable contribution

Appendices

1)Technical report.

2) Table of PAR readings.

3) Table of TNSC data.

4) Sunlight hours graph.

5) Summary graphs of both A and Hawaiian varieties by region.

6) Photographs of sampling procedure.

Project MC 13009: Total Non Structural carbohydrate testing in Macadamias

TECHNICAL REPORT

INTRODUCTION

Following an earlier project where TNSC was measured as part of a much larger project there was interest in the results which showed that TNSC increased from nut maturity up until flowering before falling as the crop grew and matured. If TNSC could be managed and this was an indication of potential crop then it was likely to be a valuable tool.

Because the original project used varieties different from those favoured today and tree spacing's were also different this project was initiated to investigate:

1. Was the general trend found earlier still valid?
2. Were routine laboratory methods still in use and easily adapted?
3. Practical reliable TNSC sampling techniques.
4. How did results compare with current varieties?
5. Could TNSC possibly be used as a crop predictor?

A comprehensive literature review was carried out as part of the project and found that;

a) TNSC was commonly used in many tree fruit crops and also in forestry to help explain on/off cropping and growth.
b) The main period of TNSC accumulation was found to be in the cooler months of the year when tree demands for energy (respiration and water uptake) were lower and there was no crop load.
c) A large proportion of TNSC reserves are stored in the fine root system, possibly as much as half while the rest was in major structural timber in a shallow layer under the vascular system. The importance of roots was a major addition to our knowledge.

Following discussion with leading growers 15 sites were sponsored by 9 growers with funding for a project to investigate the above matched by HIA. At various times a number of grower funded sites were added as growers became aware of the project or to try and fill perceived gaps in variety or representation of the industry. These sites increased the amount of data available and have contributed valuable information. No project funds were used for these sites.

Details of each site are in this report.

METHODOLOGY

At each site 50 trees were selected either in one long row or up to five short rows depending on block layout. At each site trees were numbered and five consecutive trees divided into ten blocks. At each sampling one of the five trees in every block was sampled moving through the block consecutively with trees being sampled up to seven times. Trees were sampled monthly using the following method.

Using a handheld rasp the bark of the tree was smoothed and debris removed to enable accurate depth measurements with a veinier calliper.

A 25mm spade bit was used to drill through the bark just removing the vascular layer.(Brown in colour) A foil tray was pinned to the tree below the hole to collect shavings which were drilled out to depth of 4mm (+-0.5mm) and the wound sprayed with a bitumen wound dressing. The shavings from the ten trees was composited . The drill bit was sterilised after each site with alcohol. Comments on tree health, flowering, flushing and nut set were recorded at every sampling which was on a monthly basis.

Photographic documentation of the procedure is in attachment 6.

The samples were kept refrigerated until drying at 60^0C. They were then finely ground before dispatch to the laboratory.

All sites were managed by co-operators and the only yield data was usually from whole farms or blocks.

The team visited all sites at least annually to try and assess yields but this information is variable as with 16m tall trees it is difficult to see clearly.

A PAR (photosynthetically active radiation) meter was purchased and used to measure light available for photosynthesis at 0.5m intervals from the top of the tree to a point where results were similar to ground level measurements.

This information was used to model the photosynthetically active portion of the tree.

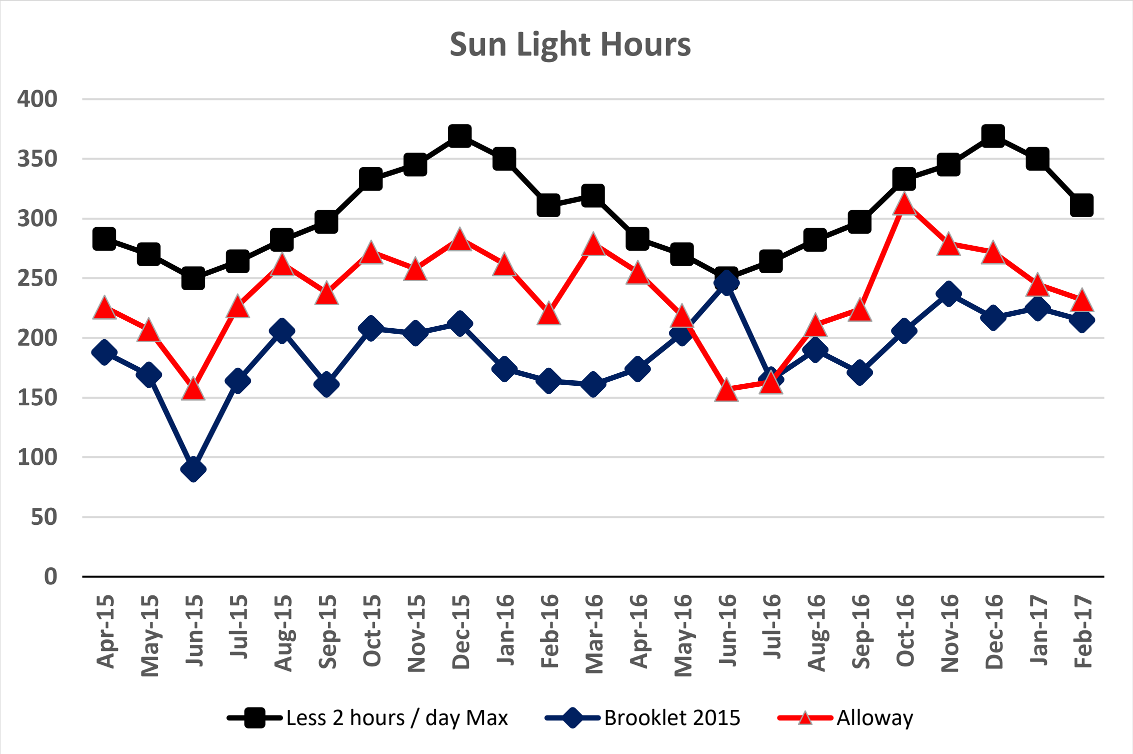
A sunshine duration sensor was used from early in the second year for both Bundaberg and the Northern rivers with readings taken every 30 seconds and recorded on a logger. Data was downloaded monthly and graphed. (Attachment 4)

RESULTS

Sunshine measurements.

The sensor used is able to accurately distinguish full sun from a cloud passing over so the values are a good measure of actual light available for photosynthesis.

The data are graphically displayed below. Potential sun hours are taken from Bureau of Meteorology sunrise to sunset data and have an hour at sunrise and an hour at sunset deducted from daily totals.

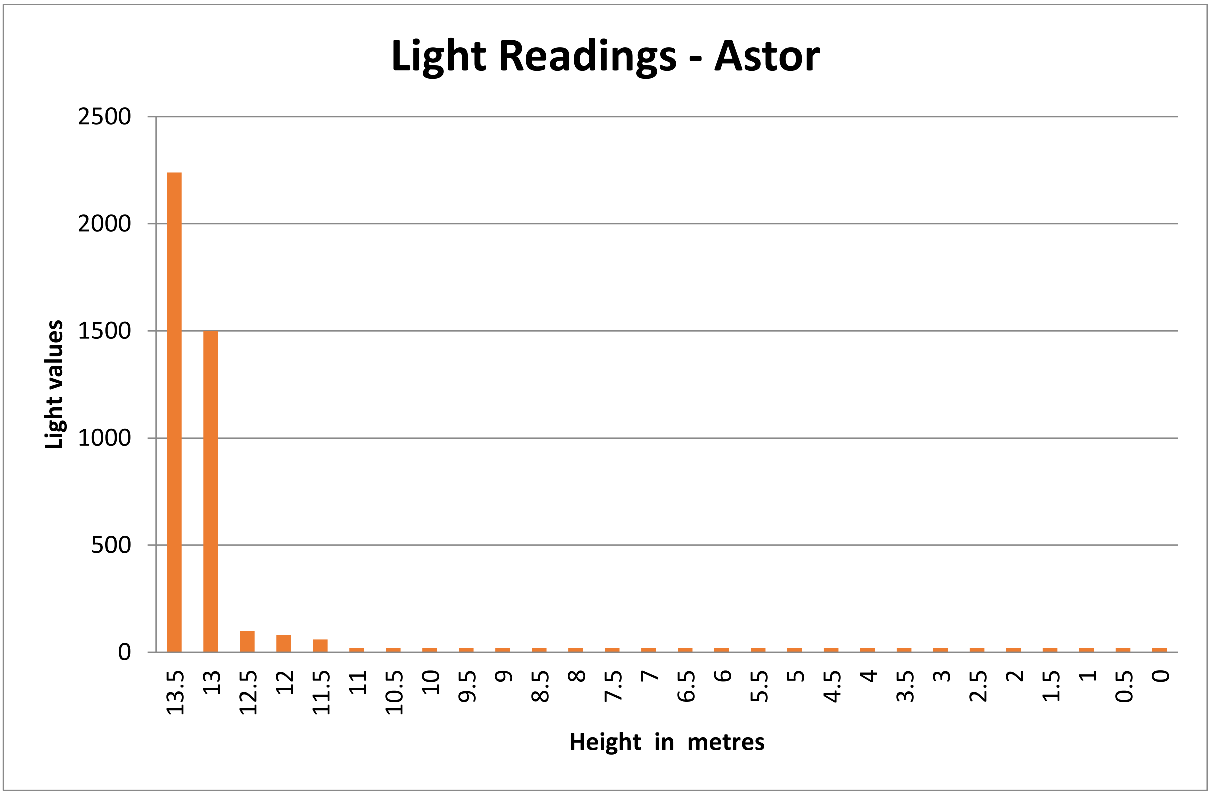


The Bundaberg area receives significantly more sun than the northern rivers and in both areas the potential sun hours have only occurred once in each district over the two years. Attachment 4 shows the actual sun hours.

PAR measurements.

The PAR readings from all sites are shown in attachment 2 and indicate a very rapid drop once 1 – 1.5m into the canopy is reached (it was not always possible to accurately determine the exact top of the canopy in the very large trees in many orchards). The literature indicates that below 500 µ mols $m^{-2}s^{+}$ there is not enough light for photosynthesis

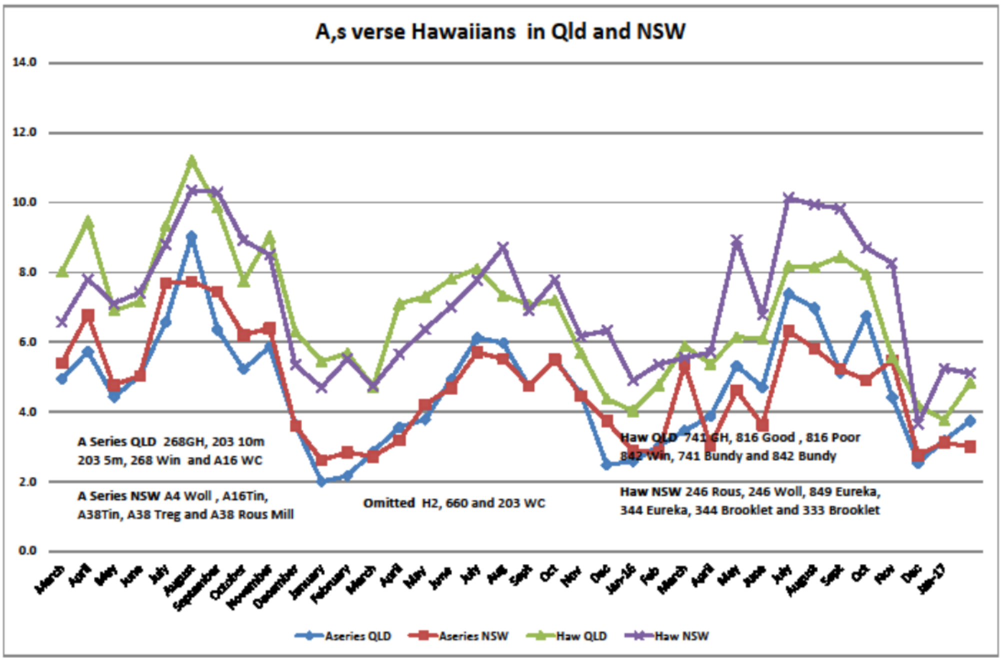
A graphical representation of a typical PAR reading through the canopy is shown below. Note the PAR interception in the top 1.5m of the canopy, and the dramatic drop in PAR past that point.



TNSC Data

Attachment 3 shows the tabulated results for percent TNSC monthly over the three years. The graphs of individual sites are in this report. Of particular note is the that the Bundaberg graphs are far more uniform on an annual basis than the northern rivers and this is possibly related to greater sun hours.

The graph below illustrates the difference in TNSC when Hawaiian varieties and Australian ("A") bred varieties are grouped together respectively and compared over a three year period. It is evident that the A varieties accumulate less TNSC, or perhaps they have a reduced ability to store TNSC in comparison to the Hawaiian varieties.



Site details

Northern Rivers

Site 1.

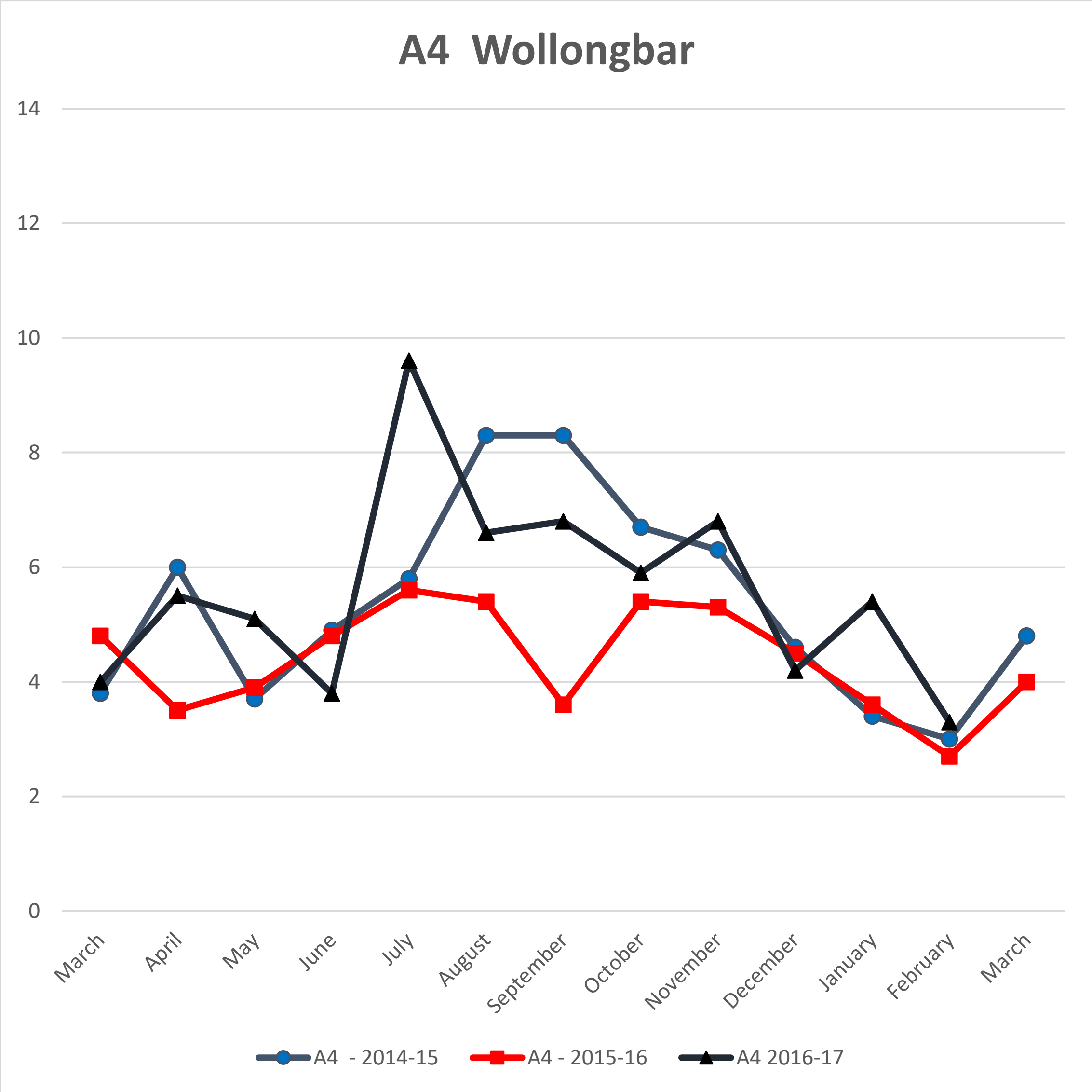
Area: Northern Rivers   Locality: Alstonville

Co operator: MWF

Variety: A4   Spacing: 7x3.5m   Age: 25

Yields 2015/ 5kg   2016/ 5 kg

Observations: The trees are very tall, annually hedged for light but are dark with nearly closed canopies and have produced very small crops during the project.



TNSC graphs are similar in all years except for a greater build in early winter in year 1 and a significant build winter 2016 when we had high sun hours. A significantly early minimum in December 2016.

Site 2.

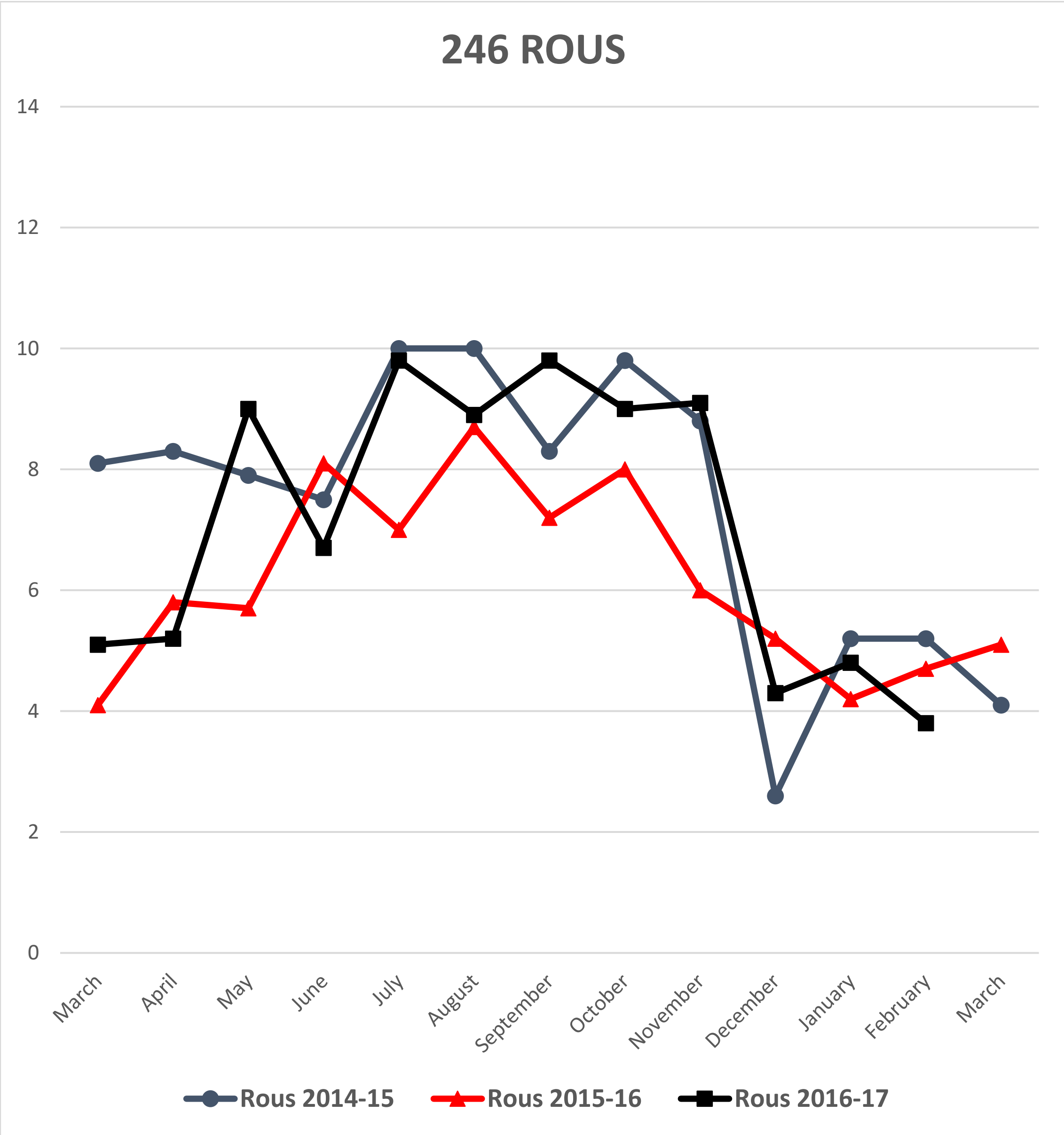
Co operator: MWT

Area: Northern Rivers Locality: Alstonville

Variety: 246 Spacing: 8x4m 0 Age: 30

Yields 2015/8kg 2016/5kg

Observations: The trees are tall, canopied over and quite dark despite annual hedging and have only produced very small crops.



The TNSC graphs show little variation between the 3 years but also have an early minimum in December 2016.

Site 3.

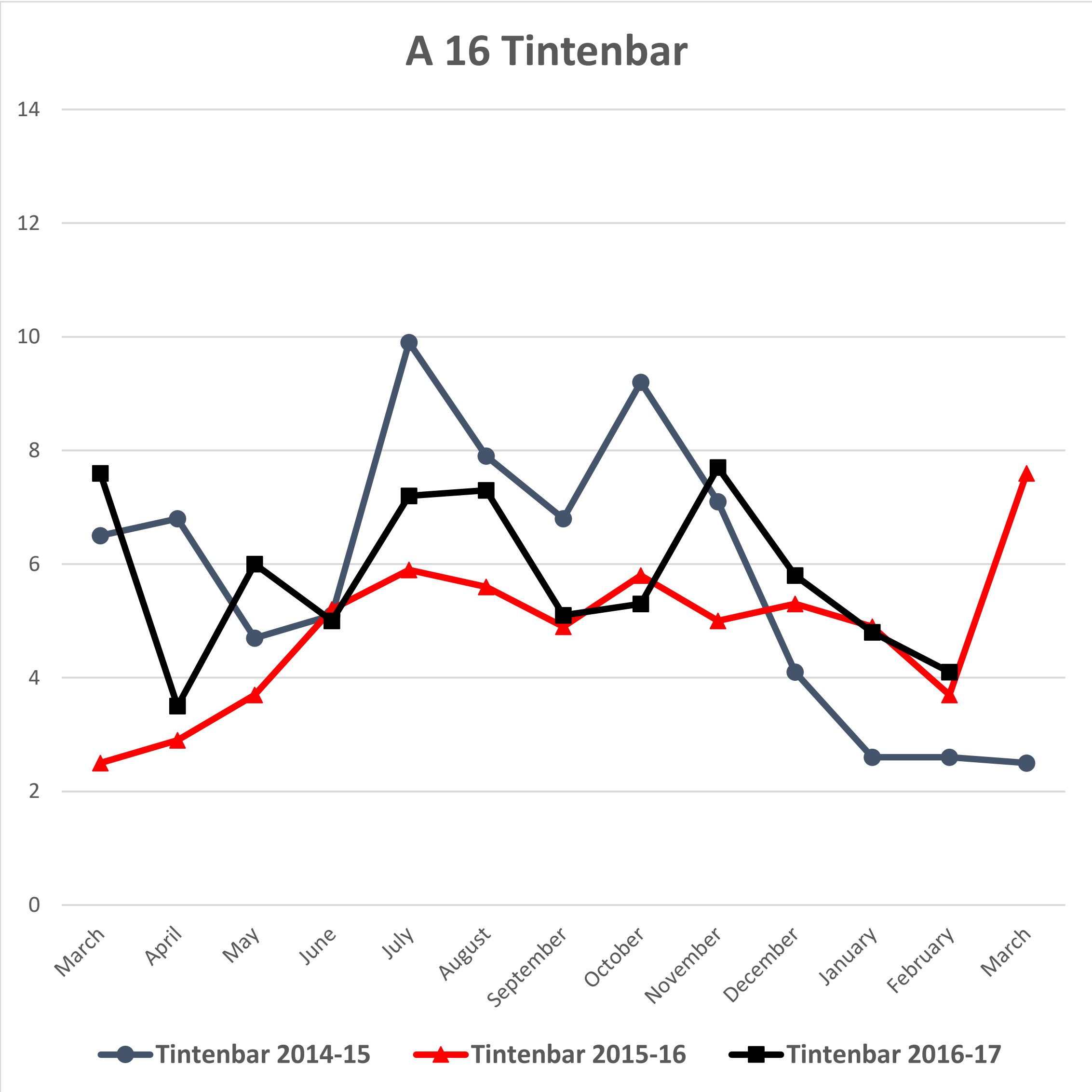
Co operator: William Moore

Area: Northern Rivers Locality: Tintenbar

Variety: A 16 Spacing: 9x4m Age: 20

Yields 2015/16kg 2016/2kg

Comments: The trees are healthy, dense and look very good with adequate light and annual light hedging but have produced almost no nut during the project.



The TNSC graphs are fairly similar but are higher in year 1 when the only crop of note occurred.

Site 4.

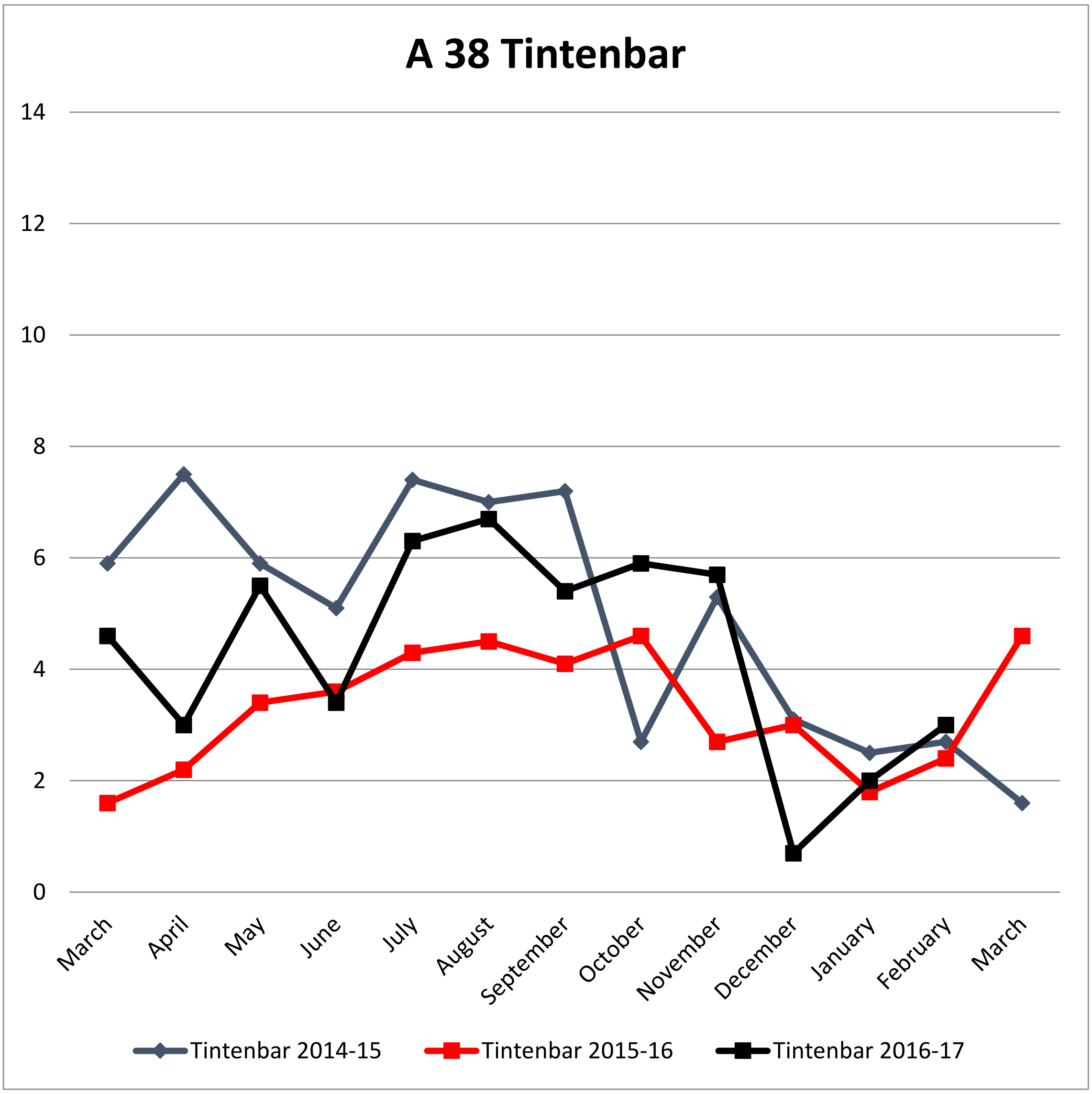
Co operator: William Moore

Area: Northern Rivers Locality: Tintenbar

Variety: A 38 Spacing: 9x4m Age: 16

Yields 2016/14kg 2016/8kg

Observations: The tree are open and have adequate light but a number of trees have deteriorated in health during the project but the better trees have yielded quite well.



The TNSC graphs are quite different in year 1 and 3 from year 2 with higher build but also an early minimum in December 2016.

Site 5.

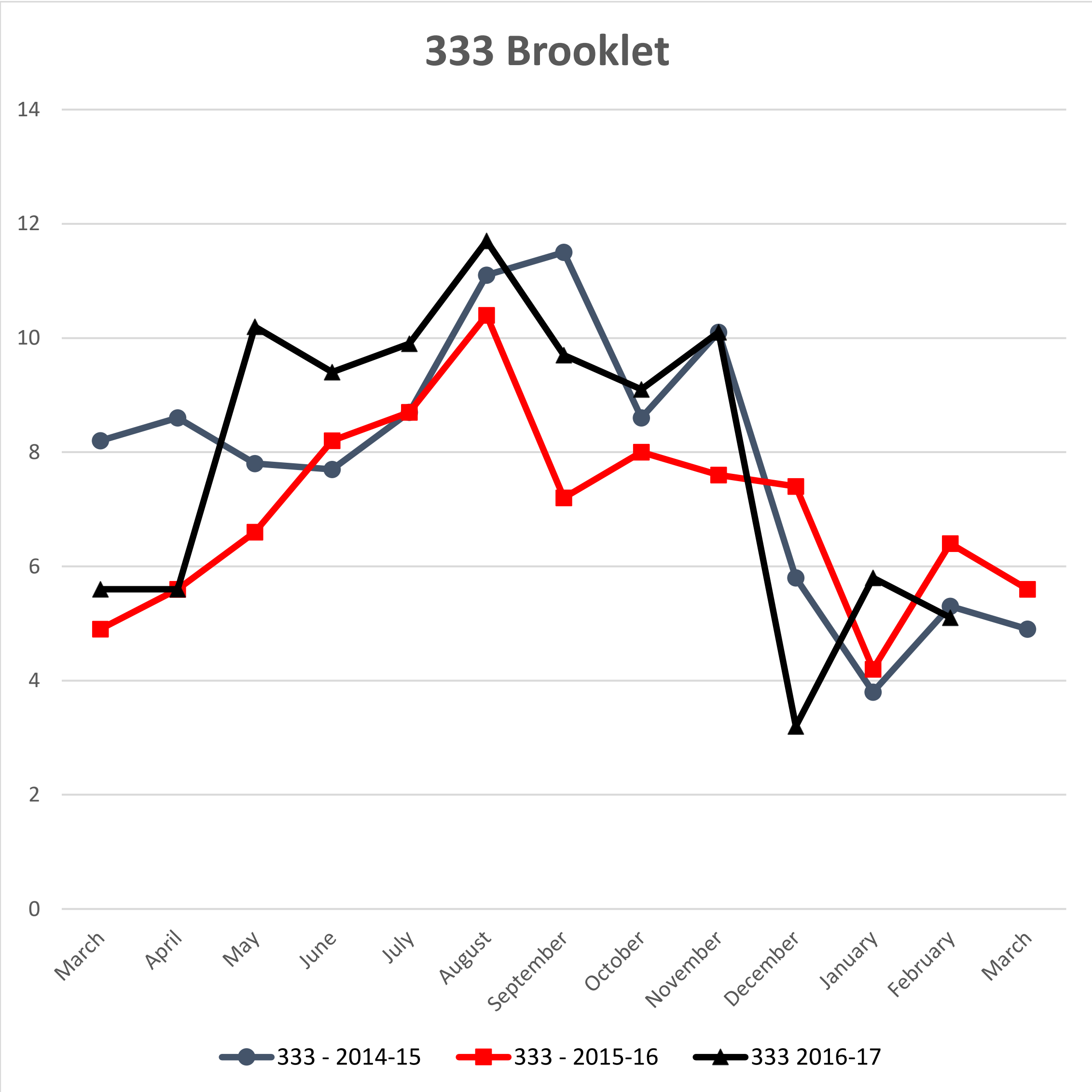
Co operator: Surrey Bogg

Area: Northern rivers Locality: Brooklet

Variety: 333 Spacing: 10x4m Age: 33

Yields 2015/15kg 2016/11kg

Observations: Very large trees with closed canopies but more open than some varieties and are good croppers.



The TNSC graphs are similar in all 3 years but have significantly more build in years 1 and 3 but an early minimum in year 3. The build in yr 3 also occurs earlier.

Site 6.

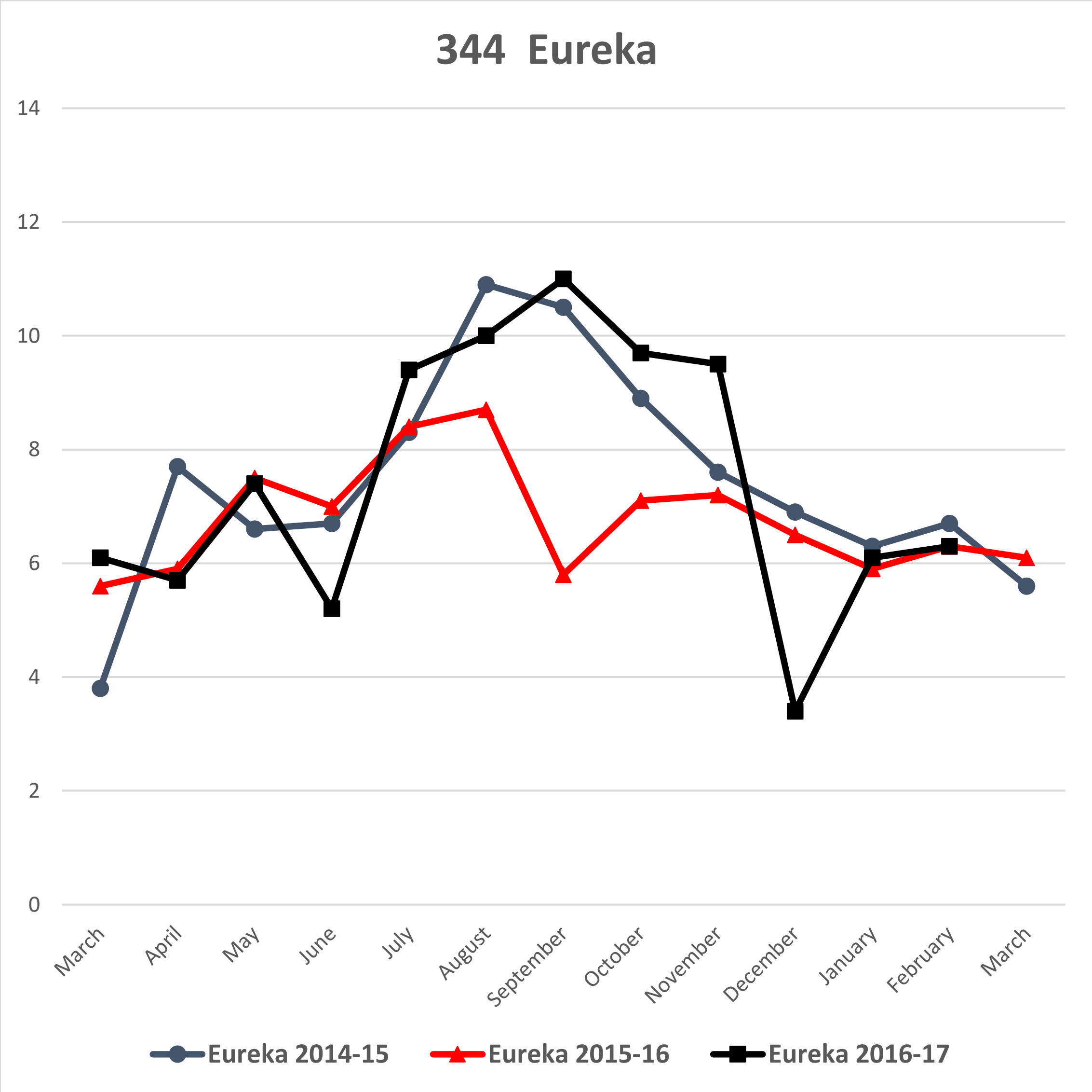
Co operator: Gray Plantations

Area: Northern Rivers Locality: Eureka

Variety: 344 Spacing: 10x4 Age: 26

Yields 2015/12kg 2016/10kg

Observations: Very large healthy trees, annually hedged in the same place to maintain light and cropping reasonably. Farm sold during the second year, hedging has stopped and trees are growing out to closed canopies with reduced cropping.



The TNSC graphs show a much greater build in the first and last years which we know may be due to increased sunlight in the third year, The final year also has an early minimum compared to the other two years which was considered normal.

Site 7.

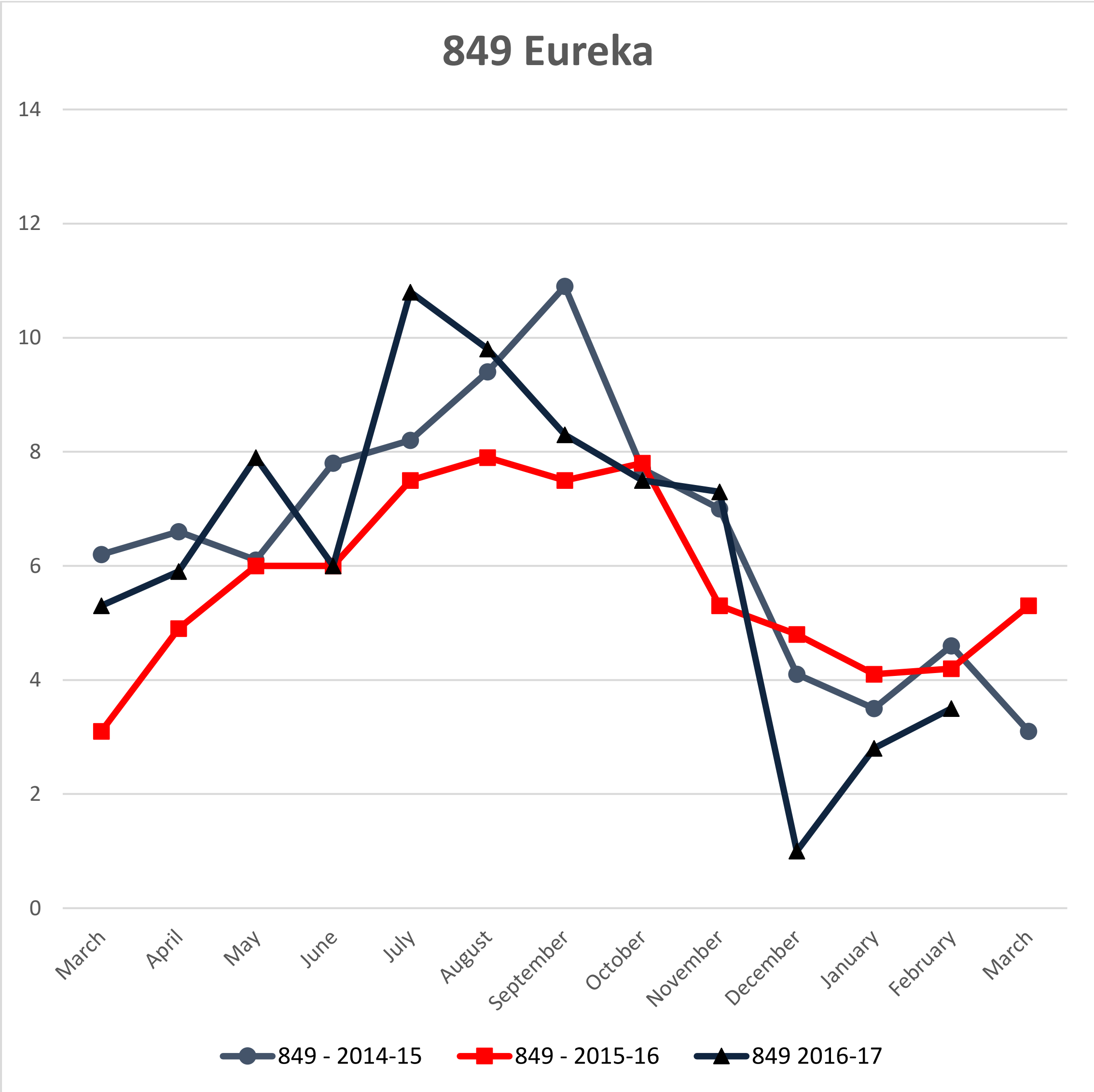
Co operator: Gray Plantations

Area: Northern Rivers Locality: Eureka

Variety: 849 Spacing: 9x4m Age: 20

Yields 2016/10kg 2016/7kg

Observations: The site is steep with erosion and tree health is slightly affected. Being younger light is not affected and crops have been reasonable.



The TNSC graphs are similar in the three years but have higher build in first and third years which is earlier in year I and has an early minimum in year 3.

Site 8.

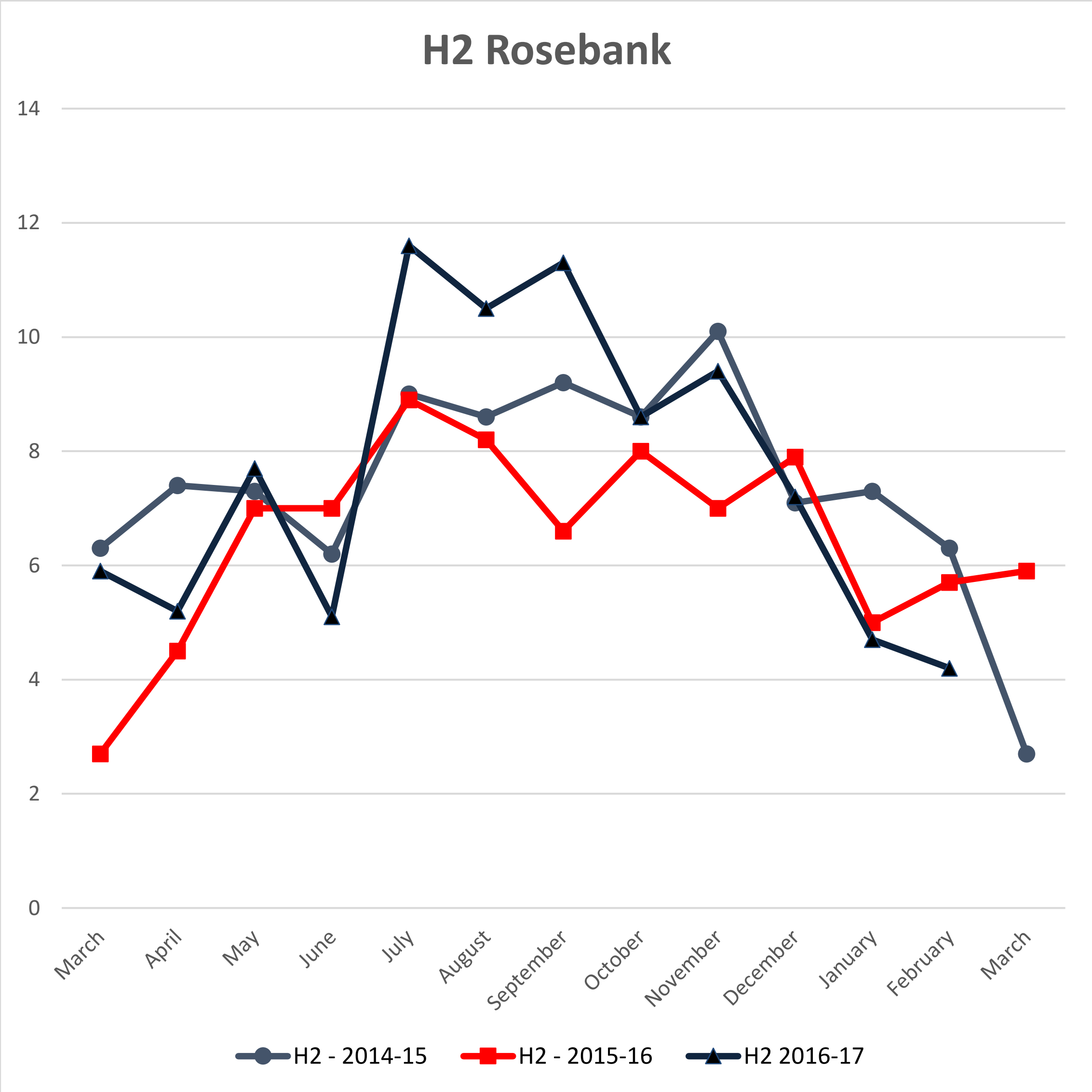
Co operator: Richard Willis

Area: Northern Rivers Locality: Rosebank

Variety: H 2 Spacing: 10x5m Age: 35

Yields 2015/16kg 2016/20kg

Observations: Very large fairly open trees which have previously been severely pruned but are now slowly canopying over . Appear to be alternate bearing with a very big crop in the second year.



The TNSC graphs are similar in years 1 and 2 but have a much greater build in year 3 with a poor crop.

Site 9.

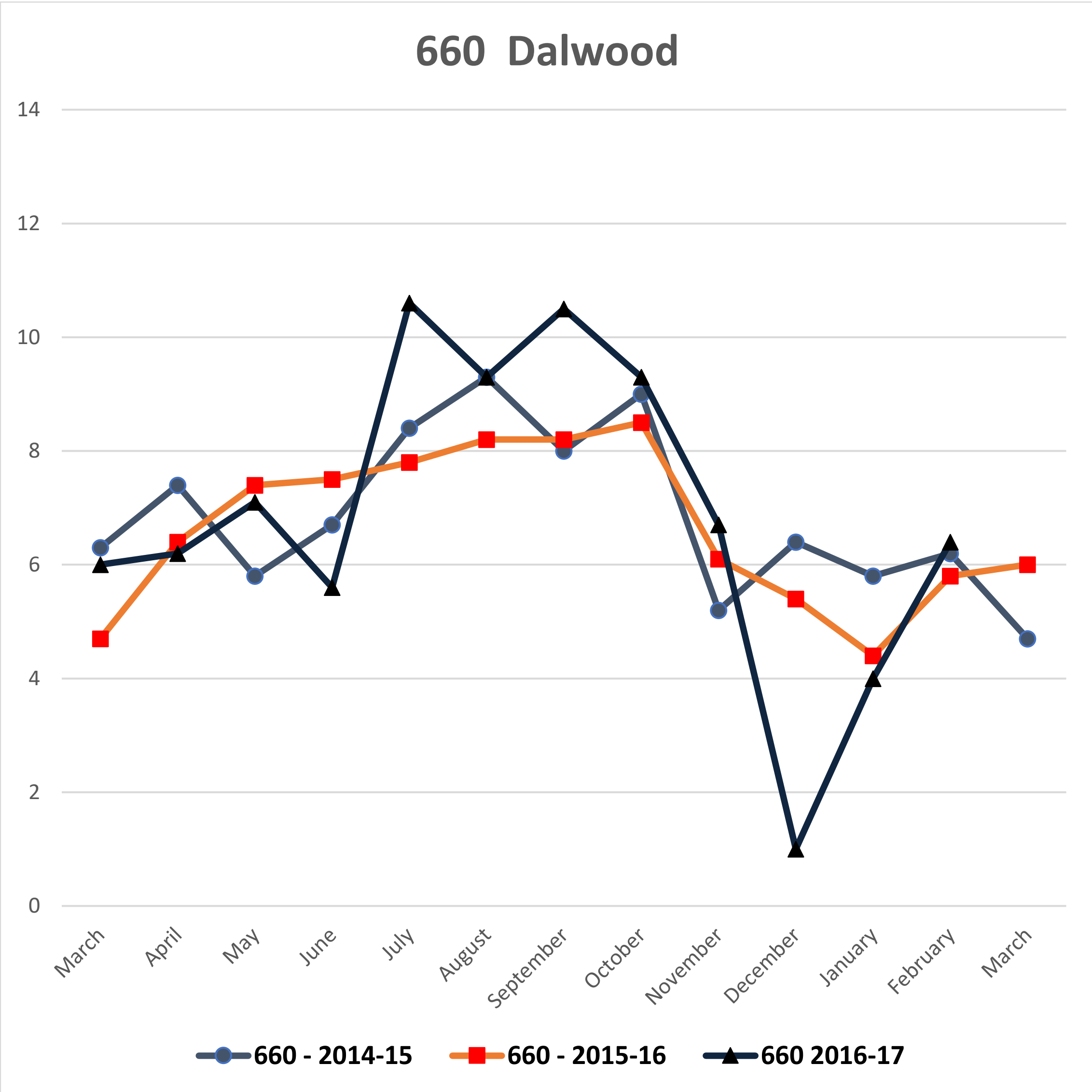
Co operator: David Berman

Area: Northern Rivers Locality: Dalwood

Variety: 660 Spacing: 8x5m Age: 35

Yields 2015/20kg 2016/15kg

Observations: Very large healthy trees which were fairly dark, every second tree removed in second year and then row removal before the third year. Extra trees added after tree removal and totally relocated for the last year. This orchard has consistently yielded +_ 20kg NIS/ tree.



The TNSC graphs are very similar for all years with a greater build in year 3 and a very early minimum.

Site10.

Co operator: Surrey Bogg

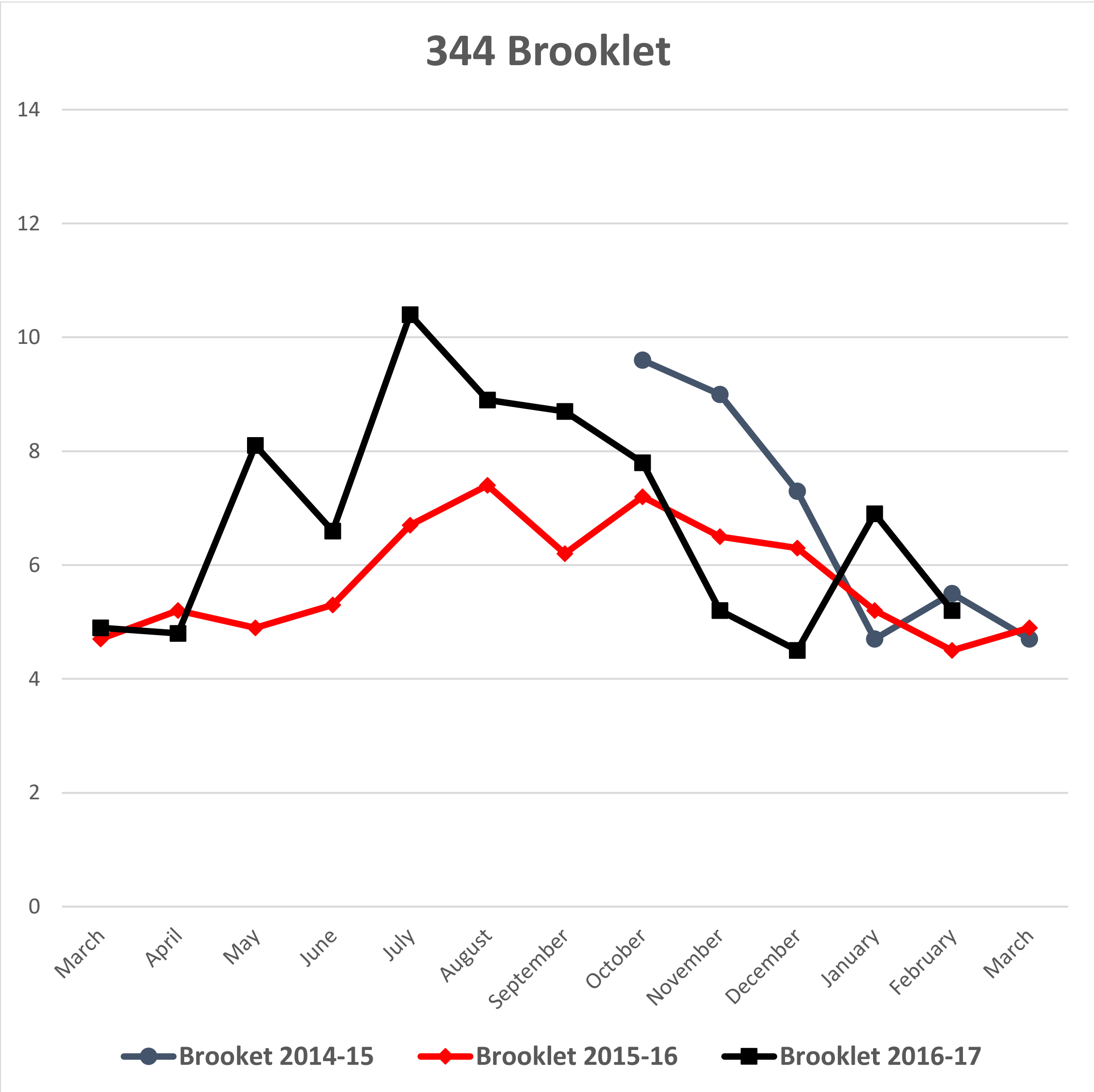
Area: Northern Rivers Locality: Brooklet

Variety: 344 Spacing: 7x3.5m Age: 25

Yields 2015/15kg 2016/10kg

Observations: This site is more typical of many on the northern rivers and are very tall trees with closed canopy and very dark, all active canopy only a crown on top.

Healthy but only producing small crop. Commenced during the second year.



TNSC graphs are similar for the two years but a much greater build in the last year and an early minimum.

Site 11.

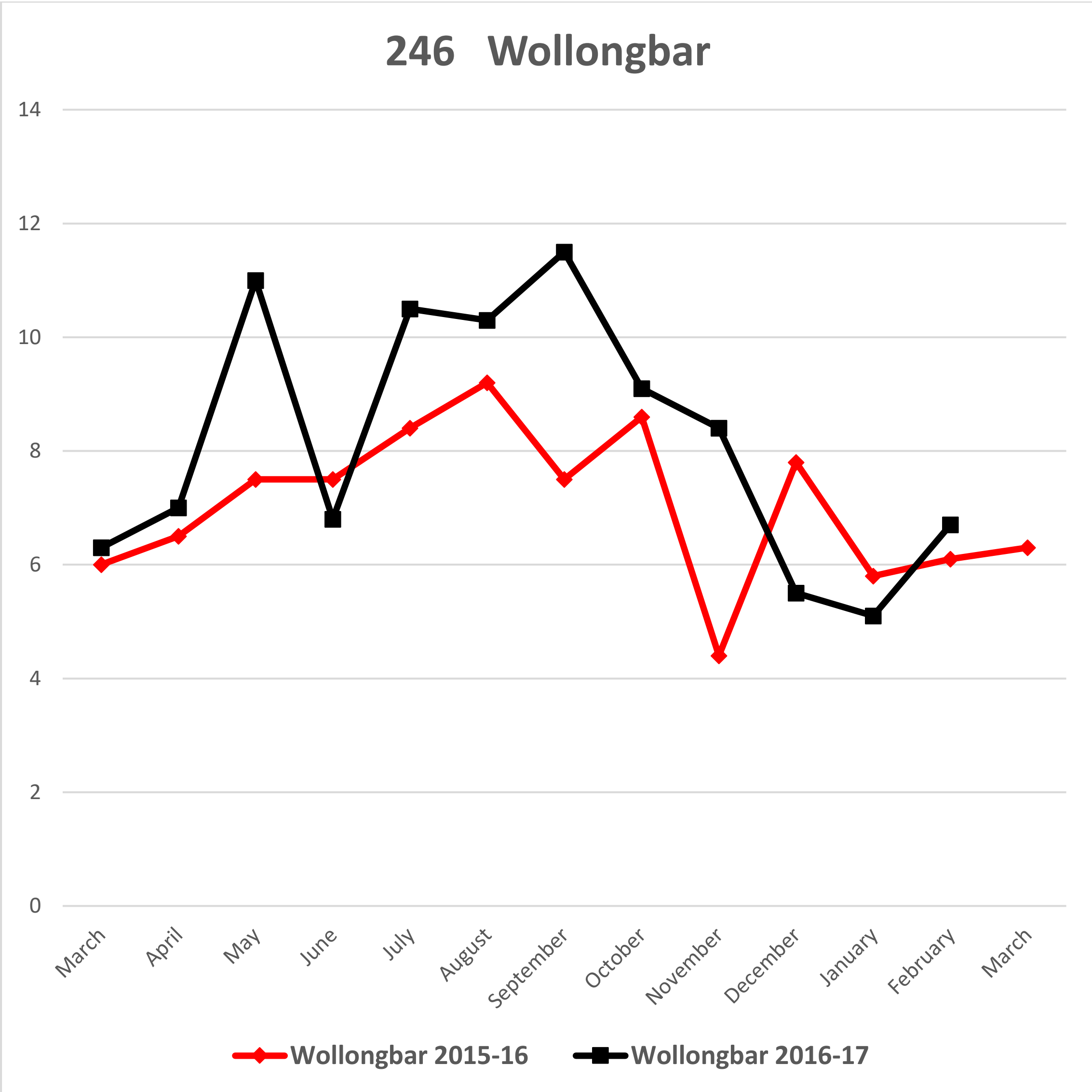
Co operator: David Berman

Area: Northern Rivers Locality: Wollongbar

Variety: 246 Spacing: 10x5m Age: 40

Yields 2015/20kg 2016/15kg

Observations: Very large trees which have consistently produced +_ 20kg NIS/tree. Trees are healthy and occasional hedging maintains some light, typical of many older orchards. Only commenced during the second year.



The TNSC graphs have a large build in the second year and show the effects of a large flush in the first year.

Site 12.

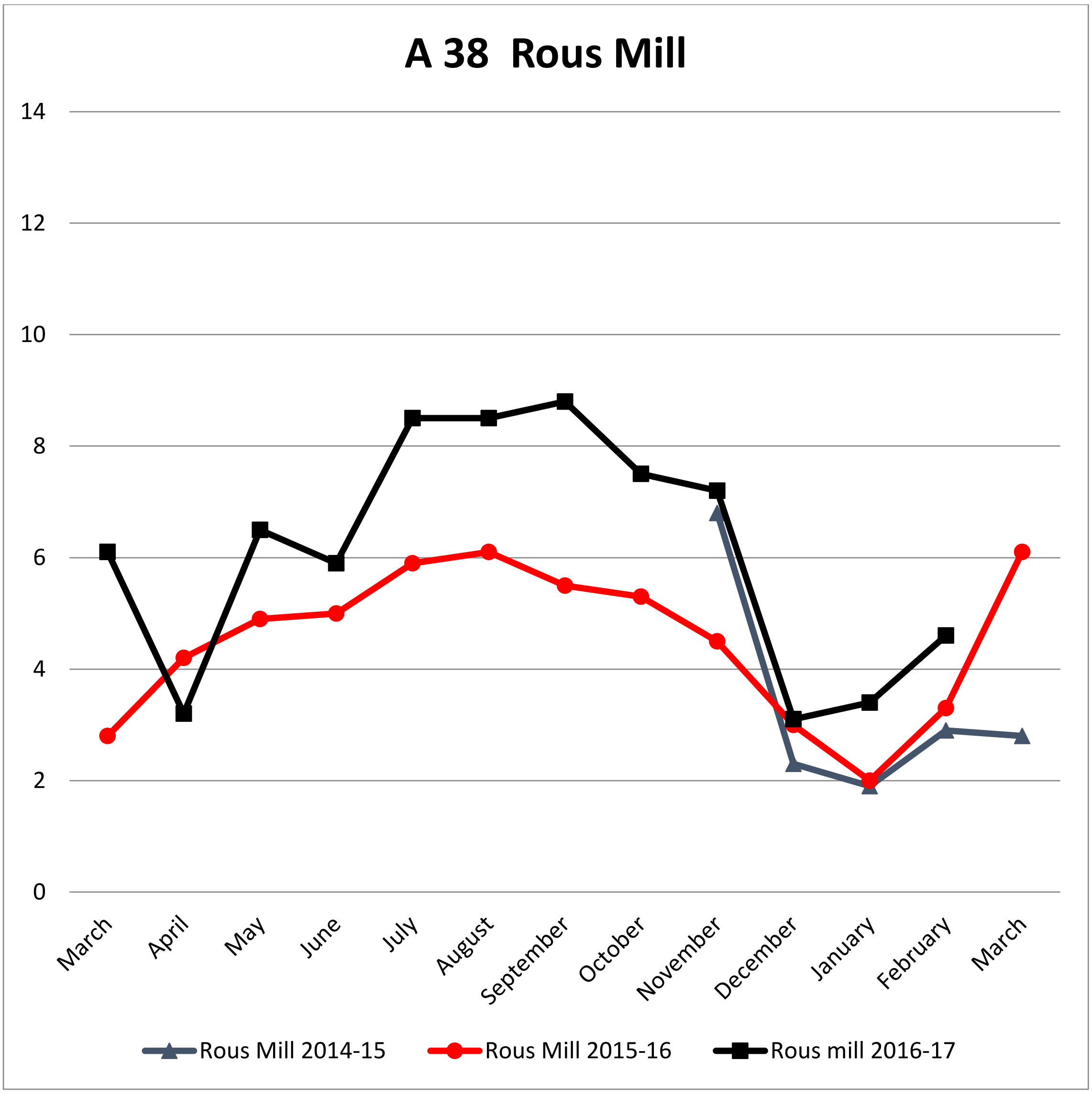
Co operator: Keith Frederickson

Area: Northern Rivers Locality: Rous Mill

Variety: A 38 Spacing: 10x5m Age: 16

Yields 2015/15kg 2016/20kg

Observations: Smaller healthy trees with a typical open canopy and producing large crops consistently. Only commenced during the second year.



Graphs show a greater build in the second year but also an early minimum.

South Queensland

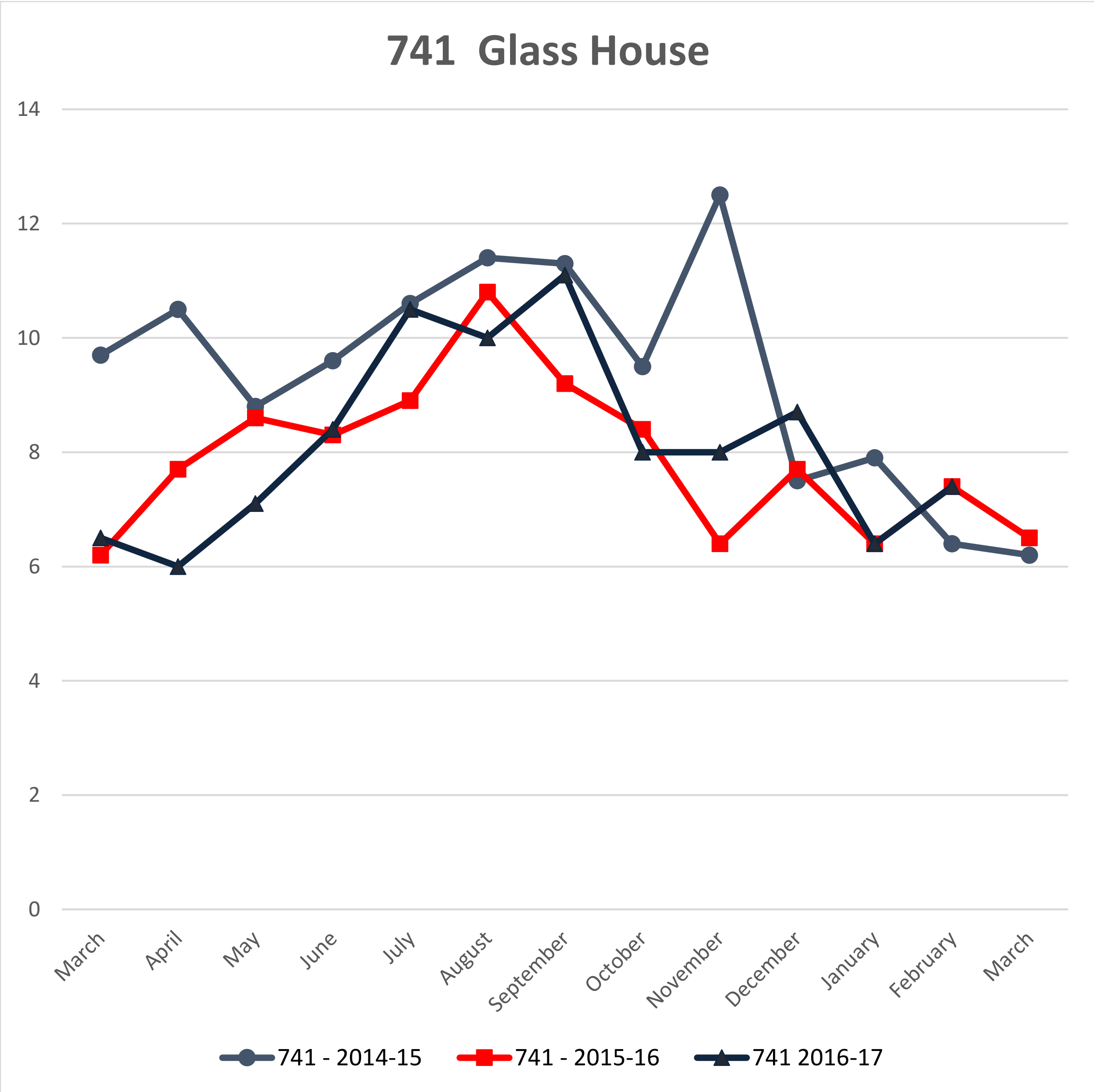
Site 1 Co operator: Mike Cooper

Area: Glasshouse Mts Locality: Elimba

Variety: 741 Spacing: 7x4 Age: 30

Yields 2015/10kg 2016/8kg

Observations: Well grown trees which are biannually hedged and while tight are not canopied over. The farm produces consistently good crops depending on moisture as the sandy soils suffer moisture stress. The site chosen was a poorer performer due to being wet.



TNSC graphs are more consistent in the three years.

Site 2.

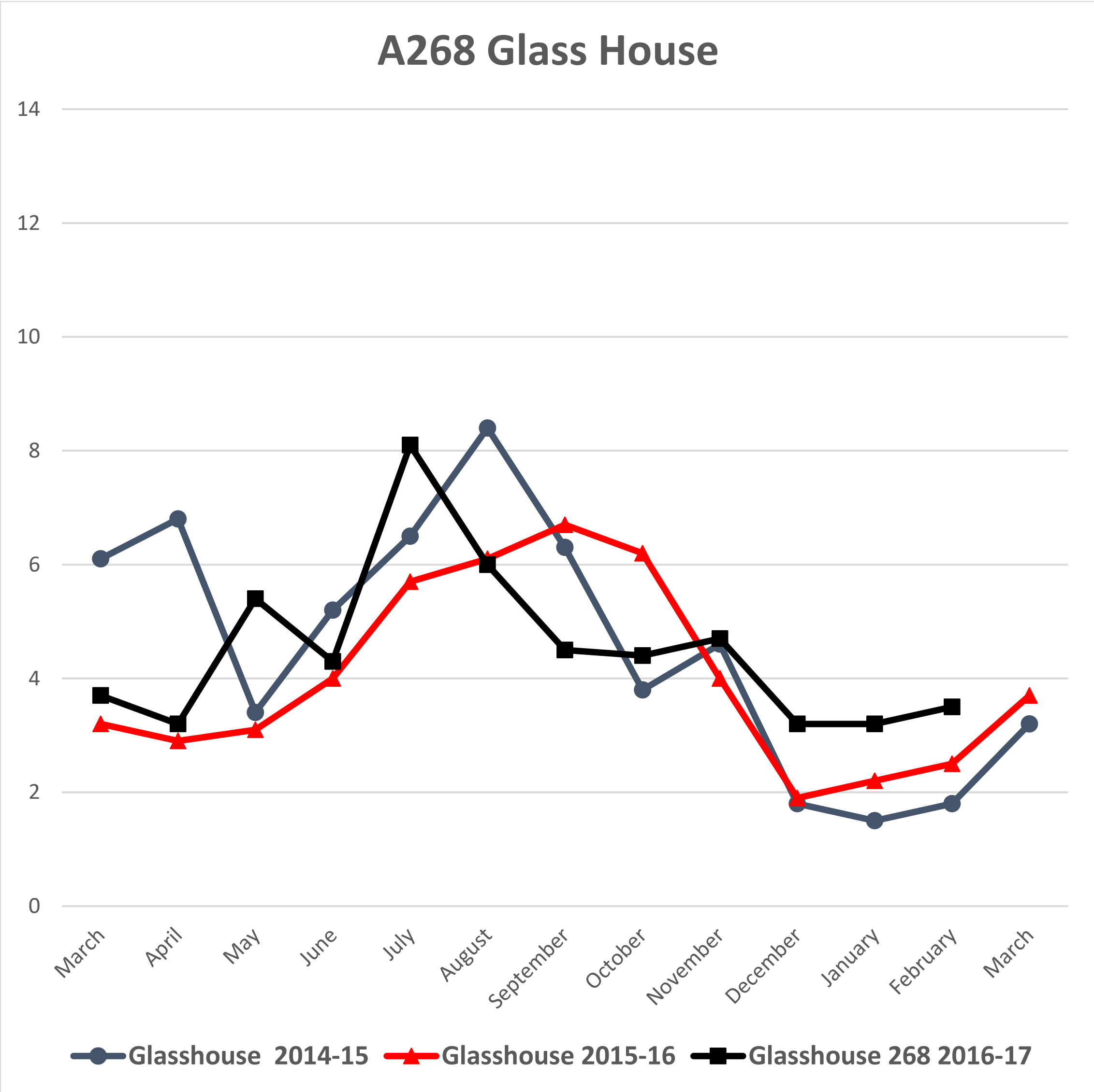
Co operator: Fullerton Family Farms

Area: S.E.Qld Locality: Glass House

Variety: 268 Spacing: 8x4 Age: 15

Yields 2015/11kg 2016/8kg

Observations: Smaller trees with plenty of light. Vigorous and heavy flowering but not particularly heavy croppers.



Very similar TNSC graphs in all years.

Wide Bay Qld

Site 1

Co operator: Alloway Macadamias

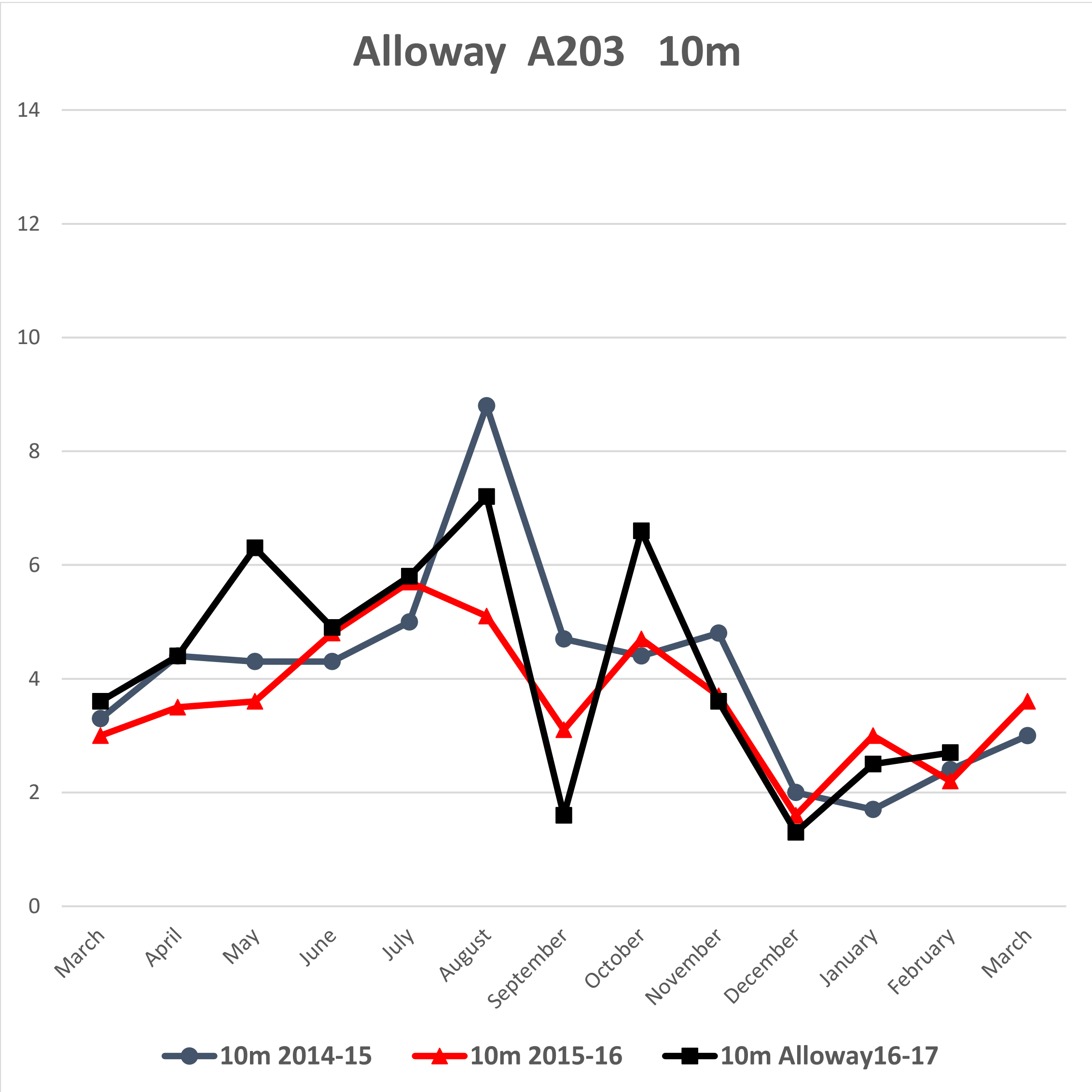
Area: Bundaberg   Locality: Sth Bundaberg, Alloway

Irrigation: Drippers

Variety: 203   Spacing: 10x2m   Age: 10

Yields   2016/5kg   2016/2kg

Observations: Planted at 5x2 m and thinned to 10x2 before the trial commenced. The trees are still limited by the close spacing in the row and have never produced good crops.



TNSC graphs are fairly even over all years but show a minimum in December for all years.

Site 2.

Co operator: Steinhart Family Farms

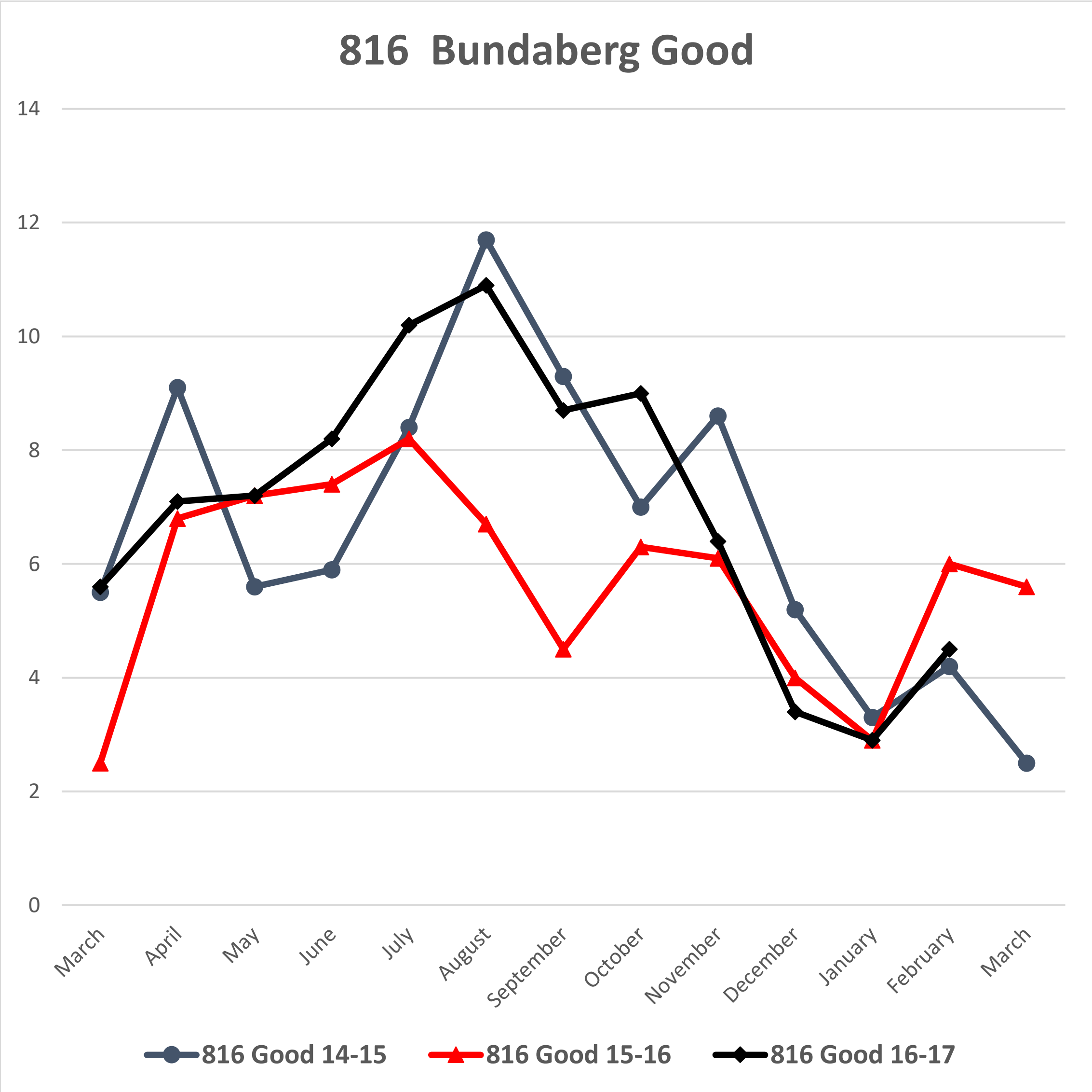
Area: Bundaberg Locality: Sth Bundaberg, Alloway

Irrigation: Sprinklers

Variety: 816, Good Spacing: 8x4m Age: 10

Yields 2015/11kg 2016/9kg

Observations: Fairly open, sticky tress with light leaf cover producing moderate annual crops.



The TNSC graphs have a marked difference between years 1&3 and year 2. Sun hours April/Aug were similar for both years but the second year started from a significantly lower level than the first and third and this may be significant.

Site 3.

Co operator: Steinhart Family Farms

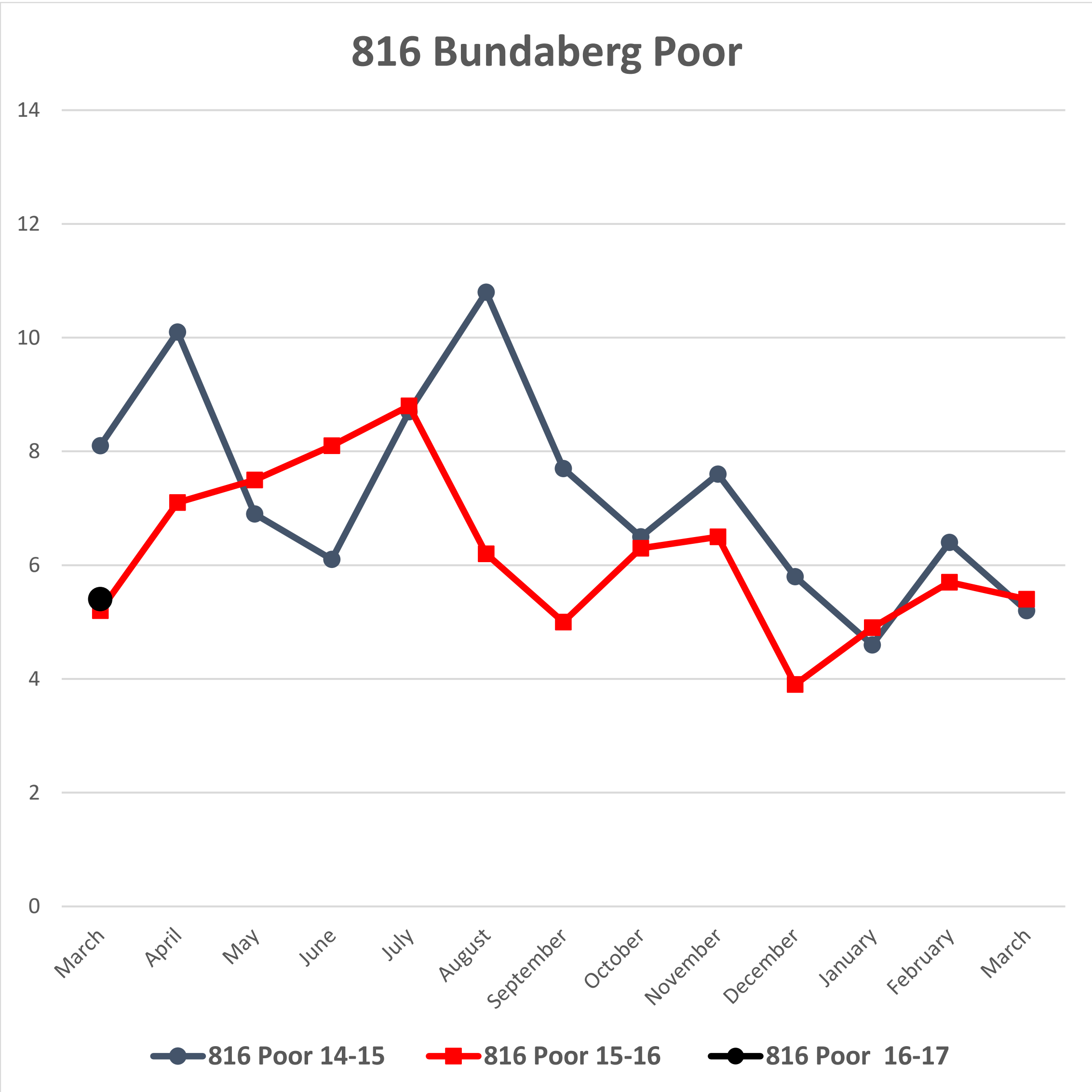
Area: Bundaberg Locality: Sth Bundaberg, Alloway and

Irrigation: Sprinklers with slightly poorer coverage in yr 1 but corrected. New site is dripper.

Variety: 816, poor/741 Spacing: 8x4 Age: 10

Yields 2015/10kg 2016/9kg

Observations: Near site 2 but yielding poorly due to unknown factors but improving by year 2 so as to be similar to site 2. Replaced by new site with 741 in last year. The latter has good healthy dense trees of similar age and is yielding well.



Site 4.

Co operator: Macadamia Farm Management

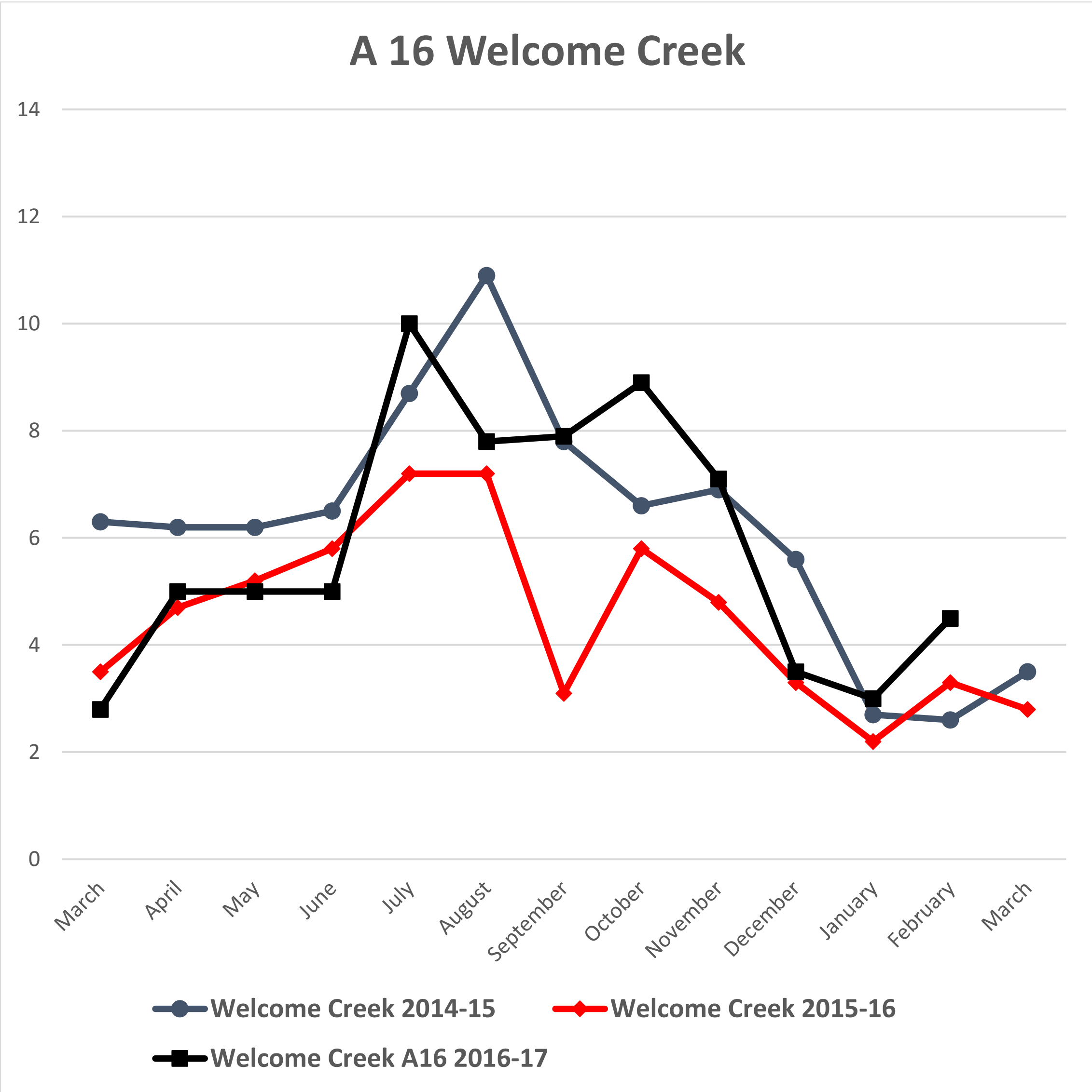
Area: Bundaberg Locality: Nth Bundaberg, Welcome Creek

Irrigation: Sprinklers

Variety: A 16 Spacing: 8x4m Age: 15

Yields 2015/16kg 2016/12kg

Observations: Fairly large open trees at commencement but becoming denser by year 3 due to management. Good cropper but possibly less so at finish due to light.



The TNS graphs also show a difference between years 1&3 and year 2 with year 3 having a dramatic build in early winter. Minimums also occur earlier in December/January.

Site 5.

Co operator: Hancock Farming Company

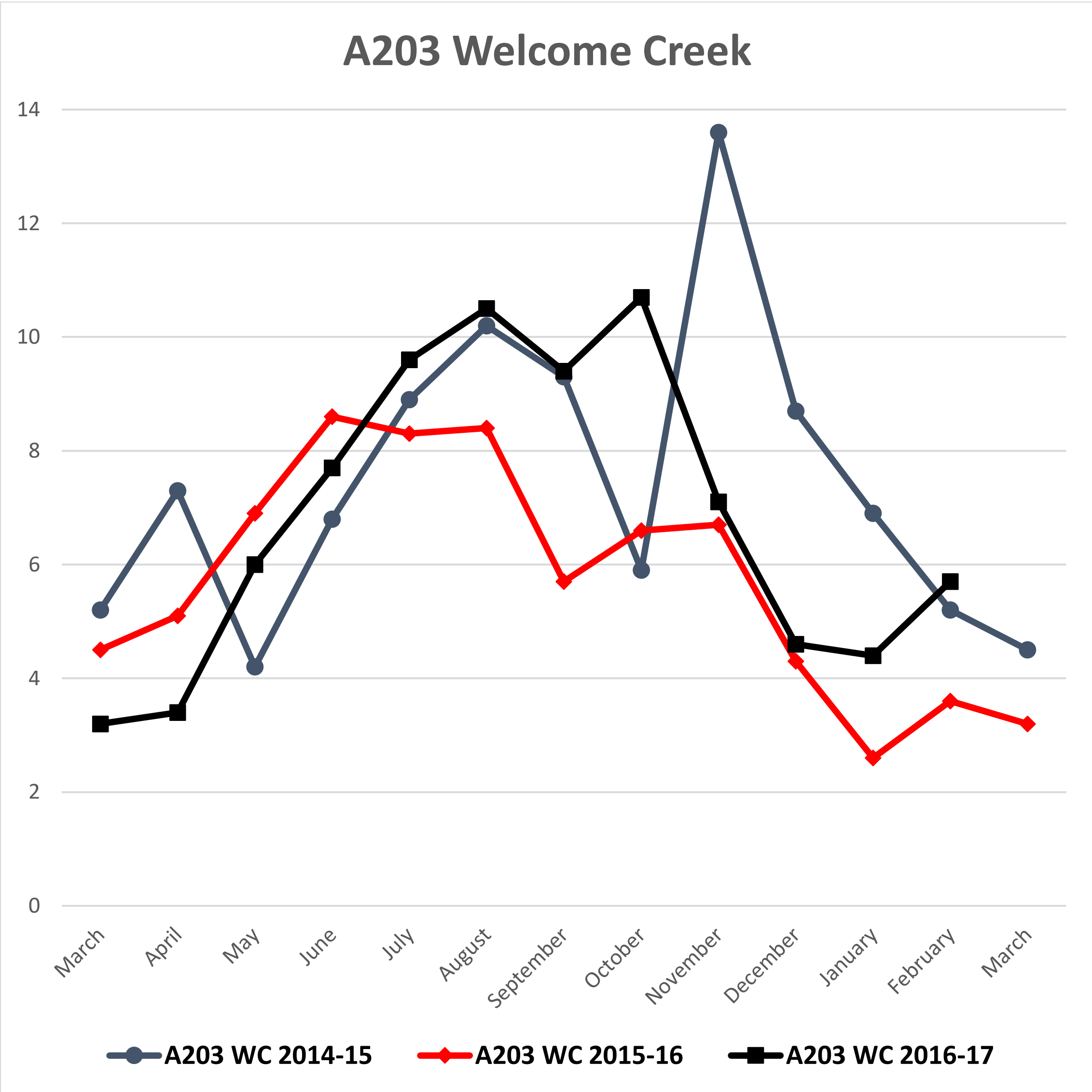
Area: Bundaberg Locality: Nth Bundaberg, Welcome Creek

Irrigation: Sprinklers

Variety: 203 Spacing: 8x4m Age: 16

Yields 2016/10kg 2016/8kg

Observations: Moderately large trees with good leaf and some hedging for access and cropping well at commencement but declining in health over time. Mixed variety row corrected in Feb 2015.



The TNSC graphs are more even with only a small difference in winter but an unusual build in November the first year.

Site 6.

Co operator: Hancock Farm Company

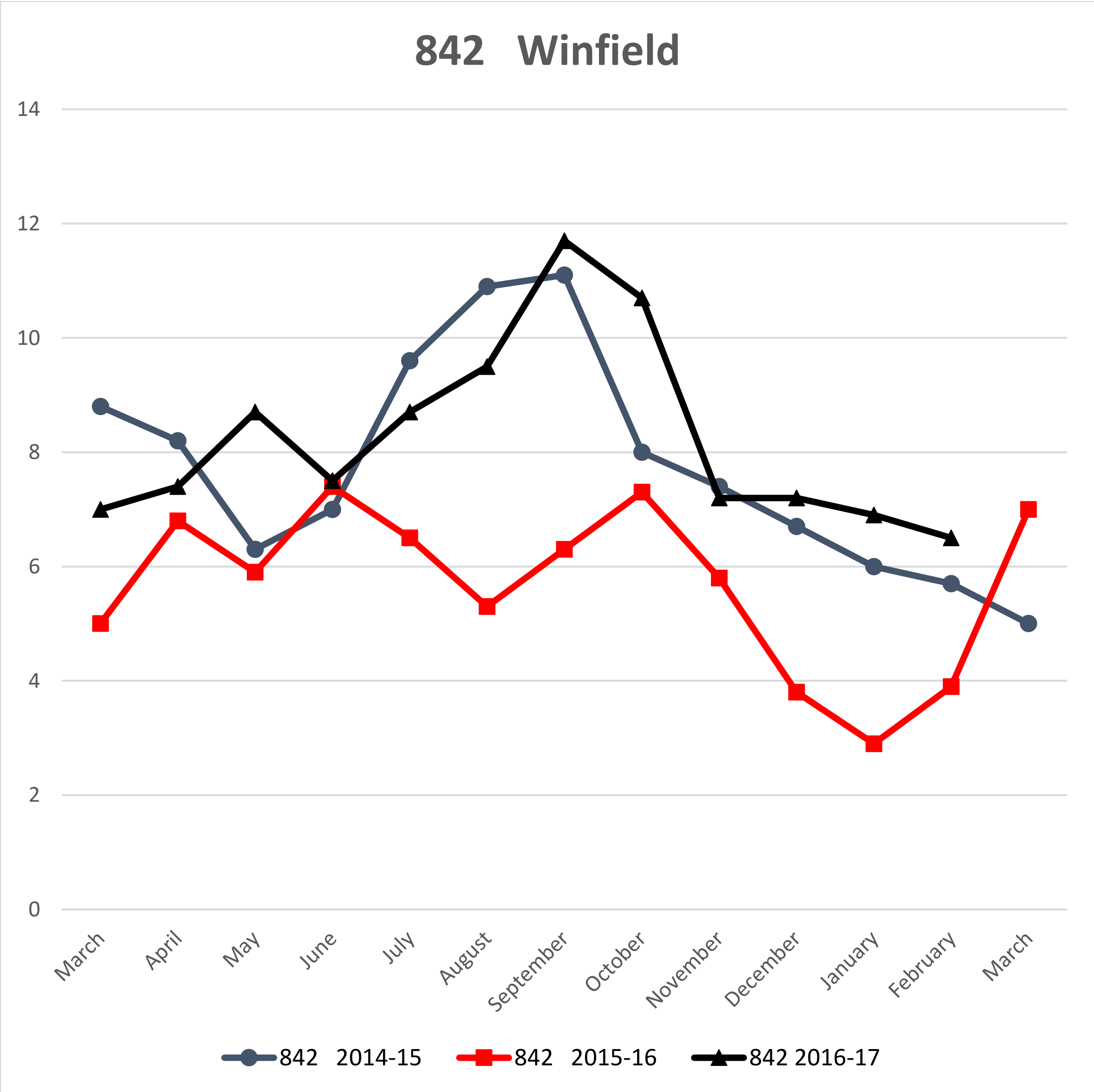
Area: Bundaberg Locality: Winfield

Irrigation: Drippers

Variety: 842 Spacing: 7x3.5m Age: 15

Yields 2015/10kg 2016/8kg

Observations: Well grown trees with good leaf cover and vigorous requiring hedging for access and cropping moderately. Tree health deteriorated by year 2 due to poorly drained soil and the site was relocated across headland to healthy trees at the beginning of the 3rd year.



The TNSC graphs also show a large difference in year 2 in build over winter and a much greater fall in summer. The minimum occurs very early in year 3.

Site 7.

Co operator: Hancock Farm Company

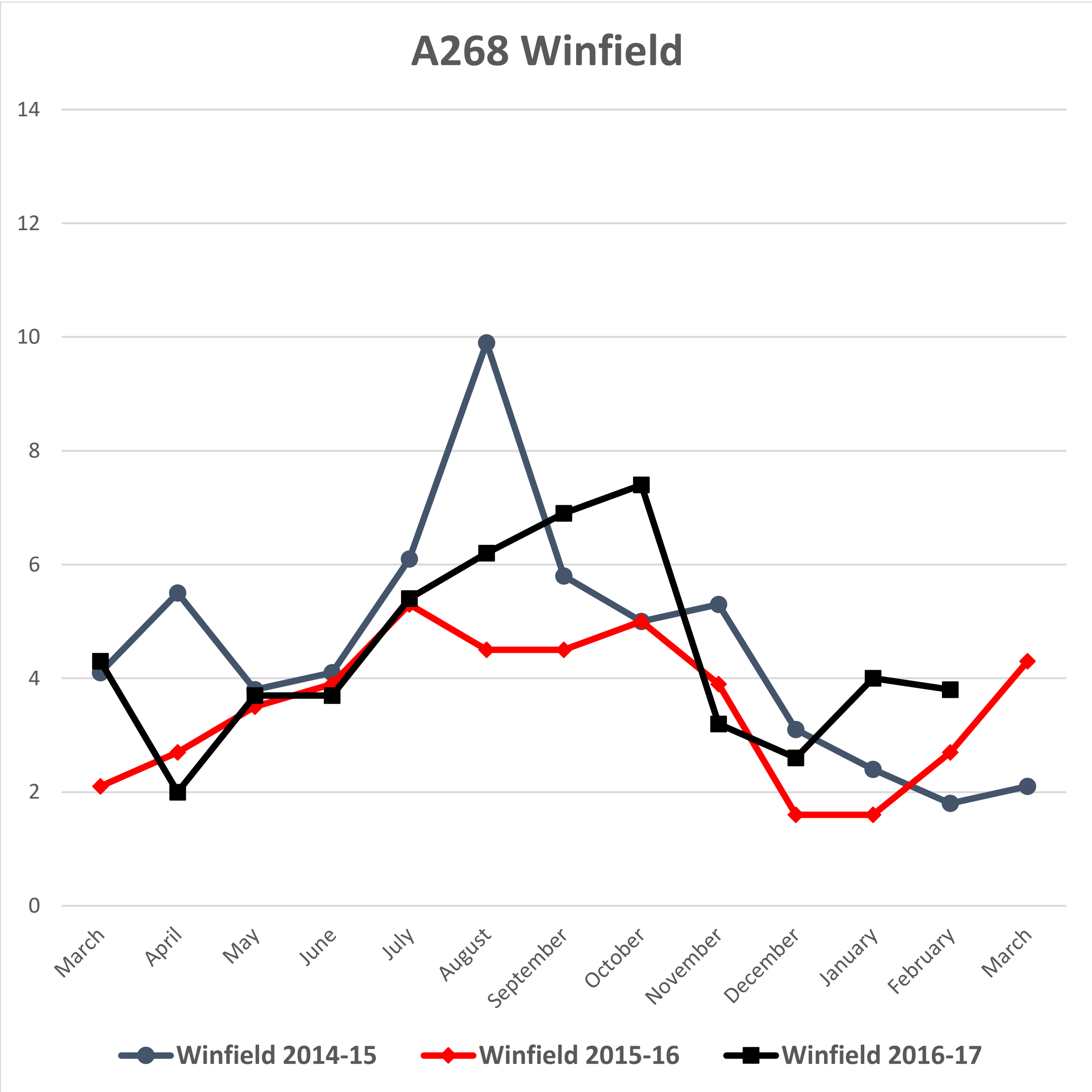
Area: Bundaberg Locality: Winfield

Irrigation: Drippers

Variety: 268 Spacing: 7x3.5m Age: 15

Yields 2015/8kg 2016/7kg

Observations: Good healthy trees located not far from site 6. Vigorous trees requiring hedging for access and only yielding moderately.



The TNSC data are fairly even over time.

Site 8.

Co operator: Scott Norval

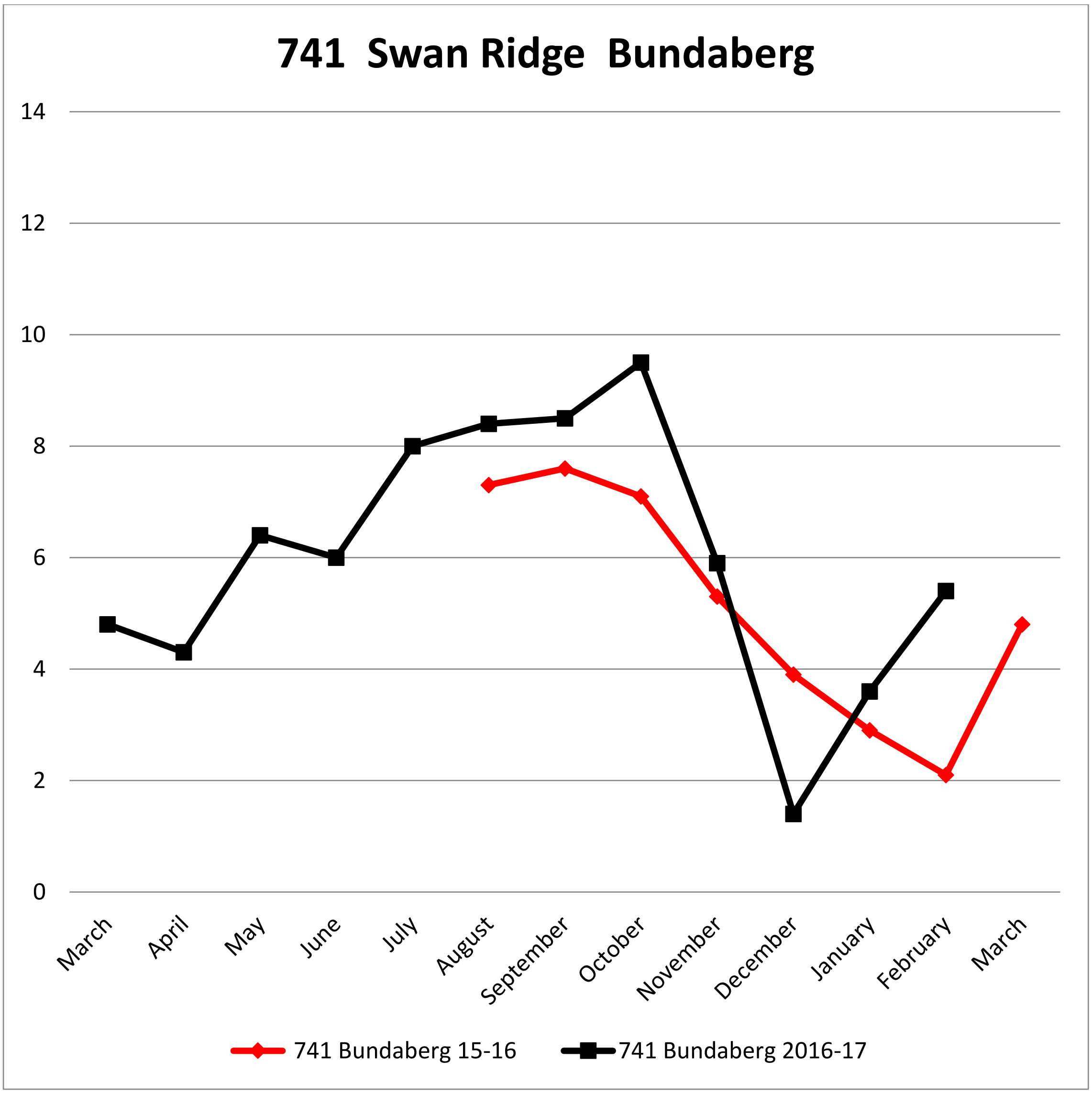
Area: Bundaberg Locality: Nth Bundaberg, Swan Ridge

Irrigation: Drippers

Variety: 741 Spacing: 8x4m Age: 12

Yields 2015/18kg 2016/12kg

Observations: Good healthy young trees not light limited and cropping well. Only commenced during the second year.



The TNSC data are limited but confirm early minimums in last year.

The TNSC graphs

Site 9.

Co operator: Scott Norval

Area: Bundaberg

Locality: Nth Bundaberg, Swan Ridge

Irrigation: Drippers

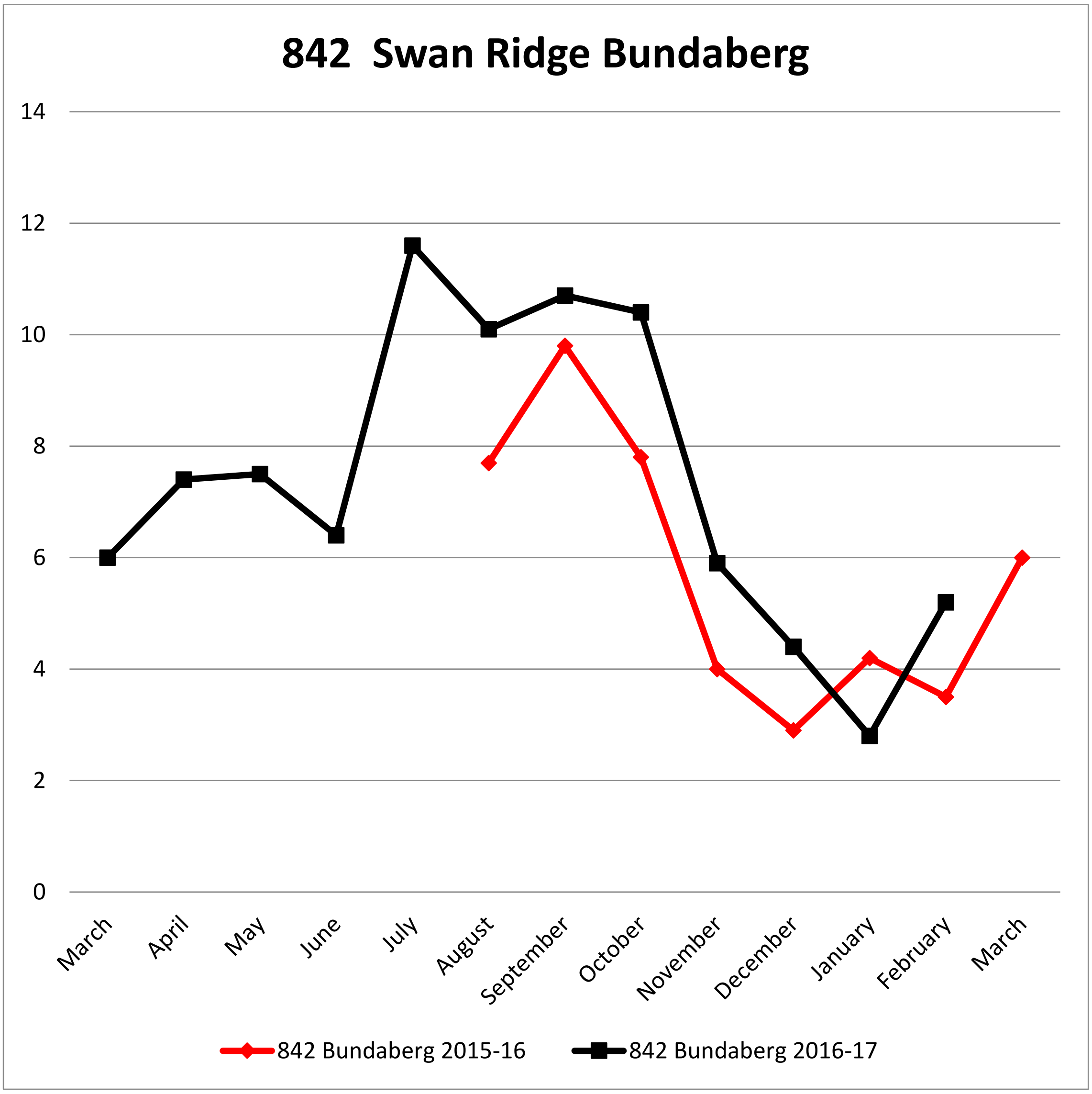
Variety: 842

Spacing: 8x4m

Age: 12

Yields 2015/15kg 2016/12kg

Observations: Good healthy young trees not light limited and cropping well. Only commenced during the second year.



The TNSC data are limited but confirm early minimums.

Site 10.

Co operator: Alloway Macadamias

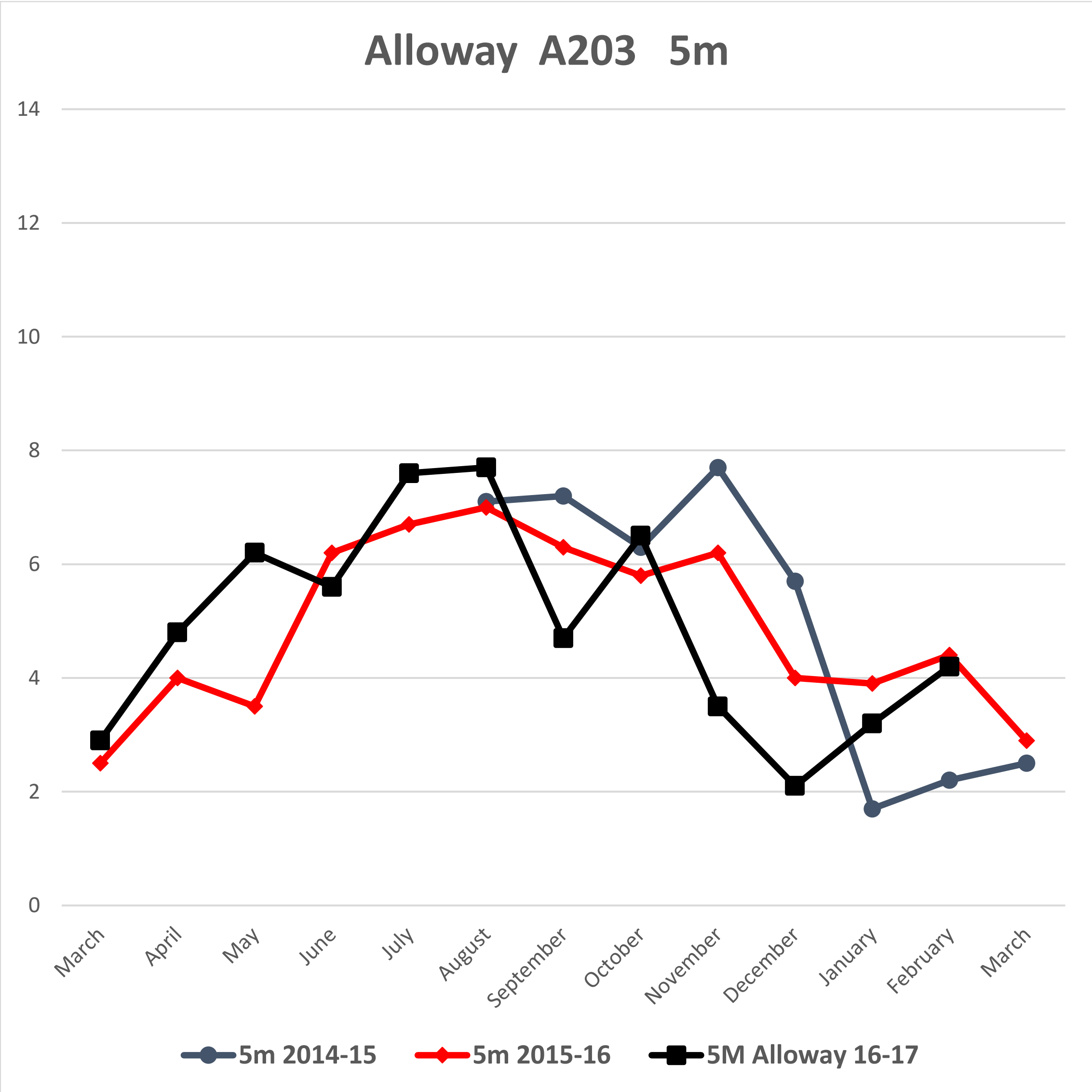
Area: Bundaberg

Locality: Sth Bundaberg, Alloway

Variety: 203 Spacing: 5x2m Age: 10

Yields 2015/4kg 2016/2kg

Observations: Partner trees to site 1 but not thinned and commenced several months after the start of project. Healthy and dense but producing very little nut. Alternate rows were removed during the last year changing the spacing to 10x2m.



TNSC data are even but confirm early minimums.

Discussion and Implications

Sunshine hours

It is possible that the sun hours from April/August may play a significant role in determining TNSC build and evidence for this is the markedly high TNSC build in the Lismore sites in winter 2016 compared to 2015 when sun hours in 2015 April/Aug were 815 and in the same period in 2016 were 980 – nearly 25% more. By contrast the sun hours in Bundaberg were 1080 and 1007. New Scientist has published data on increased corn production in the USA due to increased sun brightness!

The TNSC graphs for the Bundaberg area are far more uniform on an annual basis than the northern rivers possibly confirming a benefit from more sun hours.

Literature on the subject indicates that the greatest build can be expected to occur during the cooler months when the trees demand for energy used in respiration and water transport are lower therefore increased sun hours from April- August may be important.

One variety in particular (A38) is able to produce good crops with smaller leaf canopies and low TNSC and this may indicate a trait for greater photosynthetic efficiency than any other variety or the ability to photosynthesise at lower light levels.

The determination of photosynthetic efficiency of all varieties both in total and as light levels fall could provide valuable information for the breeding programme.

Effect of Temperature.

There is evidence from work done by D. Huett that when leaf temperatures exceed 31^0C photosynthesis stops and the TNSC data show very steep declines in late summer of 2016/17 on the northern rivers where there were long periods with temperatures in excess of 30^0C and this effect needs further investigation. Bundaberg was not as hot but shows similar trends. Similar trends occurred in late summer of 2015/16 in both districts.

If photosynthesis stops or is reduced during crop finishing then not only is the tree using reserves for the crop but also to stay alive.

In the first year TNSC declined slowly as the crop matured up until March as was found in the original project but in the second and third years the drop was sharp and finished in December and this may be the heat effect, a large crop or other environmental factor.

Knowledge of the temperature needed for photosynthetic extinction of all varieties would be valuable in the breeding programme.

Irrigation

Both the quantity and method of irrigation will influence the spread and volume of the root system and since the literature indicates that up to half of all TNSC is stored in the root system the impact of irrigation is likely to be significant.

Several investigations have revealed that the root systems of drip irrigated trees are restricted largely to a small wetted zone and as trees age can resemble a tree trunk in density.

Greater spread of water and increased quantity will result in greater root volume.

There are two sites in Bundaberg with the variety 203. One is sprinkler irrigated (Welcome Creek) and the other is drip irrigated (Alloway). The sprinkler irrigated site produces more nut than the dripper site and consistently has higher TNSC although there may be other management factors influencing this result.

PAR Readings

The measurements have significant implications for tree architecture and pruning.

Modelling of a *free standing* tree as it increases in height and diameter when only the outer 1m of the canopy is photosynthesising shows that the unproductive centre of the tree increases more rapidly than the productive outer canopy and that somewhere between 15- 20 years the unproductive canopy exceeds the productive portion. This unproductive dead heart still consumes energy for respiration and the energy demand to supply water to very tall trees is increased over smaller trees.

If trees are too close in the row then a portion of the productive circle is lost once tree radius exceeds tree spacing and when hedging is carried out the sides are also lost and only a producing crown is left drastically reducing the productive canopy.

I draw attention to the fact that the typical 8x4m planting when it was 15 years old had good light, grass cover and produced 5t/ha NIS with trees 5-6m high and ever since, as they have increased in height production has decreased. Some 15-20 years ago the statisticians reported that older orchards were declining in productivity but little attention was paid to this.

In 1987 our industry was told that we were pruning our trees all wrong and creating a dead heart while having learnt nothing about the importance of light!

There is an urgent need to develop pruning techniques to maintain tree height to 5-6 meters which has been shown to maintain good yields and in addition the increased light will promote grass growth and reduce erosion.

Cutting holes in tree canopies is not successful as the leaves exposed have *gone to sleep* and do not resume photosynthesis when re exposed to light and regrowth also soon fills the void.

Limb removal is one such technique but is labour intensive and the longevity of the benefits is questionable

TNSC Data

While it was hoped that the project would give clear indications of whether TNSC could be a useful tool in predicting crop potential this has not been achieved resulting from several deficiencies.

a) Multiple varieties;

b)Multiple management practices;

c) Different irrigation strategies;

d) Lack of accurate yield data;

e) Insufficient time to encompass a greater range of climatic factors many of which could override TNSC.

On the positive side the project has given valuable insights into some of the many factors which might influence yield and indicated many gaps in our knowledge and shown where we might focus our efforts in the future.

The data show that the A varieties have TNSC values approximately half of that found in the Hawaiian varieties (Attachment 3) yet in many cases (A 16 and A 203 at Welcome Creek and A 38 on the northern rivers) they can produce good crops with A 38 being of particular note.

In relation to crop prediction the data show that in the first year TNSC and crop was higher than the second year.

It is thought that this was the result of the large industry wide flush that occurred in autumn 2014 resulting in a large fresh productive leaf canopy.

There is anecdotal information that suggests a large flush in late summer/early autumn will result in a good crop the following year. The suggestion is not unreasonable as a large flush will cover the outside productive area of the tree with fresh foliage which should assist with TNSC build leading to better crop potential.

If this is the case, then control of flush timing and size could be major determinants in raising TNSC which could translate into better crops as indicated in the literature.

It is worth noting that the graphs for the two Winfield sites in Jan/Feb (16/17) do not continue falling and the co-operator has indicated that he applied heavy fertiliser and mulch in December 16.

The following is a conclusion that is plausible when all the information is taken as a whole.

1.) The data show that flushing draws down TNSC and if it occurs at the wrong time then TNSC build is interrupted or drawdown increased.
2.) This may be the reason the A varieties have lower TNSC as except for A 38 they all tend to flush frequently during the year.
3.) We know that trees have large reserves and take a long time to show decline or recovery if they are allowed to go into decline.
4.) Current fertilizer recommendations are to split fertilizer into a minimum of four applications

coinciding with cropping cycles – flowering, nut sizing, oil formation and recovery. This may need to be reviewed if fertiliser can be used to manage flush timing.

5.) Only the outer meter of the canopy receives enough light for active photosynthesis.
6.) A large flush in late summer/early autumn will cover the tree in freshly hardened foliage capable of producing energy at the critical time for TNSC build coming into the cooler months of the year and there is anecdotal information that this leads to a good crop.
7.) Application of a significant proportion of the fertilizer (with water) to generate this flush on an annual basis may prevent all the small flushes during the year. The old recommendation to apply all the fertilizer just before winter so as not to generate flush during summer suggests that fertiliser timing and quantity may in fact be a tool to generate flush in late February – March when we know bud initiation is will occur shortly after.
8.) We know that trees have large reserves within their structure so changing fertiliser timing may not necessarily be deleterious.

This management of flush size and timing could possibly be achieved by the above and irrigation management or a combination of both.

Flush management may also prevent the several unseasonable flushes which occurred unpredictably as shown by the unexpected dips in TNSC build or run down and which are obviously undesirable.

Two findings are contrary to current thinking about what part of the annual cycle consume the most energy:

1) Results indicate that flushing consumes more energy than flowering!
2) The early minimums in TNSC in December in many sites suggest that oil formation may not consume as much energy as nut growth! This is earlier than found by Stephenson et al and is climate change playing a role?
3) If both these findings are correct then our current fertiliser recommendation times will need revision particularly if we also wish to manage flushing.

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Recommendations

Our understanding of some of the many factors influencing the TNSC cycle will be improved by the implementation of the following recommendations in future research.

The potential of TNSC to be a predictor of crop yields will only be determined by long term trials where adequate funding will allow accurate yield assessment (individual tree harvests).

- The use of Ethrel to totally prevent cropping on producing trees may produce valuable information on the trees ability to build TNSC after small crops as the total failure to crop of healthy dense A16 trees does not appear to result in increased TNSC build.

- Trials to test whether treatments are available to influence TNSC either negatively or positively.

- Treatments to determine whether flushing can be influenced as there is anecdotal evidence that large flushes as occurred in 2014 are followed by large crops – large volumes of new growth may boost TNSC.

- Measurements of photosynthetic capacity as light decreases and temperature increases for each variety which will also be useful in the breeding programme.

- Development of pruning techniques to maintain tree architecture as small open tress maximizing productive canopy as has been the case for many other fruit tree crops.

- This project has shown large differences between cultivars in TNSC accumulation but the reasons for this are not clear but may relate to some or all of the above, root volumes or major timber structures and needs to be understood.

- Sun hours appear to be valuable and simple to measure and there continue recording is recommended.

- Effects of irrigation management on root volume and TNSC.

These recommendations will require far greater financial resources than the modest grower contributions in this project.

We gratefully acknowledge the financial contribution from Horticulture Innovation Australia which matched grower contributions and made the project possible.

Acknowledgements

We gratefully acknowledge the financial contributions made by the cooperating growers who made this project possible and the access to their properties for collection of samples and farm visits by other parties,

We also gratefully acknowledge the contribution by other growers who contributed funds when joining the project after the commencement and those whose orchards were used unfunded to fill perceived gaps.

Financial contributors – HIA matched funding.

Alloway Macadamias – 1 site.

Surrey Bogg – 1 site.

Gray Plantations – 2 sites.

Hancock Farm Company – 3 sites.

Macadamia Farm Management – 1 site.

Steinhart Family Farms -2 sites.

William Moore – 2 sites.

MWT Foods – 2 sites.

Richard Willis – 1 site.

Other financial contributors.

Alloway Macadamias – 1 site.

David Berman – 2 sites.

Fullerton Family Farms – 1 site.

Scott Norval – 2 sites

Keith Frederickson – 1 site.

Surrey Bogg -1 site.

The work of collecting samples in Bundaberg was done by Ngarie Meyers and we gratefully acknowledge her valuable contribution

Tree Heights	Kona A 16	Norval 741	Norval 842	Alloway 203 5M	Steinhart 816 Poor	Moore A38	Hancock 203	Hancock 268	Alloway 203 10M	Steinhart 816 Good	Hancock 842	Frederick A 38	Fullerton 268	Cooper 741	Wilson 849	Waring A 4	Wilson 344	Moore A 16	Gall H2	Tim Lein 246	Kerogen 333	Waring 246	Kerogen 91/344	Astor 660
													29N12N	29N12N		7/12/1.00	21/12/					7/12/12.45		7/12/12.00
													EST	EST		DST						DST		DST
													Cloudy	V Cloudy										cloudy
14m																								
13.5m																							2239	2240
13m																							110	1500
12.5m																						2280	1900	100
12m																					2230	2100	50	80
11.5m																			2232	2250	2161	2080	40	60
11m																	2430	2290	200	2183	2038	20	26	20
10.5m																2250	330	120	80	17	20	20	24	21
10m																2183	170	84	40	1700	7	20	130	
9.5m																117	30	40	50	38	11	20	16	
9m														2300	2383	1700	34	27	46	22	11		21	
8.5m														1500	230	38	30	15	43	20				
8m														800	65	22	38	19	27	18				
7.5m													2400	215	43	20	35	10	25					
7m										2320	2170	2038	250	170	4	18	33		20					
6.5m						2280	2110	2185	2290	2270	1940	1940	80	160	40									
6m					2290	2130	60	2120	2190	105	170	1160	40	126	30									
5.5m				2300	100	280	65	110	40	150	70	70	50	106	25									
5m	2080	2354	2491	2270	42	60	40	45	33	45	50	43	40	90										
4.5m	2020	114	170	105	34	44	33	36	28	47	38	15	28	35										
4m	64	80	230	150	37	36	27	30	32	37	36	35		24										
3.5m	46	125	150	45	36	37		30	20	30		27		20										
3m	38	94	113	47	24			23	8															
2.5m	50	72	60	37				14																
2m	28	33	60	30																				
1.5m																								
1m																								
o.5m																								
0m						240						33	40	15	40	22	113	18	18	21	37	50	13	40

Variety	Cooperato	Date	Location		March	April	May	June
A4	Waring	2014	Alstonville	1	3.8	6	3.7	4.9
		2015			4.8	3.5	3.9	4.8
		2016			4	5.5	5.1	3.8
246	Waring	2014	Alstonville	2	8.1	8.3	7.9	7.5
		2015			4.1	5.8	5.7	8.1
		2016			5.1	5.2	9	6.7
246	246 Tim	2014	Wollongbar					
		2015			6	6.5	7.5	7.5
		2016			6.3	7	11	6.8
H 2	Gall	2014	Rosebank	3	6.3	7.4	7.3	6.2
		2015			2.7	4.5	7	7
		2016			5.9	5.2	7.7	5.1
660	Tully	2014	Dalwood	4	6.3	7.4	5.8	6.7
		2015			4.7	6.4	7.4	7.5
		2016			6	6.2	7.1	5.6
849	Wilson	2014	Eureka	5	6.2	6.6	6.1	7.8
		2015			3.1	4.9	6	6
		2016			5.3	5.9	7.9	6
344	Wilson	2014	Eureka	6	3.8	7.7	6.6	6.7
		2015			5.6	5.9	7.5	7
		2016			6.1	5.7	7.4	5.2
344	Bryen	2014	Brooklet					
		2015			4.7	5.2	4.9	5.3
		2016			4.9	4.8	8.1	6.6
333	Bryen	2014	Brooklet	7	8.2	8.6	7.8	7.7
		2015			4.9	5.6	6.6	8.2
		2016			5.6	5.6	10.2	9.4
A 16	Moore	2014	Brooklet	8	6.5	6.8	4.7	5.1
		2015			2.5	2.9	3.7	5.2
		2016			7.6	3.5	6	5
A 38	Moore	2014	Brooklet	9	5.9	7.5	5.9	5.1
		2015			1.6	2.2	3.4	3.6
		2016			4.6	3	5.5	3.4
A 38	Fredericksc	2014	Rous Mill					
		2015			2.8	4.2	4.9	5
		2016			6.1	3.2	6.5	5.9
268	Fullerton	2014	Ghouse	10	6.1	6.8	3.4	5.2
		2015			3.2	2.9	3.1	4
		2016			3.7	3.2	5.4	4.3
741	Cooper	2014	Ghouse	11	9.7	10.5	8.8	9.6
		2015			6.2	7.7	8.6	8.3
		2016			6.5	6	7.1	8.4
203	Alloway 10	2014	Bundaberg	12	3.3	4.4	4.3	4.3
		2015			3	3.5	3.6	4.8
		2016			3.6	4.4	6.3	4.9
203	Alloway 5m	2014						
		2015			2.5	4	3.5	6.2
		2016			2.9	4.8	6.2	5.6

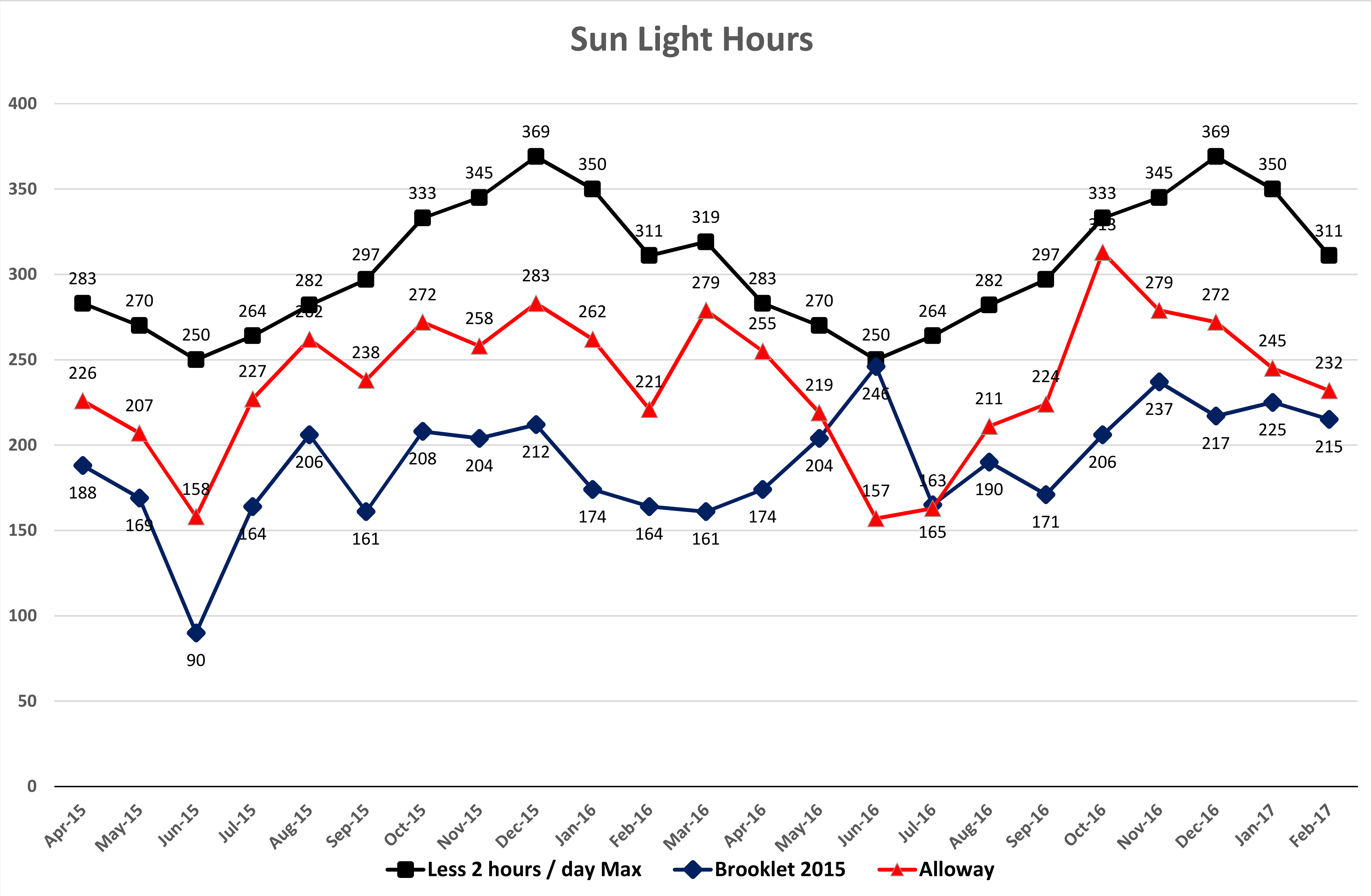
816 poor	Steinhart	2014	Bundaberg		13	8.1	10.1	6.9	6.1
		2015				5.2	7.1	7.5	8.1
		2016				5.4			
816 Good	Steinhart	2014	Bundaberg		14	5.5	9.1	5.6	5.9
		2015				2.5	6.8	7.2	7.4
		2016				5.6	7.1	7.2	8.2
741	Steinhart	2016				3.1	5.9	6.3	8.4
842	Hancock W	2014	Bundaberg		15	8.8	8.2	6.3	7
		2015				5	6.8	5.9	7.4
		2016		new		7	7.4	8.7	7.5
268	Hancock W	2014	Bundaberg		16	4.1	5.5	3.8	4.1
		2015				2.1	2.7	3.5	3.9
		2016				4.3	2	3.7	3.7
203	Hancock W	2014	Bundaberg		17	5.2	7.3	4.2	6.8
		2015				4.5	5.1	6.9	8.6
		2016				3.2	3.4	6	7.7
A 16	Allcott Kon	2014	Bundaberg		18	6.3	6.2	6.2	6.5
		2015				3.5	4.7	5.2	5.8
		2016				2.8	5	5	5
741	MacaCorp	2014	Bundaberg						
		2015							
		2016				4.8	4.3	6.4	6
842	MacaCorp	2014	Bundaberg						
		2015							
		2016				6	7.4	7.5	6.4

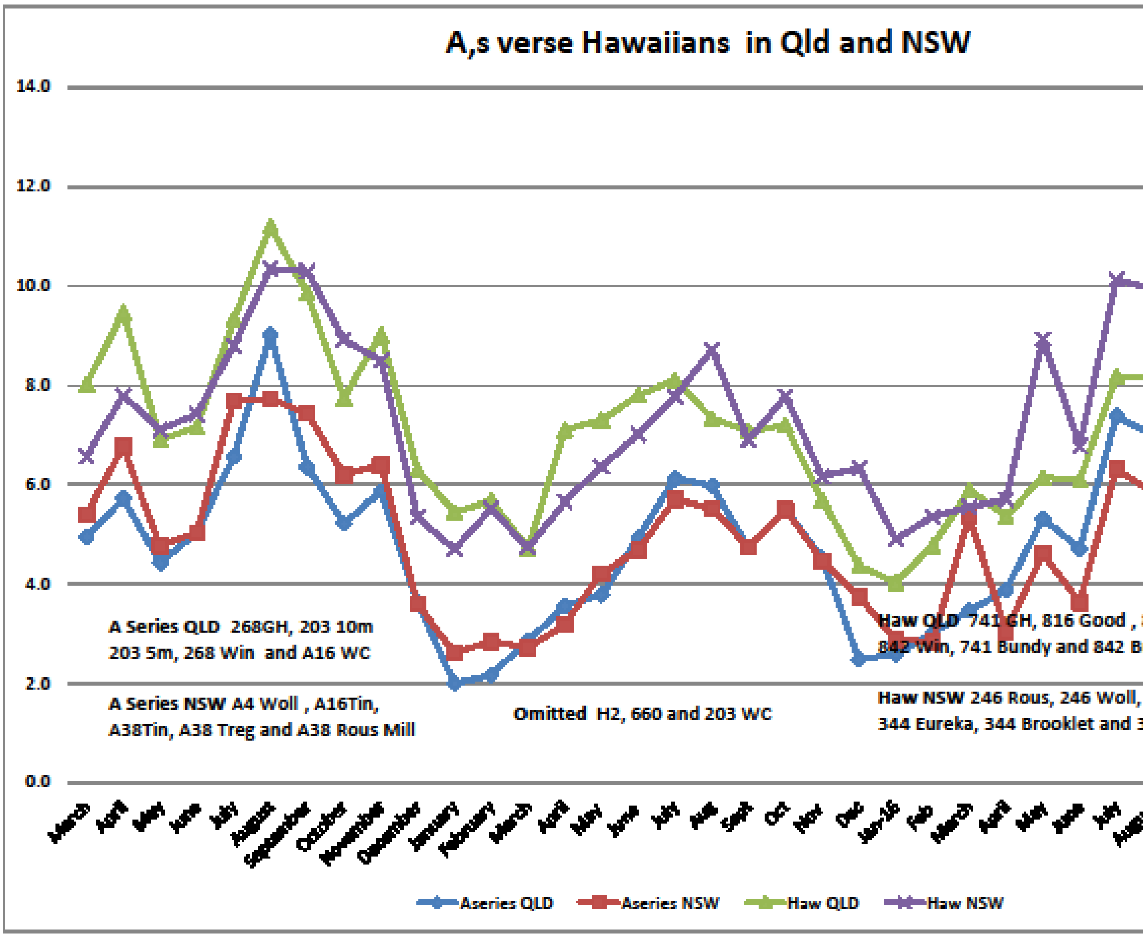
July	August	Sept	Oct	Nov	Dec	Jan	Feb	Date
5.8	8.3	8.3	6.7	6.3	4.6	3.4	3	2014
5.6	5.4	3.6	5.4	5.3	4.5	3.6	2.7	2015
9.6	6.6	6.8	5.9	6.8	4.2	5.4	3.3	2016
10	10	8.3	9.8	8.8	2.6	5.2	5.2	2014
7	8.7	7.2	8	6	5.2	4.2	4.7	2015
9.8	8.9	9.8	9	9.1	4.3	4.8	3.8	2016
							5.8	2014
8.4	9.2	7.5	8.6	4.4	7.8	5.8	6.1	2015
10.5	10.3	11.5	9.1	8.4	5.5	5.1	6.7	2016
9	8.6	9.2	8.6	10.1	7.1	7.3	6.3	2014
8.9	8.2	6.6	8	7	7.9	5	5.7	2015
11.6	10.5	11.3	8.6	9.4	7.2	4.7	4.2	2016
8.4	9.3	8	9	5.2	6.4	5.8	6.2	2014
7.8	8.2	8.2	8.5	6.1	5.4	4.4	5.8	2015
10.6	9.3	10.5	9.3	6.7	1	4	6.4	2016
8.2	9.4	10.9	7.7	7	4.1	3.5	4.6	2014
7.5	7.9	7.5	7.8	5.3	4.8	4.1	4.2	2015
10.8	9.8	8.3	7.5	7.3	1	2.8	3.5	2016
8.3	10.9	10.5	8.9	7.6	6.9	6.3	6.7	2014
8.4	8.7	5.8	7.1	7.2	6.5	5.9	6.3	2015
9.4	10	11	9.7	9.5	3.4	6.1	6.3	2016
			9.6	9	7.3	4.7	5.5	2014
6.7	7.4	6.2	7.2	6.5	6.3	5.2	4.5	2015
10.4	8.9	8.7	7.8	9	3.7	6.9	5.2	2016
8.7	11.1	11.5	8.6	10.1	5.8	3.8	5.3	2014
8.7	10.4	7.2	8	7.6	7.4	4.2	6.4	2015
9.9	11.7	9.7	9.1	10.1	3.2	5.8	5.1	2016
9.9	7.9	6.8	9.2	7.1	4.1	2.6	2.6	2014
5.9	5.6	4.9	5.8	5	5.3	4.9	3.7	2015
7.2	7.3	5.1	5.3	7.7	5.8	4.8	4.1	2016
7.4	7	7.2	2.7	5.3	3.1	2.5	2.7	2014
4.3	4.5	4.1	4.6	2.7	3	1.8	2.4	2015
6.3	6.7	5.4	5.9	5.7	0.7	2	3	2016
				6.8	2.3	1.9	2.9	2014
5.9	6.1	5.5	5.3	4.5	3	2	3.3	2015
8.5	8.5	8.8	7.5	7.2	3.1	3.4	4.6	2016
6.5	8.4	6.3	3.8	4.6	1.8	1.5	1.8	2014
5.7	6.1	6.7	6.2	4	1.9	2.2	2.5	2015
8.1	6	4.5	4.4	4.7	3.2	3.2	3.5	2016
10.6	11.4	11.3	9.5	12.5	7.5	7.9	6.4	2014
8.9	10.8	9.2	8.4	6.4	7.7	6.4	7.4	2015
10.5	10	11.1	8	8	8.7	6.4	7.4	2016
5	8.8	4.7	4.4	4.8	2	1.7	2.4	2014
5.7	5.1	3.1	4.7	3.7	1.6	3	2.2	2015
5.8	7.2	1.6	6.6	3.6	1.3	2.5	2.7	2016
	7.1	7.2	6.3	7.7	5.7	1.7	2.2	2014
6.7	7	6.3	5.8	6.2	4	3.9	4.4	2015
7.6	7.7	4.7	6.5	3.5	2.1	3.2	4.2	2016

8.7	10.8	7.7	6.5	7.6	5.8	4.6	6.4	2014
8.8	6.2	5	6.3	6.5	3.9	4.9	5.7	2015
								2016
8.4	11.7	9.3	7	8.6	5.2	3.3	4.2	2014
8.2	6.7	4.5	6.3	6.1	4	2.9	6	2015
10.2	10.9	8.7	9	6.4	3.4	2.9	4.5	2016
9	9.7	9.9	9.5	8.5	5.3	2.8	3.9	2016
9.6	10.9	11.1	8	7.4	6.7	6	5.7	2014
6.5	5.3	6.3	7.3	5.8	3.8	2.9	3.9	2015
8.7	9.5	10.7	10.7	7.2	7.2	6.9	6.5	2016
6.1	9.9	5.8	5	5.3	3.1	2.4	1.8	2014
5.3	4.5	4.5	5	3.9	1.6	1.6	2.7	2015
5.4	6.2	6.9	7.4	3.2	2.6	4	3.8	2016
8.9	10.2	9.3	5.9	13.6	8.7	6.9	5.2	2014
8.3	8.4	5.7	6.6	6.7	4.3	2.6	3.6	2015
9.6	10.5	9.4	10.7	7.1	4.6	4.4	5.7	2016
8.7	10.9	7.8	6.6	6.9	5.6	2.7	2.6	2014
7.2	7.2	3.1	5.8	4.8	3.3	2.2	3.3	2015
10	7.8	7.9	8.9	7.1	3.5	3	4.5	2016
								2014
	7.3	7.6	7.1	5.3	3.9	2.9	2.1	2015
8	8.4	8.5	9.5	5.9	1.4	3.6	5.4	2016
								2014
	7.7	9.8	7.8	4	2.9	4.2	3.5	2015
11.6	10.1	10.7	10.4	5.9	4.4	2.8	5.2	2016

Site		
A4		Waring
	246	Waring
	246	246 Tim
H 2		Gall
	660	Tully
	849	Wilson
	344	Wilson
	344	Bryen
	333	Bryen
A 16		Moore
A 38		Moore
A 38		Frederickson
	268	Fullerton
	741	Cooper
	203	Alloway 10m?
	203	Alloway 5m

816 poor	Steinhart
816 Good	Steinhart
842	Hancock Win
268	Hancock Win
203	Hancock WC
A 16	Allcott Kona
741	MacaCorp
842	MacaCorp


Sun Light Hours
400
350
300
250
200
150
100
50
0
Apr-15
May-15
Jun-15
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
Feb-16
Mar-16
Apr-16
May-16
Jun-16
Jul-16
Aug-16
Sep-16
Oct-16
Nov-16
Dec-16
Jan-17
Feb-17
283 270 250 264 282 297 333 345 369 350 311 319 283 270 250 264 282 297 333 345 369 350 311
226 207 158 227 262 238 272 258 283 262 221 279 255 219 157 165 211 224 313 279 272 245 232
188 169 90 164 206 161 208 204 212 174 164 161 174 204 246 163 190 171 206 237 217 225 215
Less 2 hours / day Max
Brooklet 2015
Alloway


A,s verse Hawaiians in Qld and NSW
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
A Series QLD 268GH, 203 10m
203 5m, 268 Win and A16 WC
A Series NSW A4 Woll , A16Tin,
A38Tin, A38 Treg and A38 Rous Mill
Omitted H2, 660 and 203 WC
Haw QLD 741 GH, 816 Good ,
842 Win, 741 Bundy and 842 B
Haw NSW 246 Rous, 246 Woll,
344 Eureka, 344 Brooklet and
March
April
May
June
July
August
September
October
November
December
January
February
March
April
May
June
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Aug
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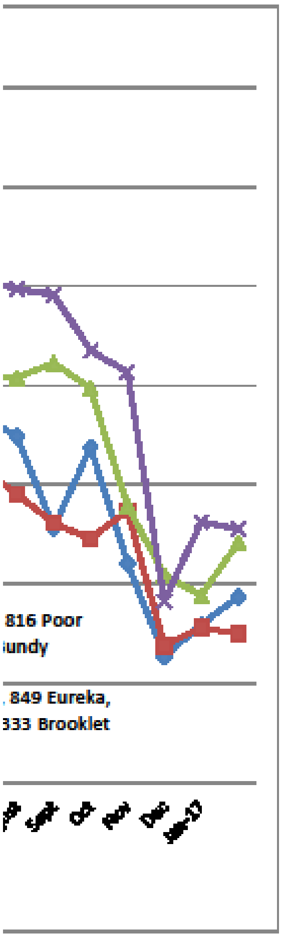
Jan-16
Feb
March
April
May
June
July
Aseries QLD
Aseries NSW
Haw QLD
Haw NSW


816 Poor
undy
849 Eureka,
333 Brooklet
Sept
Oct
Nov
Dec
Jan-17

Sampling Techniques for TNSC in Macadamias

Photographs from the 2014 Start of the Macadamia Project

MC13009

Ian Vimpany

First Rasp off the Bark

Drill Just Past the Dark Brown Layer

Measure the Depth before Sampling

Collect the Sample 4mm Deep

Remeasure the hole to check correct Sampling Depth

Treat the hole with Graft Wound Dressing

Calliousing sampling Hole 6months

Sample Dried and Ground ready for Analysis