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Final Report

Supplementary grower trial of elite macadamia selections

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AS & FJ Bogg

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MC09017

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Supplementary grower trial of elite macadamia selections

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Summary

At the time this project commenced the macadamia industry was funding a series of regional variety trials (MC06009) which had the aim of assessing the potential of progeny from the first round of crosses (B1.1) conducted by the macadamia breeding program (MC08001). However, not long after project MC060099 commenced material from the second round of crosses, round B1.2 became available. Initial evaluation of these progeny suggested that they had the potential to deliver significant yield and quality advances to the macadamia industry. Unfortunately, the industry at the time did not have the funding available to assess progeny from this second round of crosses and a decision had been made not to asses this material until 2015/16 at the earliest. Consequently, funding this project through a voluntary contribution meant that the industry would not only save a considerable amount of time, 7-8 years, it would also advance the breeding program generally by allowing material from the first round of crosses (B1.1) to be compared with material from the second round of crosses (B1.2), thus allowing some assessment to be made of the genetic progress of the breeding program.

After considerable discussion with staff from the breeding project a decision was made to examine a total of 19 selections, 13 elite clonal selections from round B1.2 of the industry breeding program, the top three selections from round B1.1, and three industry standards.

The trial was planted on the 15th of November 2011 at a site just north of Bundaberg, Queensland an area where the macadamia industry is rapidly expanding. Trees were planted at seven metres between the rows and three and a half metres within the row, the same density as the surrounding orchard.

Fourteen months after the trial was planted it was damaged by cyclone Oswald and as a consequence trees had to be heavily pruned to correct tree damage and prevent tree loss. This pruning resulted in the loss of some early tree growth data. Tree height and canopy diameter were measured and a count made of nut number per tree in February 2015, some three years and three months after the trial was planted.

There was a significant difference in height and canopy diameter among the selections with A16 and HIN 01 55BAFF01 (around 2.5m) the shortest and BAFF01 1532 (3.4m) the tallest. Out of the 19 selections seven had flowered and set nut with one selection HIN 01 210 estimated to have a potential yield of around 1.29 kilos of nut per tree. The majority of current commercial cultivars do not start to produce nuts until four years after planting.

This first part of an ongoing project to assess material from round B1.2 of the macadamia breeding project would suggest there is considerable potential amongst the selections used in this trial for the identification of a new precocious high yielding macadamia cultivar.

Keywords

Macadamia, breeding, elite selections, varieties, precocity, rootstocks.

Introduction

At the time this project commenced the macadamia industry was funding a series of regional variety trials (MC06009) which had the aim of assessing the potential of progeny from the first round of crosses (B1.1) conducted by the macadamia breeding program (MC08001). However, not long after project MC060099 commenced material from the second round of crosses, round B1.2 became available. Initial evaluation of these progeny suggested that they had the potential to deliver significant yield and quality advances to the macadamia industry. Unfortunately, the industry at the time did not have the funding available to assess progeny from this second round of crosses and a decision had been made not to asses this material until 2015/16 at the earliest. Consequently, funding this project through a VC meant that the industry would not only save a considerable amount of time, 7-8 years, it would also advance the breeding program generally by allowing material from the first round of crosses (B1.1) to compared with material from the second round of crosses (B1.2) thus allowing some assessment to be made of the genetic progress of the breeding program.

The current method of assessment in the industry funded regional variety trials is very expensive and time consuming as it involves single tree plots replicated up to six times for each trial. This design makes mechanising the process of harvesting the nuts for yield determination expensive and difficult. In addition, the single tree plots design means that there are potential problems associated with cross contamination of yields and sample nuts due to the close proximity of trees within the trial. Consequently, one of the additional aims of this project was to test a trial design that would allow for mechanised yield collection without compromising data integrity.

It was also decided to examine the differences between clonal and seedling Beaumont rootstocks. Clonal Beaumont rootstocks had been used as the rootstock for most of the trial sites in project MC06009 in order to reduce what was seen as a potential source of variability within trials, however there was some disquiet in the industry about the use of clonal rootstocks as they were perceived to be potentially weaker rootstocks and possibly more susceptible to wind damage than seedling rootstocks. In order to test this assumption it was decided to graft each scion line to an equal number of both clonal and seedling Beaumont rootstocks. The trial was then designed in such a way that within each six tree replicate, three trees were on clonal rootstocks and three were on seedling rootstocks. This would then allow the data to be analysed as a split plot design. Unfortunately, insufficient good quality clonal rootstocks were generated in time for grafting and only a small number of scion cultivars were grafted to both clonal and seedling rootstocks.

There was a considerable delay at the start of this project due to a number of problems associated with the handover of the breeding project from CSIRO to DEEDI. As a consequence,

it was difficult to finalise selections as information necessary to complete the selection process was not released by CSIRO. In addition, due to the complications associated with transferring the breeding project, the legal department of DEEDI was reluctant to enter into negotiations with this project until all matters associated with the transfer of the breeding project had been finalised. These delays meant that the time frame for this project was pushed out from three to five years.

Methodology

Candidate selection

An initial evaluation process was undertaken in 2009 in conjunction with Dr Cameron McConchie from CSIRO, who was then in charge of the breeding project. As there was a large environmental effect, identified by the CSIRO staff between trial sites in NSW and those in Queensland it was decided to only concentrate on selecting material from sites in Queensland as this was where the trial was to be established.

The three Queensland progeny sites used were the BQRS1.2 progeny trial planted in 2001, the Hinkler Park progeny trial planted in 2001, and the Baffle Creek progeny trial planted in 2002. While the first two sites were relatively close, within 15km of the proposed trial site, the third site at Baffle Creek was 100km away.

These initial selections were then refined over the next two years using a combination of site visits and yield and quality data as they became available. Many of the initially high yielding selections identified were then eliminated due to poor kernel characters, erratic production figures, stick tight nuts and poor tree structure, during this period.

Following discussions with staff from the breeding project it was decided to examine a total of 19 selections, 13 elite clonal selections from round B1.2 of the industry breeding program, the top three selections from round B1.1 and three industry standards. The inclusion of the top three selections from round 1.1 and the industry standards meant that information from the already established regional variety trials (MC06009) and this trial could be compared. It also meant that potential progress of the breeding program could be evaluated by comparing the performance of progeny selected from crossing round B1.1 with those produced from round B1.2.

The three industry standards selected for inclusion were HAES 741, HAES 816 and A16. HAES 741 was chosen as it's been a long time industry standard and has been the most popular cultivar planted in the Bundaberg area since 2000. HAES 816 was selected as it had performed well in the Hinkler Park variety trial where it had the highest cumulative kernel yield over time. A16 was selected as it had performed well on surrounding orchards and was seen as a good

industry performer though it does have a problem with stick tight nuts. It is also a small tree which produces high yields of kernel for its size. The final selections for inclusion in the trial are listed in Table 1.

Table 1: List of industry cultivars and 16 elite selections, from the macadamia breeding program with their source, those chosen for inclusion in the supplementary variety trial.

	Plan Number	Scion	Source
1	15	741	Industry standard
2	9	816	Industry standard
3	19	A16	Industry standard
4	10	BQRS98 246	1.1.1
5	2	BQRS98 1493	1.1.2
6	18	BQRS98 631	1.1.3
7	1	BQRS01 202	1.2.1
8	8	BQRS01 215	1.2.2
9	14	BQRS01 1207	1.2.3
10	3	BQRS01 2004	1.2.4
11	11	HIN 01 35	1.2.5
12	7	HIN 01 54	1.2.6
13	13	HIN 01 55	1.2.7
14	16	HIN 01 210	1.2.8
15	4	BAFF 01 426	1.2.9
16	5	BAFF 01 1508	1.2.10
17	12	BAFF 01 1532	1.2.11
18	6	BAFF 01 1917	1.2.12
19	17	BAFF 01 177	1.2.13

Note. BAFF 01 177 the top performer at the Baffle Creek progeny trial is an industry selection.

Trial design

In order to ensure the scientific integrity of the trial the project engaged Dr J Giles, the Queensland Department of Primary Industries statistician who was involved with Dr R Stephenson in designing and analyzing the industry funded varietal assessment project (MC06009) to prepare the trial design.

The trial design was a randomised block design with six tree plots, with data to be collected from the centre four trees only. Each plot was replicated four times for each progeny or

commercial line (a total of 80 plots or 480 trees). Where the material allowed for it, each plot was further split into either three successive clonal rootstocks or three seedling Beaumont rootstocks (one guard and two data trees) thus allowing the performance of either clonal or seedling rootstocks with the same scion variety to be compared. Trees were planted at 7x3.5m (408 trees/ha) the same density as for the commercial orchard which surrounds the trial site

A trial design is not included with this document but will be supplied separately and confidentially. Inclusion of the plan may allow for the identification of the position of the elite selections within the trial and the possible loss of this material.

Site Characterisation

The site was characterised in terms of soil properties by using a mechanical soil coring machine mounted on the back of a tractor to extract a 50mm diameter core of soil to a depth of 1.2m or as deep as was possible. This machine is similar to those used by the Department of Natural Resources and Mines to conduct soil sampling.

Using this machine soil cores were taken across the site, approximately every 25m along the row and 36m apart across the rows, in a grid pattern. In reference to the trial plan (Fig1) all samples were taken in the two outside rows of the trial (rows starting 6c and 3s and ending 1c and 5c). The trial site lies roughly north south and sites 1-4 were collected on the western side of the trial and sites 5-8 on the eastern side. Unfortunately, the site had already been mounded and ripped with a bulldozer in preparation for planting making it impossible to get a true depth for the A horizon. Consequently, it was decided to take soil samples on the crest of the mound in the position of where the trees were to be planted. While this gave an over-representation of the thickness of the A horizon, relative to an undisturbed site, it did reflect the soil environment in which the trees were to be grown.

The tree mounds are broad shallow mounds approximately 6m in diameter and 30cm high and typical of those constructed in commercial orchards in Bundaberg (Fig 1).

Fig 1. Trial site tree mounds. The mounds are approximately 6m in diameter and 30cm high. Soil cores were taken through the top of each mound

Once the soil had been extracted from the coring tube it was described in terms of its physical properties. The very dry conditions made soil coring extremely difficult, and in some case cores were only able to be extracted to a depth of 80cm. Unfortunately, the signs indicating at which site the cores were taken did not come out in the photograph due to the very bright conditions, though photographs could be identified by comparing the photograph number with diary notes taken at the time.

Fig 2. Site 1. Grey, sandy, clay loam to 50cm over light red clay becoming medium clay to B horizon to 1.2m, Ferruginous nodules present from 1m

Fig 3. Site 2. Grey, sandy, clay loam to 30cm, over light becoming medium yellow clay B horizon with significant ferruginous band present at 50cm. Heavy, red/yellow clay from 75cm which was very dry and which the machine could not penetrate.

Fig 4. Site 3. Grey, sandy, clay loam to 35cm, over medium yellow clay B horizon. Strong ferruginous band present at 50-60cm with heavy red clay. Could not penetrate past 60cm..

Fig 5. Site 4. Grey, sandy, clay loam to 40cm, light brown clay to 45cm Strong ferruginous band present at 50cm with heavy red clay. Very dry could not penetrate red clay.

Fig 6. Site 5. Grey, sandy, clay loam to 45cm over yellow red clay with ferruginous nodules present. In contrast to the other sites, the clay at depth in this site was wet and very sticky from 45cm.

Fig 7. Site 6. Grey, sandy, clay loam to 35cm over yellow, light becoming medium clay. Conspicuous ferruginous band at 50cm becoming medium red clay with ferruginous nodules present.

Fig 8. Site 7. Grey, sandy, clay loam to 35cm over yellow, light to 50cm, becoming medium yellow/red clay from 50-80cm. Medium red clay from 80cm containing furrugious nodules.

Fig 9. Site 8. Grey, sandy, clay loam to 40cm over yellow, light clay to 60cm, becoming medium yellow/red clay from 75cm to 1m.

The Department of Natural Resources and Mines soils map classifies the soil in the trial areas as a yellow Dermosol, Kepnock mapping unit. Though very close to the trial site there is a band of red Dermosol soil, Otoo mapping unit, running across the property. These mapping units are however on a very large scale and when the map was made units were only verified with a soil sample every 20ha.

These two soils are described, in their undisturbed state as:

Kepnock 0.05m to 0.35m grey to black loam fine sandy to clay loam over bleached A2 horizon (0.3-0.4m) over acid to neutral mottled, yellow light to medium yellow clay B2 with ferruginous nodules present.

Otoo, 0.25m to 0.45m black to brown fine sandy clay loam to clay loam A horizon over yellow to brown; light clay (0.55-0.95m) over acid , mottled, red light to red medium clay structured B horizon to 1.5m.

From the soil samples collected it would appear that the trial site varies from a red dermosol at the southern end through to a yellow dermosol at the northern end. The blocking in the trial design has taken this change in soil type into account. The presence of ferruginous nodules and ferruginous bands at relatively shallow depths would indicate that the trial site may be subject

to seasonal water logging. This means that over the life of the project considerable care will have to be taken with irrigation management to avoid exacerbating this problem.

The soil in the trial site is very similar to that on which the regional variety trial has been established on this property and is typical of many farms which have been purchased in the last few years for the production of macadamia nuts in the Bundaberg area.

Propagation

A propagation agreement was signed between the managers of this project and the Queensland government in March 2011. This agreement set strict limits on propagation and use of the propagated material with all material surplus to the project destroyed after planting. It took over two years for the propagation agreement to be signed due to the delays in the handover of the breeding project from CSIRO to DEEDI, DEEDI being unwilling to sign an agreement with a third party during this period and until it had final confirmation of its ownership of the breeding program. This delay, while frustrating, did not stop the entire project with effort during this period placed on improving the selection process. This delay did, however, push out the timeframe for this project from three to five years. .

The selected scion material was cinctured in February 2011. The grafted material then remained on the trees for a further 12 weeks until sufficient start reserves had developed in the scion material to ensure good graft success. Grafting took place in early May 2011 with one of the best industry grafters used to ensure a high rate of success and good uniform trees. Most selections had a high rate of "takes" requiring only a small number to be regrafted in August 2011.

One of the biggest disappointments was poor standard of the Beaumont clonal cutting rootstocks supplied by an external nursery with much of the material rejected due to poor root systems or sick weakly trees. Out of the 350 cuttings established only 140 grafted trees were deemed to be of high enough standard for inclusion in the trial. This severely compromised what was to be one of the major areas of research for this trial.

The production of clonal material is one area where the Australian industry needs to improve its performance. In South Africa clonal Beaumont rootstocks are commonly used and clonal material of a very high standard is produced. Anecdotal reports suggesting that this has led to the production of very even and uniform orchards.

Fig 10 Planting material in the nursery prior to dispatch to the trial site

Planting

The trial was planted on the 15th of November, 2011 using a commercial mechanical tree planter and was completed in a day (Figs 12, 13, and 14). Prior to planting the trial all trees were carefully retagged to ensure that they could be clearly identified during the planting process. Trees were then sorted into the correct order for mechanical planting so that no mistakes occurred. After planting all trees were rechecked against the field plan to ensure they were in their correct position. Following planting the irrigation system was connected and all trees were thoroughly watered.

Fig 11. Trees being planted using a commercial mechanical planter, November 2011

Fig 12. Newly planted tree in the field. Note new identification tag

Fig 13. First trial row planted, irrigation system irrigation installed but not hooked up. (November 15th 2011)

Fig 14. Trial site four months after planting (February 2012). Note new growth on trees compared with figs 12 and 13.

Trial management

Following planting, the trees were managed under commercial conditions. This involved irrigation according to tree demand and the application of soluble nutrients through the irrigation system every 3-4 weeks. In February 2012, the trial was reassessed and four trees that had died during this period were replaced using reserve trees that had been held in the nursery.

Due to the need to supply the older surounding orchard with sufficient nutrients on occasions this meant the trees in the trial block received luxury applications of fetiliser through the irrigation system. While this did promote growth the trial managers did not belive this promoted 'excessive growth' and allowed the trees to express their full genetic potential.

In spring 2013 it was decided to remove the the current trickle-tape irrigation system two years early and change to a micro-sprinkler system. This move was prompted by the conversion of the surrounding blocks from trickle to sprinklers and once this had been completed it would have been difficult to regulate the pressure in this one small trickle irrigation block when the whole farm had been converted to sprinlers. It was also felt that the move to sprinklers would not only provide better water distribution and possibly the delopment of a better root system, but it would also benefit the application of organic amendments to improve long term soil structure. Consequently, in spring 2013 'mill mud', a byproduct from the processing of sugar cane, was applied at the rate equivalent to 50 'wet tons' per hectare, but only in a two metre wide band either side of the tree row. (Fig 16) .

A decision was also made to reduce the width of the bare soil strip either side of the tree and mow closer to the trees rather than use herbicides which had been used in the past. This move

to mowing to contriol weed and grass rather than herbicides would, it was believed, allow for better retention of products, such as mill mud, and an improvement in soil structure over the long term. The soils at the trial site were very low in in organic carbon (<1%) and prone to surface crusting which prevents both water and nutrient penetration into the soil.

Fig 15. Installing sprinkler irrigation

Fig 16. Mill mud applied at the rate of 50 wet tons per hectare in a two metre wide strip either side of the tree row

Glyphosate damage

At the October 2012 inspection it soon became apparent that there was damage from the systemic herbicide glyphosate in most of the trial rows, which was particularly bad in rows one and two of the trial. This was despite a stipulation to the managers that glyphosate was not to be used in the trial. A decision was then made to score for the level of glyphosate damage. An additional consequence of the herbicide damage was that it was decided to leave the foil frost protectors, which cover the lower portion of the trunk of the tree, to reduce the potential for further herbicide damage. As a result, trunk diameter was not measured as the foil would have had to be removed and then replaced which would have taken several days. The measurement could also be compromised by the herbicide damage as the trees with damage had smaller canopies and this, in turn, could have resulted in smaller trunk diameters.

A robust discussion was also had with the farm manager regarding the glyphosate damage and we were assured that this would not happen again.

Fig 17. Leaves damaged by the herbicide glyphosate and normal sized leaves that have been produced after the tree has grown out of the damage

Wind damage

Wind damage is a constant problem in the Bundaberg area mainly due to the strong SE trade winds that blow off the adjacent ocean for most of the year. This can result in trees with more lee side growth (NW side) and leaning trees that are then more susceptible to storm and cyclone damage. While the threat from cyclones is low, one passing close by or crossing the coast every 10-15 years they can cause major damage to macadamia orchards.

In the first year following planting, several trees had developed a hole in the soil around the base due to wind moving the trunk. It was decided to fill this hole with crusher dust, which held the trunk firmly in place while providing drainage to prevent trunk canker. Two trees badly leaning trees were also staked.

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Fig 18. Crusher dust placed around the base of the tree. As the tree moved on the wind the dust falls down the hole alongside the trunk locking the tree in place and providing stability

Starting on January the 26th, ex-tropical cyclone Oswald travelled down the Queensland coast causing extensive wind and water damage to properties and orchards. Fortunately, no trial trees were lost but most of the taller trees were left with a permanent lean towards the North West (photographs 1 and 2). As a consequence, a decision was made to mechanically top all the trees at 1.75metres and hand remove the surplus growth from the downwind side in order to prevent the trees from falling over completely if further wet and windy conditions were encountered (Figs 19 and 20). The level of pruning was quite drastic in some of the taller trees while the smaller trees required only minor pruning. A small number of trees were also staked in order to allow the trees to remain upright while they grew new supporting roots. A potassium phosphonate spray was also applied to the trees to prevent the fungus, Phytophthora cinamomi , colonising the damaged roots and causing trunk cankers. Notes were made as to which trees were damaged and the extent of damage for future reference.

Following a meeting with Dr Russ Stephenson, leader of regional variety trials (MC06009) and Dr Bruce Topp, leader of the macadamia breeding project (MC08001) it was decided to prune all trees in the regional variety trials heavily in order to reduce the chances of further wind damage following cyclone Oswald.

It was realized that severe pruning may have a differential affect on some cultivars with taller more upright trees being affected more than shorter more compact trees, but this was done to prevent the complete loss of the trial should there be a further severe wind event.


Figs 19 and 20. Severely leaning trial trees following ex-tropical cyclone Oswald.


Figs 21 and 22. Mechanical Afron pruner topping trees at 1.75m and resulting pruned trees.


Figs 23 and 24. Hand pruning material from downwind side of trees before and after pruning.

Pest damage

Apart from some minor damage to the emerging flush from Thrips, in most years there was no pest damage to the trial during the course of this project. Thrips are an emerging pest of macadamias in the hotter, drier production areas of central Queensland where they can do extensive damage to both the flowers and foliage. Consequently, it was decided to score the progeny for thrips damage to see if there is any genetic variation in susceptibility. The thrips damage, again on initial field examination, also appeared to be more prevalent in some progeny.

As aside, while conducting the November 2012 assessment a parasitized, but still alive, green vegetable bug (Nerida viridula) was found on one of the racemes with small nuts. This bug was carefully collected and sent to Dr Craig Maddox, NSW DPI, so that the parasite could be grown out. It is highly likely that it is the parasite *Trichopoda giacomelii,* but any new parasite for this intermittent pest of macadamias would be highly beneficial.

Fig 25. Green vegetable bug with, possibly, eggs of a parasite on its back.

Measurements and Results

Tree height

The trial was planted on the 15th of November 2011 and the tree height was measured on two occasions, firstly in October 2012, at 11 months of age (Fig 26) and secondly in February 2015, at three years and three months, (Fig 27). Tree height was to have been measured annually, but following cyclone Oswald and the resultant remedial action which required all tree to be pruned to 1.75 metres high it was decided not to measure trees in the second year as they were all approximately the same height.

Fig 26. Trees being measured for height and scored for precocity (flowering) October 2012 eleven months after the trial was planted.

Fig 27. trees being measured for height February 2015, three years and three months after planting. Note increase in tree size

At eleven months from planting the three shortest lines were BQRS01 215, HIN01 55 and the industry standard A16 all of which had a mean height of 139cm (Table 2) while the three tallest were BAFF01 1917 (1.81m), BQRS98 1493 (1.74m) and the industry standard HAES 816 (1.71m). Trees were ranked from shortest to tallest as short stature is potentially more advantageous in an orchard situation than a tall tree.

Table 2. Mean tree height (m) for three industry cultivars and 16 elite sections from the macadamia breeding program at eleven months and three years and three months of age.

Cultivar and or elite selection	Mean tree height (m) 11months from planting		Cultivar and or elite selection	Mean tree height (m) three years and three months from planting
BQRS01 215	1.39 a		A16	2.53 a
HIN 01 55	1.39 a		HIN 01 55	2.55 ab
A16	1.39 ab		BQRS01 215	2.63 abc
BQRS01 202	1.47 abc		HIN 01 35	2.70 abcd
HIN 01 35	1.48 abc		BQRS01 202	2.73 bcd
HIN 01 54	1.49 abc		HIN 01 210	2.76 cde
BAFF 01 426	1.49 abc		HIN 01 246	2.85 de
HIN 01 210	1.54 abcd		BAFF 0 1177	2.92 ef
BQRS98 631	1.55 abcd		BAFF 01 426	2.93 ef
HAES 741	1.55. abcd		HIN 01 54	2.90 ef
BQRS98 246	1.61 abcde		BQRS 01 2004	3.05 fg
BQRS 01 1207	1.63 bcde		BQRS 01 1207	3.08 fg
BQRS 01 2004	1.64 cde		BQRS98 631	3.10 fg
BAFF 01 1532	1.65 cde		HAES 741	3.15 gh
BAFF 01 1508	1.67 cde		BAFF 01 1508	3.18 gh
BAFF 01 177	1.69. cde		BAFF 01 1917	3.18 gh
HAES 816	1.71 cde		BQRS98 1493	3.18 gh
BQRS98 1493	1.75 de		HAES 816	3.33 hi
BAFF 01 1917	1.81 e		BAFF 01 1532	3.30 i
Mean	**1.57**		**Mean**	3.0
Lsd	**0.20**		**Lsd**	
Means followed by the same letter are not significantly different from each other				

When the trees were measured again at three months and three years of age there was no change in the ranking of the shortest trees with industry standard A16 the smallest followed BQRS01 215 and HIN01 55. There was some re-ranking amongst the tallest trees with the tallest genotype now being BAFF01 1532 (3.4m) though the industry standard HAES 816 (3.3m) and BQRS98 1493 at (3.18) were still in the top three genotypes for tree size.

Canopy area was also calculated in February 2015 by measuring the canopy radius at a standard height of 1m from the ground and on the eastern side of the tree only. Canopy area provided some estimate, along with tree height, of tree size. Measuring and then calculating canopy volume, a measurement made in the regional variety trials, was not considered as many of the trees were fan shaped and or had considerable growth on the lee side (NE side) of the trees due to the prevailing SE wind. This variability made trying to calculate canopy volume meaningless.

However, this measurement will be made in future years as the trees grow larger the effect of the prevailing wind on tree shape lessens.

While there was a range in the canopy diameter from 3.5 to 5.86m there was no relationship between tree height and canopy width (Table 3). With small lines such as BQRS01 215 (2.63m) having one of the largest canopy areas (5.17m) and a tall lines such as BAFF 01 1917 (3.18m) having one of the smaller canopy areas (4.22m).

Table 3. Mean tree canopy area (metres) for three industry cultivars and 16 elite selections from the macadamia breeding program at three years and three months of age.

Line	Mean tree canopy diameter (m)
HIN 01 35	3.15 a
HIN 01 55	3.33 ab
BQRS01 202	3.50 ab
A16	3.79 abc
HIN 01 210	4.00 abcd
BAFF 01 1917	4.22 bcde
BQRS 98 631	4.42cde
HAES 741	4.64 cdef
BQRS98 246	4.65 cdef
HIN 01 54	4.77 defg
BQRS98 1493	4.77 defg
HAES 816	4.81 defg
BQRS 01 2004	4.93 defgh
BAFF 01 426	5.16 efgh
BQRS01 215	5.17 efgh
BAFF 01177	5.41 fgh
BQRS 01 1207	5.41 fgh
BAFF 01 1532	5.63 gh
BAFF 01 1508	5.86 h
Mean	4.61
LSD	0.82

Means followed by the same letter are not significantly different from each other

Yield

The trial was planted in November 2011 and in early October 2012, eleven months later, trees were assessed for flowering and nut production in order to asses precocity. Current commercially available cultivars do not normally flower until three to five years from planting.

Seven out of the 19 genotypes in the trial produced either flowers or nuts, one year post planting (Table 4). While only some trees flowered within each replicate the data shows there is the potential for early precocity in macadamia. The two lines with the most number of trees flowering were BAFF 011 77, with five out twenty trees flowering and HIN 01 55 with four out of twenty flowering.

Table 4. Number of macadamia genotypes and numbers of trees within a replicate flowering and producing nuts in October 2012 one year from planting.

Genotype	Replicate				Total number of trees flowering
	1	2	3	4	
BQRS01 202					
BQRS98 1493			1		1
BQRS 01 2004					
BAFF 01 426					
BAFF 01 1508					
BAFF 01 1917					
HIN 01 54					
BQRS01 215			1		1
HAES 816					
BQRS98 246			1		1
HIN 01 35	1	1		1	3
BAFF 01 1532					
HIN 01 55		1	3		4
BQRS 01 1207					
HAES 741					
HIN 01 210					
BAFF 01177	1	3		1	5
BQRS 98 631					
A16	1				1
Grand Total					**16**

Unfortunately, the major pruning required following cyclone Oswald in February 2013 pushed the trees into a strong vegetative growth pattern and there was no flowering in 2013.

All trees flowered in 2014 and the majority of trees in most replicates set some crop. In order to estimate yield for the final report, the report being due before the 2015 harvest would have commenced, it was decided to count the nuts on each trees and then divide the number by 130. One hundred and thirty was used as this is an industry 'rule-of-thumb' for an approximate number of nuts per kilo.

The three best producing genotypes were HIN01 210 which produced an estimated 1.29 kilos of nuts per trees, followed by a HIN01 55 with an estimated 1.26kgs of nuts per tree and BAFF01 177 with around 1.06 kg of nuts per tree. The three industry standards produced fewer nuts with an estimated yield of 0.40kgs per tree for HAES 741, 0.33kgs of nut per tree for HAES 816, and 0.15kgs of nut per tree for A16.

Table 5. Estimated nut-in-shell yield for three industry cultivars and 16 elite selections from the macadamia breeding program at three years and three months of age

Genotype	**Estimated yield per tree (kg nut-in-shell)**
HIN 01 210	1.29
HIN 01 55	1.26
BAFF 01177	1.06
HIN 01 54	0.98
BQRS 01 2004	0.79
BQRS98 1493	0.75
BAFF 01 1917	0.53
HAES 741	0.40
BAFF 01 1532	0.36
BQRS 01 1207	0.34
HAES 816	0.33
BQRS 98 631	0.30
BAFF 01 426	0.28
BQRS01 215	0.28
HIN 01 35	0.24
A16	0.15
BQRS01 202	0.13
BQRS98 246	0.04
BAFF 01 1508	0.03
Mean	0.49

Outputs

The outputs for phase one of this project were:

- Selection of a number of elite progeny from round B 1.2 of the macadamia breeding project for inclusion in a trial to compare their performance against material from round B1.1 of the breeding project and known industry standards.
- Design and establish a trial that will allow the phase two outputs to be achieved.

- Collect initial information on tree growth habits prior to the start of cropping.

Phase two outputs

- Information that will assist growers in making sound commercial decisions as to the suitability of the material evaluated by this project to either be used in new plantings or to replace material in existing plantations.
- A sound commercial evaluation of the economic potential of 16 elite selections from crossing rounds B1.2 and B1.1 of the macadamia breeding program.
- An improved experimental design for evaluating new macadamia germplasm that allows new material to be statistically evaluated while reducing the costs to industry.
- A practical and economic evaluation of clonal rootstocks as a method of improving yields and reducing orchard variability compared to seedling rootstocks.

Outcomes

Phase one outcomes

- The collection of tree growth data for 16 elite selections from rounds B1.2 and B1.1 of the macadamia breeding project.

Phase two outcomes

- The identification of new varieties that have higher yields and better kernel quality than exiting varieties which, in turn, will improve the profitably and long term economic sustainability of the Australian macadamia industry.

Evaluation and Discussion

The phase one outputs for this project have been met despite some setbacks. While the delay in commencing this project, due the prolonged handover of the breeding project from CSIRO to QDAF, put back the planting date for this trial it did allow for a longer evaluation period and, as a consequence, some of the material that had been put forward in the initial evaluation was eliminated due to poor attributes such as 'stick-tight' nuts and disease susceptibility. The delay did, however, put additional strain on project resources and caused problems in areas such as the production of rootstocks.

The trial has been established and there are no missing trees, despite cyclone Oswald, or associated problems that will compromise the ability of the researchers to meet the phase two objectives.

The phase one project outcome, the collection of initial tree growth information, has also been met with considerable variation amongst the progeny both in terms of tree height and canopy diameter recorded identified. This variation was maintained from the first measurement, in year one, through to the second measurement in year three despite all the trees being pruned to the same height in year two following cyclone Oswald. Tree height and canopy diameter are important characteristics for orchard management for a range of both environmental and management reasons. Tall trees are inherently more prone to wind damage than shorter trees and an important consideration in windy environments such as Bundaberg. Canopy diameter is also important as potentially this will determine how many trees can be planted in a given orchard area and this will have ramifications for management practices into the future. For example, shorter more compact trees may require less pruning over the life of an orchard compared with tall spreading trees. When the canopy information is combined with yield then this allows those lines with a high canopy efficiency, i.e. those trees that produce the most nut per unit of canopy area/ volume to be selected.

There was some indication from the initial data that there is potential to develop macadamia cultivars with improved precocity. Precocity is important in that it not only may allow a faster return on investment it may also produce slower growing trees with energy that would have been used for growth diverted to towards crop. Factors such as these have the potential to significantly change the economics of macadamia production in Australia. However, precocity may carry some potential risk as earlier and heavier bearing could result in earlier tree decline and, in turn, this may result in lower cumulative yields over the life of an orchard. The potential link between precocity and early orchard decline will be examined as an ongoing component of this trial.

The estimated yield data, while not particularly accurate, suggests there are potentially large differences between not only the elite selections, but also between some of the selections and the industry standards. Some of the selections potentially producing two to three times more crop at year three than the industry standards. This will need to be validated by proper measurements of the year three yield and further yield determination for years four to eight. Hardner et al (2002) have suggested that yield potential in macadamia can be estimated by measuring cumulative yield from the start of cropping until year eight.

The industry has also recently decided to start another round of regional variety trials in 2019 and this will include some of the progeny (B1.2) used in this trial along with newly generated material. This voluntary contribution project has therefore considerably shortened the

evaluation period as it will be reporting, should it gain future funding to 2019 with five years of yield data just as this next round of regional variety trails is about to be planted. This represents a considerable shortening in the breeding cycle, a major saving to industry and the possibility of an earlier release of new cultivars to industry.

Recommendations

That the second phase of the project be funded to allow the collection of yield, kernel quality and tree growth characteristics. The collection of this information has the potential to advance the macadamia industry through the identification of high yielding cultivars. There will also be benefits to the breeding project by shortening the evaluation period for germplasm from round 1.2 of the breeding project and also allow some assessment to be made of the genetic progress of the breeding project by comparing the performance of material from round 1.1 of the breeding project with round 1.2.

It may also be worth re-testing the two progeny, BAFF 011 77 and HIN 01 55, that produced flowers eleven months after planting, to see if this is a repeatable result and whether they also able to flower and produce a crop in their second year. Unfortunately, we were not able to measure flowering in the second year due to the impact of the remedial pruning on vegetative growth following cyclone Oswald. This precocity information could then be fed back into the breeding program and, if these two progeny also have reasonable yields and kernel quality, they then may make potential parents when breeding for improved precocity.

Scientific Refereed publications

No publications were produced during the course of this project

IP/Commercialization

There is no IP associated with this project. All IP and commercialisation rights lie with the Queensland Government, HIA and the Australian Macadamia Society.

References

Genetic parameters for yield in macadamia Craig M. Hardner, Calvin W. Winks, Russ A. Stephenson, Eric G. Gallagher & Cameron A. McConchie1 (2002) Euphytica 225: 255–264,

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