Hort Innovation

Final Report

New custard apple varieties and enhanced industry productivity

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CU16002

Project:

New custard apple varieties and enhanced industry productivity (CU16002)

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Content

Summary

The objectives of CU16002 were to successfully develop new high-yielding green and red skin custard apple selections, evaluate the performance of clonal and seedling rootstock selections and increase grower awareness and knowledge of a range of production issues through a series of industry development field days and workshops.

This project built on the previous project phase (CU13001) to develop new green and red skin high yielding custard apple varieties and clonal and seedling rootstock selections.

Over 2000 hybrid progeny were established during the project term using red and pink skin parents. Approximately 1800 hybrid seedlings were evaluated for tree and fruit characteristics, resulting in over 40 new selections being identified for further evaluation.

A series of trials evaluating new elite selections from the breeding program were established in the previous project phase. Evaluation of these selections in major production regions has resulted in 3 green skin selections being recommended for commercialisation. Two promising red skin selections have also performed well in trials, however further evaluation will be required before they are progressed to commercialisation.
Rootstock trials have evaluated a range of seedling and clonal rootstocks and recommendations have been developed on their suitability to different growing regions.

A small clonal propagation program with a collaborating nursery in North Queensland has successfully produced rootstock of cherimoya and DAF selection 450. Strike rates of over 75% in selection 450 means commercial quantities of this rootstock will become available for industry as the program progresses. Although high strike rates were also reported in cherimoya rootstocks the growth habit of the tree was not ideal for grafting.

All R&D aspects of project CU16002 have been extended to growers and stakeholders through industry field days and meetings, newsletter articles and social media.

Keywords

Cherimoya, custard apple, Annona, varieties, rootstock, propagation, commercialisation, clone, breeding

Introduction

Custard apple (Annona spp. hybrid or atemoya) is a unique fruit that is popular in Australia and Asia. The industry produced around 1422 tonnes of fruit in 2020 with an estimated farm gate value of $6M. There are about 150 active growers. Most of the production is consumed domestically, however around 5% or 71 tonnes of custard apples are exported, mainly to Asian markets (Australian Horticulture Statistics Handbook 19/20). Industry plantings are currently made up of 20,000 African Pride, 8900 Pinks Mammoth, 43,000 KJ Pinks, 2000 Pinks Blush and 1000 Maroochy Gold trees. The major growing regions for the Australian custard apple industry based on estimated production are Northern NSW (47%), Sunshine Coast (26%), Tablelands of North Queensland (11%), Wide Bay (9%), Central Queensland (3%) and Western Australia (4%).

There is significant opportunity to increase the productivity of Australian custard apple orchards through improved varieties and rootstocks and extension of best practice to growers.

A major component of this project was to develop new custard apple varieties to increase profitability and diversify the industry. Over 1800 trees of hybrid progeny planted at Maroochy Research Facility were evaluated between 2018 and 2021. Development of new hybrid populations were generated by crossing elite parental germplasm, which is also held at the facility. Elite green and red skin selections identified in previous project phases were also tested on commercial orchards in a range of growing regions to develop recommendations for commercialisation.

Excessive vigour and tree variability has been observed in orchards in all growing regions. The project aimed to identify alternative rootstocks that can reduce that vigour and variability. A series of rootstock and variety field trials were established on commercial orchards in CU13001. Evaluation of these trials continued throughout CU16002 and have generated valuable data for recommendations to industry.

The use of seedling rootstock causes large variability in tree performance in custard apple orchards. The use of clonal rootstocks in other horticultural industries has helped reduce this variability. A commercial clonal propagation nursery was supplied with mother stock material in 2017 as part of CU13001 and has successfully multiplied large numbers of clonal cherimoya and rootstock selection 450. The expansion of the Australian custard apple industry has been plagued by a shortage of seedling cherimoya rootstock over the last three years due to seed germination failures experienced by commercial nurseries. The successful production of clonal rootstock would guarantee the supply of rootstock for industry expansion as well as reducing orchard variability.

There are few consultants specialising in custard apple, so CU16002 project staff have historically provided advice and information to support growers and other industry stakeholders. The project delivered a range of extension materials including newsletter articles, presentations and demonstrations at field days in addition to extensive direct communication with growers.

Methodology

Breeding and testing

Recurrent phenotypic selection has been the main breeding strategy for the development new custard apple varieties. The focus of the breeding was to produce high yielding red and pink skin seedlings. This was achieved by using advanced selections as parents for hybridisation.

Over 1,000 hand pollinations were completed per season. Pollen was normally collected in the late afternoon between 2 to 3 pm. The flowers were spread out on paper and left overnight for the pollen sacs to dehisce. Pollen was extracted and placed into vials ready for hand-pollinating the next morning usually about 8.00am. Hand pollinating generally results in good fruit set, with between 60-90% of flowers setting depending on environmental conditions and pollen viability.

Seeds were extracted from fruit between April and June, treated with gibberellic acid ($GA_3$0.1%) for 24 hours at 40°C and planted out in tube cell trays in the glasshouse. Resulting seedlings were then potted into 5 litre bags approximately 3 to 4 months after germination and field planted after a further 9 to 12 months.

Approximately 800 seedling progeny were field planted annually at the Maroochy Research Facility from 2018 to 2020. Field planting was generally carried out between February and March each year, although some seedlings reached a suitable height in November/December and were subsequently planted at that time. Trees typically begin to flower three years after planting, at which time they can be evaluated..

Progeny were evaluated according to the following traits:

- yield
- precocity
- fruit quality
- disease susceptibility

Quality assessments were typically completed by sampling six to ten fruit, randomly selected from each seedling progeny. These were assessed according to the following traits by trained panel of 3-4 staff during the harvest period:

- Fruit weight (g)
- Fruit symmetry (scale of 1-9, 1=poor shape, 9=completely symmetrical)
- Skin type (smooth, tuberculate or impressa).
- Skin thickness (scale of 1-3, 1=thin or <2mm, 3=thick or >4mm)
- Seed number (total and per 100 grams of flesh)
- Flavour (hedonic scale 1-9, 1=extremely dislike, 9=extremely like)
- Texture (hedonic scale 1-9, 1=extremely dislike, 9=extremely like)
- Brix (sweetness, determined on expressed juice using a hand-held refractometer)
- Skin colour (dark red, crimson red, mauve, dark purple, dark green, pale green, yellow/green)
- Flesh colour (red, pink, white)

Results from fruit quality assessments and field performance of each seedling were used to determine whether specific seedlings would progress to the next stage of testing.

New progeny warranting further evaluation progressed to Stage 2 testing. This involved grafting selections onto the industry-standard cherimoya rootstock. Small numbers of these progeny were initially planted and evaluated on commercial farms in Queensland and NSW in accordance with material transfer agreements. Superior selections were then identified based on their observed field performance as well as feedback from collaborating growers. Larger numbers of these trees were subsequently propagated and planted on commercial farms for larger scale testing.

The performance of elite selections in these large-scale trials has informed recommendations for their commercialisation. The commercialisation process is guided by an exploitation plan developed in the early stages of the project. The limited availability of commercial rootstocks has significantly affected the number of elite selections that could be propagated. Despite significant efforts by project staff to produce rootstocks from seed, lack of available rootstocks ultimately limited the number of trees available for large scale testing. A summary of selections trailed and the total trees planted for each is shown in Table 1.

Table 1 – Advanced selections being tested in each growing region

Elite selection	Total trees planted
453-1	142
470-2	101
470-3	105
649-1	86
591-1	38

Regional rootstock and variety trials

During previous phases of the project new seedling rootstock selections were identified and incorporated into trials, as shown in Table 2. Rootstocks such as atemoya (custard apple), squamosa (sugar apple) and other cherimoya selections were evaluated to determine their suitability as an alternative to the industry standard cherimoya rootstock. Both yield and vigour were evaluated throughout the project for a range of seedling rootstocks including atemoya types such as African Pride (APV2), Gefner and selection 450, Taiwanese squamosa and cherimoya selections.

Table 2- Summary of rootstock trials

Location	Scion	Rootstock
Maroochy Research Facility	453-1, 464-1	Seedling cherimoya, Own roots
Beerburrum	470-2	Cherimoya, Gefner, 450 clonal, dwarf cherimoya
Gin Gin	453-1, 470-2, 470-3, KJ Pinks	Cherimoya seedling, dwarf cherimoya, Gefner, 450 clonal, Cherimoya clonal
Bundaberg	470-2	Chesterman, Kirkwood, Taiwanese Squamosa, Gefner, African Pride, dwarf cherimoya, cherimoya
Mareeba	KJ Pinks	Taiwanese squamosa, APV2, Cherimoya, Dwarf cherimoya

All rootstock trials were evaluated using the following ratings and measurements
Visual vigour ratings on a 1-5 scale (1= low vigour and 5 = excessive vigour)

- Shoot elongation (cm) from six randomly selected representative shoots
- Trunk circumference or diameter using a tape measure or calipers
- Difference between trunk circumference below and above the graft as a measure of graft compatibility
- Randomised trials were analysed using Analysis of Variance (ANOVA) in Genstat 21.1 using a significance level of <0.05

Mareeba rootstock trial

Six replicates of each rootstock selection were grafted to 'KJ Pinks' in 2009 and planted on a vertical trellis in 2010 in a non-randomised design at a commercial orchard in Mareeba in North Queensland. Tree spacings were 3m between trees within the row and 5m between rows. Four rootstocks were used as follows:

- 550- Dwarf cherimoya selection
- 404- low/moderate vigour Taiwanese squamosa
- APV2- moderate vigour African Pride seedling selections
- Cherimoya- industry standard rootstock

Gin Gin rootstock trial

Six replicates of clonal cherimoya, clonal 450 and seedling cherimoya were grafted to 'KJ Pinks' in 2017 and planted in a randomised block design on a vertical trellis in Gin Gin.

Bundaberg rootstock trial

Six replicates of seven rootstock selections were grafted to selection 470-2 in 2017 and planted in a randomised block design on a vertical trellis. The seven rootstock selections were:

- Cherimoya
- Kirkwood (cherimoya)
- Dwarf Cherimoya
- Chesterman (cherimoya)
- Gefner (atemoya)
- Taiwanese Squamosa
- African Pride (atemoya)

Beerburrum rootstock trial

Six replicates of four rootstock selections were grafted to selection 470-2 and were planted in a randomized single row design on a vase row growing system. The four rootstock selections were as follows:

- Cherimoya
- Dwarf cherimoya
- Clonal 450
- Gefner

Maroochy Research Facility – clone vs graft rootstock trial

This trial was designed to evaluate the performance of varieties growing on their own roots (clonal cuttings) compared with the same scion variety grafted onto the industry standard seedling cherimoya. Six replicates of the following variety/rootstock combinations were planted in randomised block design in a vase growing system at Maroochy Research Facility:

- 453-1 grafted on seedling cherimoya
- 453-1 clonal cutting (own roots)
- 464-1 grafted on seedling cherimoya
- 464-1 clonal cutting (own roots)

Clonal propagation

In the previous phase of the project a clonal propagation program was established at Walkamin in North Queensland in collaboration with Turkinje nursery. Significant work had previously identified rootstock selections that achieved high clonal replication. Two of these selections, Cherimoya and selection 450, were used to continue the rootstock program and focus on creating large numbers of these selections for commercial use and inclusion in future trials. The methodology used by Turkinkje Nursery is confidential, so no description of the clonal propagation method can be published. Strike rates and number of plants produced in each generation of cuttings can be found in the Outputs section.

Extension

Extension of R&D to custard apple growers and industry stakeholders was achieved through publication of newsletter articles in the industry newsletter. Attendance and presentations at 13 industry field days in Queensland and NSW also provided growers with first-hand project updates and allowed them to observe new selections in the field. Project staff also attended four annual Custard Apples Australia (CAA) management team meetings during the project. Individual farm visits to growers were also a key component of the project's extension strategy. Interaction with growers was significantly impacted by COVID-related restrictions during 2020 and 2021.

Outputs

Progeny evaluation and new seedling selections

Hybrid progeny populations were assessed annually for tree traits including yield, leaf type, disease susceptibility and fruit quality traits including weight, symmetry, skin thickness, flavour, texture, Brix and seed number. Over 1800 trees were evaluated between 2018 and 2021. 45 seedlings were selected for further evaluation, as shown in Table 3. 73% of new progeny selected were red or pink skin with the remaining 27% having green skin.

Table 3 - New hybrid seedlings identified for further testing

Year	Red skin	Green skin	Total
2018	10	2	12
2019	9	6	15
2020	5	2	7
2021	9	2	11
Total	**33**	**12**	**45**

New progeny selections were either propagated for on-farm testing, observed over extended periods in breeding blocks or used as parents for future crossing (Figure 1). Lack of available rootstocks limited the number of selections that could be grafted for on-farm testing, so in most cases new selections were topworked on older trees at MRF. Details of progeny identified for further evaluation can be found in Table 19 in Appendix 1.

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Figure 1 - New progeny selections in 2021

Fruit evaluations were conducted in each season between 2018 and 2021. An example of some relationships between fruit quality parameters in 2021 evaluations are shown in Figures 2 to 4. Comparison of fruit size with seed counts revealed a weak inverse correlation between fruit size and number of seeds per 100g of fruit (Figure 2).

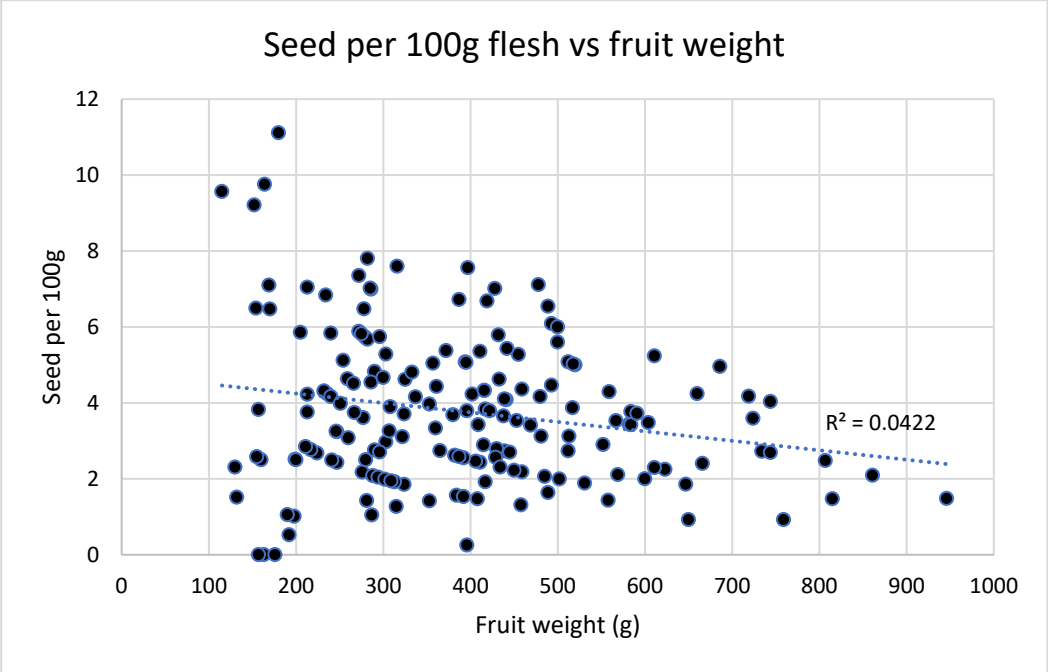


Figure 2 - Fruit weight versus seed count per 100g of flesh

Fruit from new progeny populations assessed in 2021 showed a relationship between Brix and flavour ratings using a hedonic scale (Figure 3). All fruit rated as 9 (extremely like) on the hedonic scale had a Brix value of more than 15%. Fruit rated as acceptable flavour (7 and above) ranged between 13% and 29.5% Brix indicating that other volatile compounds influenced flavour ratings. Atemoya have been found to contain phenolic compounds such as 3,4-dihydroxybenzoic acid, catechin, chlorogenic acid, epicatechin and *p*-coumaric acid (de Moraes, 2020).

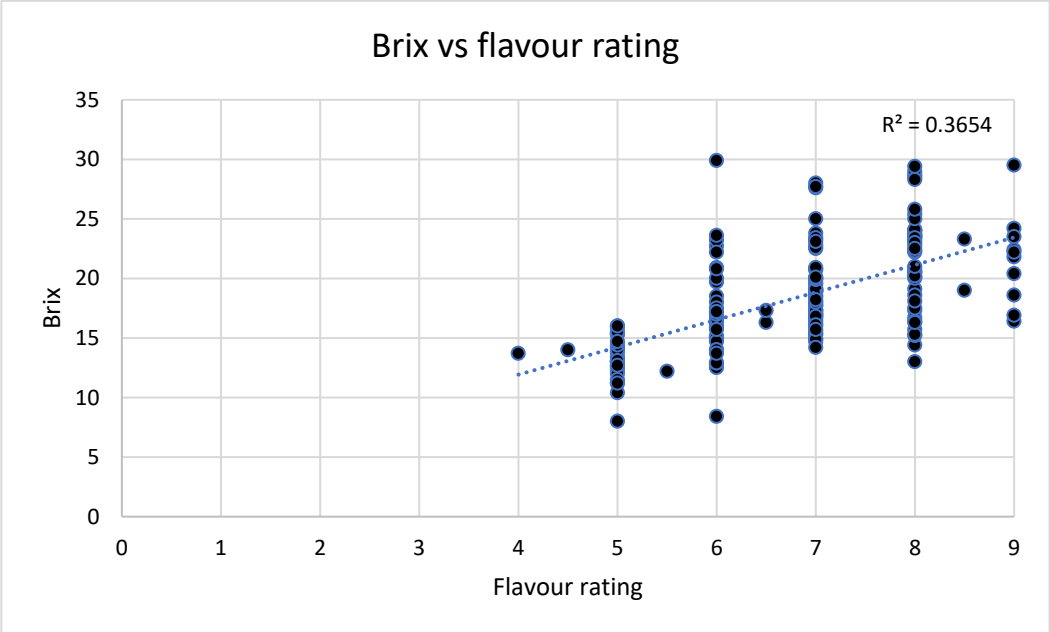


Figure 3 - Relationship between Brix and flavour rating

A relationship between flavour and texture was also evident in fruit evaluated in 2021 (Figure 4). Fruit rated as 9 for flavour had a corresponding texture rating between 6 and 8.5.

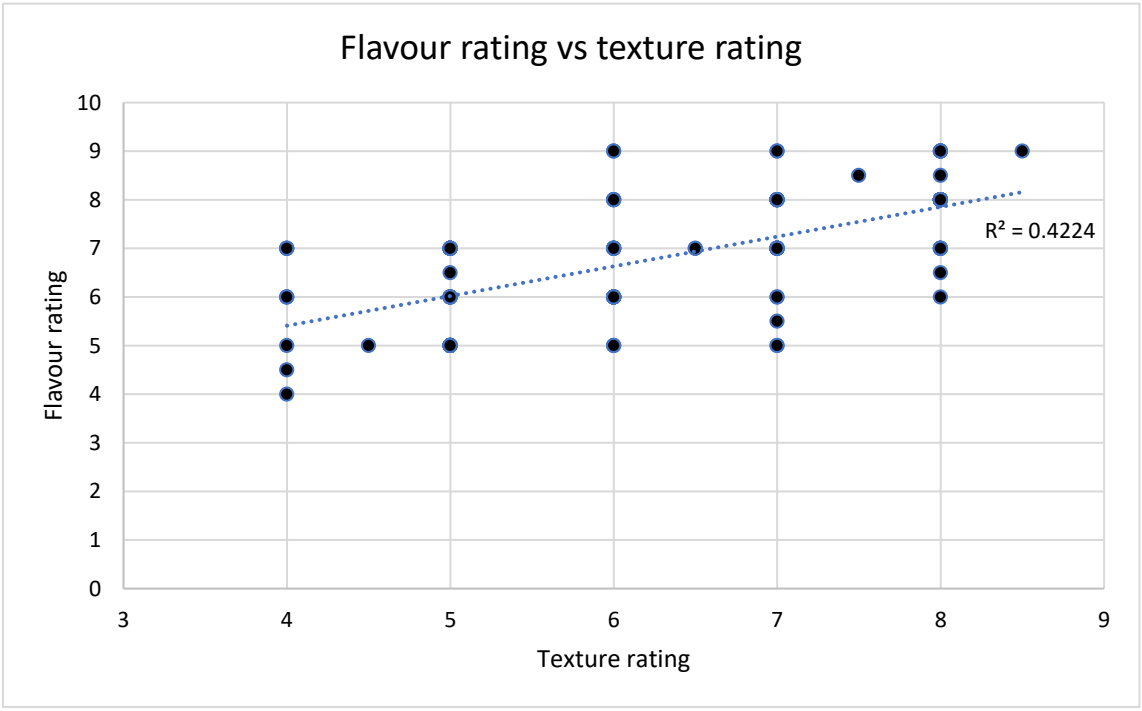


Figure 4 - Relationship between flavour and texture ratings

Figure 5 shows the range in fruit numbers per tree for all progeny families evaluated in 2021. Most fruiting trees produced less than 10 fruit per tree, although a small number exceeded 30 fruit on three- or four-year-old trees. Those families exceeding an average of 10 fruit per tree generally had *Annona reticulata* and *Annona squamosa* in their parentage.

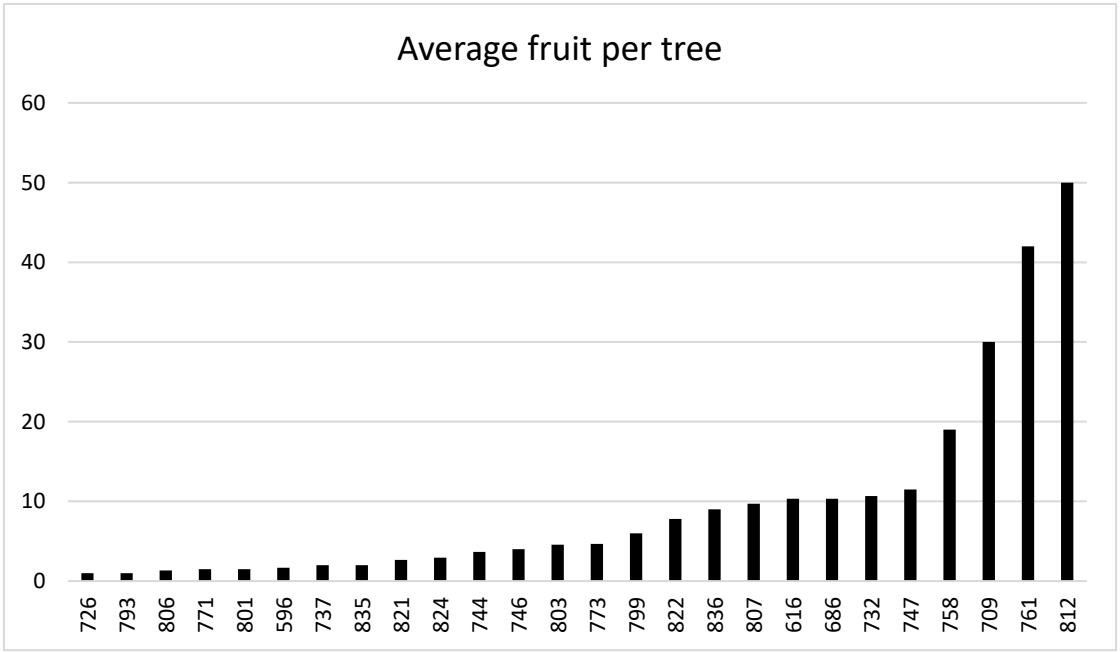


Figure 5 - Fruit numbers per tree for progeny families evaluated in 2021

Elite selection evaluation

Elite selections at Maroochy Research Facility and in regional grower trials were assessed for tree and fruit characteristics throughout the project. The total trees trialled for each selection are shown in Table 4.

Table 4 - Elite selections currently being evaluated in Queensland and New South Wales

Selection	Northern Rivers	Brisbane	Glasshouse Mountains	Bli Bli	Maroochy Research Facility	Bundaberg & Gin Gin	Mareeba	Western Australia	Total
453-1	7	3	2	10	5	35	30	50	**142**
470-2	3	8	15	10	5	20	30	10	**101**
470-3	28	0	3	10	16	15	20	13	**105**
649-1	4	0	15	0	12	50	5	0	**86**
591-1	0	0	7	0	11	15	5	0	**38**

Average results from 2019 to 2021 for elite selections in regional trials are shown in Table 5. Data from trial sites in Queensland and New South Wales have been combined for each selection. Queensland sites include Mareeba, Wide Bay and Glasshouse Mountains. NSW sites are from the Northern Rivers region of NSW. More information on each selection can be found in variety fact sheets (separate attachment).

Table 5 - Average performance data for elite selections 2019-2021

Year/season	Clone	Location	Yield score (1-9)	Vigour score (1-5)	Weight (grams)	Brix	Flavour score (1-9)	Texture score (1-9)	Seeds per 100g
2019	453-1	QLD	7	4	618.2	18.8	7.2	6.8	4.9
2019	453-1	NSW	5	4	552.1	13.1	5.6	6.6	3.4
2019	470-2	QLD	7	4	543.7	20.7	8	7.6	3.8
2019	470-2	NSW	7	4	686.2	17.2	7.3	7	4.7
2019	470-3	QLD	6	3	694.8	23.1	8.2	7.8	2.9
2019	470-3	NSW	7	3.5	407.3	19.5	7.5	7.1	5.9
2019	649-1	QLD	7	4	469.3	20.5	6.5	7.1	5.6
2019	649-1	NSW	6	4	406.3	16.7	6.1	7	6.4
2020	453-1	QLD	7	4	559.8	14.1	5.5	7	4.6
2020	453-1	NSW	5	4	443.5	9.3	4.5	5.5	4.5
2020	470-2	QLD	8	3.5	457.7	15.5	7	7.2	9.7
2020	470-2	NSW	6	4	653	11.7	6.8	7.3	3.3
2020	470-3	QLD	5	4	693.2	16.1	7	7.5	4.1
2020	470-3	NSW	6	4	402.8	13.5	6.5	7.1	5.9
2020	649-1	QLD	6	3.5	547.4	17.5	7	7	4.1
2020	649-1	NSW	3	3	357	12.8	5	7	8.2
2021	453-1	QLD	7.4	4.3	543.4	16.5	6.8	6.5	5.2
2021	453-1	NSW	4.5	4.3	669.8	11.5	5.8	5.5	4.3
2021	470-2	QLD	7.5	3.3	701.7	18.1	7.3	6.8	4.6
2021	470-2	NSW	4	3.3	1111.2	15	7.3	7	2.1
2021	470-3	QLD	6.4	4.2	596.7	19	7.2	6.5	4.8
2021	470-3	NSW	7	4	785	17.3	7.7	7.3	2.4
2021	649-1	QLD	3.4	4.1	561.4	20.1	7	6.8	4.9
2021	649-1	NSW	1.5	4.5	370	19.8	4	5	8.1

Regional rootstock and variety trials

Regional rootstock trials were conducted in Beerburrum, Gin Gin, Bundaberg and Mareeba. A trial to compare cloned and grafted trees was also conducted at the Maroochy Research Facility in Nambour.

Mareeba rootstock trial

An observational trial in Mareeba, North Queensland identified differences in vigour for KJ Pinks grown on four rootstock selections. Dwarfing selections 404 (Taiwanese squamosa) and 550 (dwarf cherimoya) reduced average tree vigour and shoot elongation when compared to trees grafted on Cherimoya and African Pride (APV2 – Atemoya) (Figure 6).

Fruit set could not be reliably measured as researchers were unable to co-ordinate travel to the trial during the harvest period in 2021.

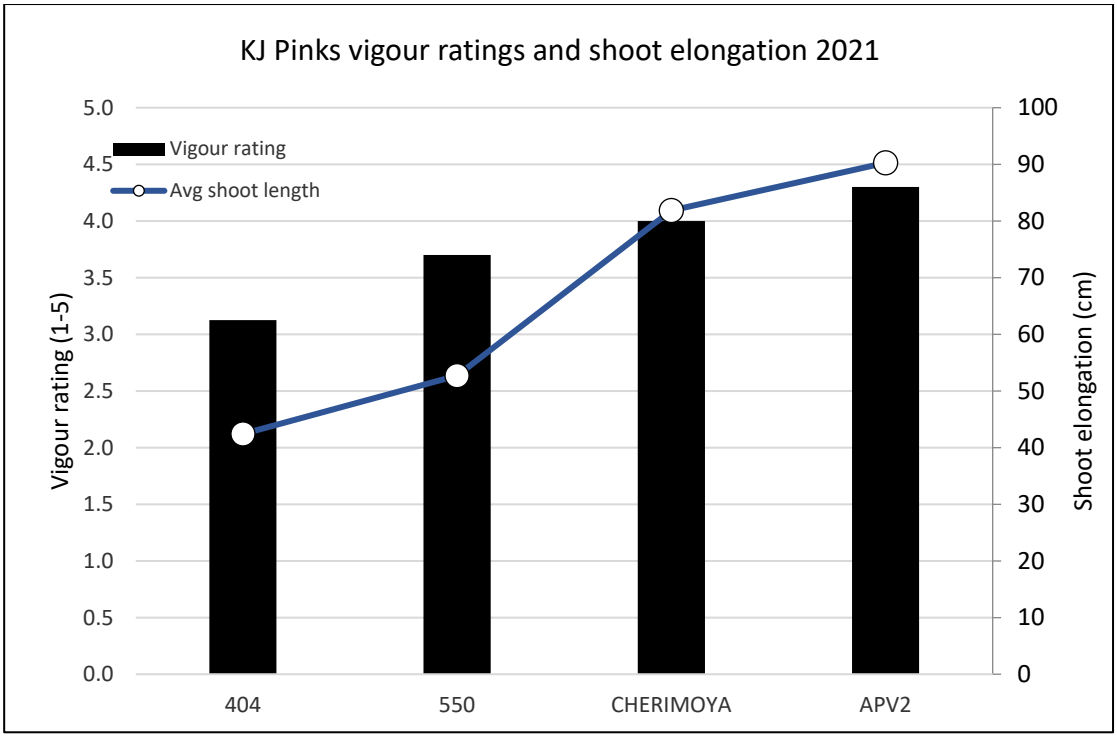


Figure 6 - Vigour rating and shoot length for KJ Pinks grown on four rootstock selections

Figure 7 shows trunk circumference measurements below and above the graft for KJ Pinks grown on four rootstock selections. KJ Pinks growing on APV2 rootstock had the largest average trunk circumference of all rootstocks. Cherimoya and 550 rootstocks produced trees with a similar trunk circumference. 404 rootstock produced trees with the smallest trunk circumference, which corresponded with the lowest vigour rating and shoot elongation. There was also little difference between trunk circumference below and above the graft (3%) for 404 rootstocks, which indicates a high level of graft compatibility. All other rootstocks ranged between 27% and 36% difference between the below and above graft circumference, indicating some rootstock incompatibility, however the growth of trees would suggest there is no impact on vigour.

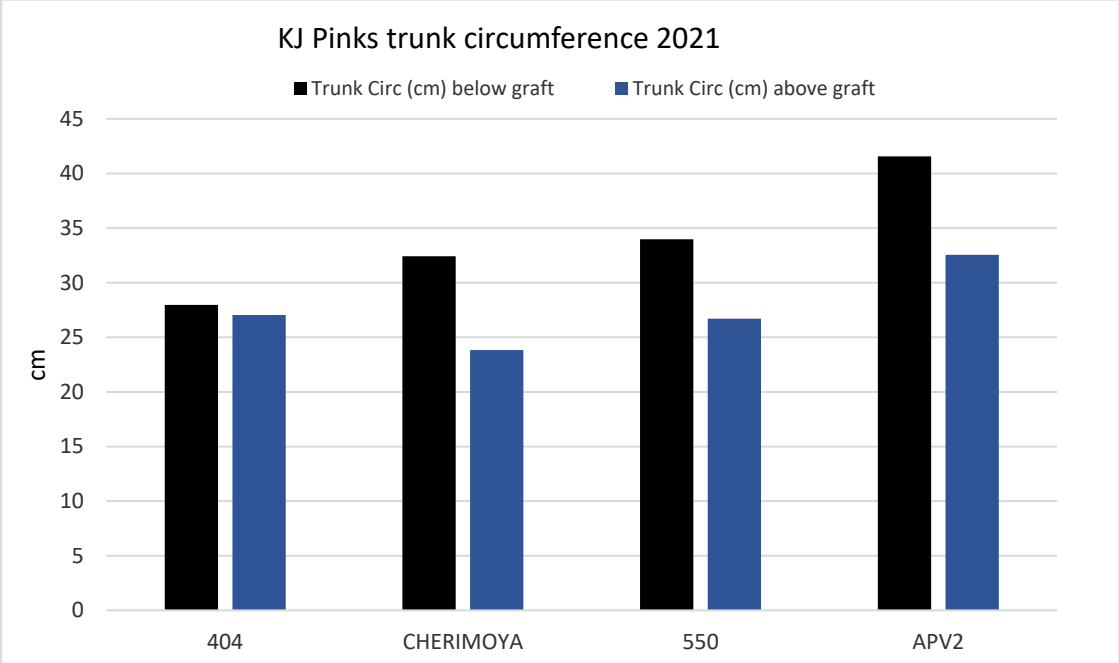


Figure 7 -Trunk measurements for KJ Pinks grown on four rootstock selections

Figure 8 - Graft unions for KJ Pinks grafted on dwarf cherimoya (top row), African Pride V2 (second row), 404 Taiwanese squamosa (third row) and cherimoya (bottom row)

Gin Gin rootstock trial

Tables 6 and 7 show tree measurements for KJ Pinks grafted on two clonal (450 and cherimoya) and one seedling (cherimoya) rootstock selection between 2020 and 2021. In 2020 trees grafted on clonal 450 and clonal cherimoya had significantly higher shoot length and vigour ratings when compared to seedling cherimoya ($P<0.05$). There was no significant difference between trunk diameter, graft compatibility or fruit number between rootstocks on 3-year-old trees in 2020.

In 2021 when trees were four years old, both clonal rootstock selections produced larger shoots than seedling cherimoya rootstock. The rootstock vigour rating for clonal cherimoya was comparable with clonal 450 and significantly higher than seedling cherimoya ($P<0.05$, Figure 9). Seedling cherimoya rootstock produced the largest difference between rootstock and scion diameter ($P<0.05$). Clonal selections showed good graft compatibility with less than 6mm variation in diameter below and above the graft union. Trees grafted on clonal 450 produced the most fruit with both clonal rootstocks producing significantly higher fruit numbers than seedling cherimoya ($P<0.05$).

Table 6 - KJ Pinks tree measurements on clonal and seedling rootstock selections 2020

Rootstock	Shoot length		Vigour rating		Trunk Diam (mm)		Diam difference below/above (mm)		Fruit number	
Clonal cherimoya	84.06	a	3.08	a	50.8	a	4.6	a	2.5	a
Clonal 450	81.88	a	2.87	a	61.2	a	9.8	a	3.75	a
Seedling cherimoya	58.78	b	1.83	b	46.7	a	8.3	a	1	a
Lsd	10.9		0.57		13.1		5.8		2.6	
F pr.	0.002		0.003		0.081		0.161		0.105	

NB: Means with same subscript are not significantly different at the P = 0.050 level

Table 7 - KJ Pinks tree measurements on clonal and seedling rootstock selections 2021

Rootstock	Shoot length		Vigour rating		Trunk Diam (mm)		Diam difference below/above (mm)		Fruit number	
Clonal cherimoya	89.7	a	4.08	a	57.4	a	5.95	b	61.3	a
Clonal 450	85.2	a	3.5	ab	58.3	a	5.49	b	70.1	a
Seedling cherimoya	66.1	a	2.75	b	55	a	16.3	a	37.8	b
Lsd	21.6		0.85		9.6		8.9		18.21	
F pr.	0.078		0.022		0.708		0.04		0.01	

NB: Means with same subscript are not significantly different at the P = 0.050 level

Figure 9 - KJ Pinks grafted on clonal cherimoya (left), clonal 450 (middle) and seedling cherimoya (right)

Bundaberg rootstock trial

Table 8 shows vigour, trunk measurements and fruit counts for four-year-old trees of selection 470-2 grafted on seven seedling selections. Shoot extension was not recorded as trees were summer pruned prior to data collection. Trees grafted on cherimoya rootstock achieved the highest vigour rating. All cherimoya rootstock selections had higher vigour ratings when compared to atemoya and squamosa selections, which had significantly lower vigour ratings when compared to the industry standard cherimoya rootstock ($P<0.05$). Dwarf cherimoya produced the largest number of fruit per tree and was significantly higher than Gefner, Taiwanese squamosa and African Pride ($P<0.05$). Dwarf cherimoya also achieved the largest trunk diameter of all rootstock selections and was significantly larger than atemoya and squamosa rootstocks. There was no significant difference between rootstock selections for below and above graft trunk diameter ($P>0.05$). Kirkwood cherimoya achieved the highest difference in trunk diameter above and below the graft union. The smallest differences were observed in the industry standard cherimoya (Figure 10) and Taiwanese squamosa.

Table 8 - Tree measurements for selection 470-2 grafted on seven rootstock selections

Rootstock	Vigour rating		Fruit number		Trunk Diam (mm)		Trunk Diam Diff	
Cherimoya	4.12	a	15.5	ab	76.65	ab	8.7	a
Kirkwood (cherimoya)	3.83	ab	14.33	ab	79.27	ab	20.5	a
Dwarf Cherimoya	3.8	a	29.2	a	85.24	a	12.3	a
Chesterman (cherimoya)	3.67	abc	19.33	ab	71.27	abc	12.7	a
Gefner (atemoya)	2.5	bcd	7	b	61.55	bcd	11.6	a
Taiwanese Squamosa	2.5	cd	6.67	b	55.93	cd	7.7	a
African Pride (atemoya)	2	d	2.8	b	50	d	12	a
Lsd	1.21		17.85		18.46		11.8	
P pr.	0.003		0.033		0.002		0.359	

NB: Means with same subscript are not significantly different at the P = 0.050 level

Figure 10 – Selection 470-2 grafted on dwarf cherimoya (left), Chesterman cherimoya (middle) and industry standard cherimoya (right).

Beerburrum rootstock trial

This rootstock trial has identified differences in vigour and fruit set for the elite selection 470-2 grafted on four different rootstock selections.

Table 9 shows tree measurements for 470-2 on four rootstock selections three years after planting. There was no significant difference in shoot length or trunk circumference between rootstocks ($P>0.05$). Trees grafted on dwarf cherimoya had significantly higher difference in circumference ($P<0.05$) between the graft and scion, indicating some level of graft incompatibility when compared to the other three rootstocks. Dwarf cherimoya produced trees with the largest trunk circumference, however shoot extension was much lower than trees grafted on the industry standard cherimoya rootstock. Trees grafted on 450 clonal rootstocks achieved the lowest shoot length and trunk circumference. Additionally, there was no difference between rootstock and scion circumference indicating a high level of graft compatibility.

Table 9 - 2020 tree measurements for 470-2 on four rootstock selections

Rootstock	Shoot length (cm)		Trunk circ. (cm)		Trunk circ. Difference (cm)	
Clonal 450	101.8	a	23.1	a	0	b
Cherimoya	121	a	27.5	a	2.29	b
GEF	111.7	a	24.8	a	1.1	b
Dwarf Cherimoya	103.7	a	28.2	a	5.07	a
Lsd	26.2		8.0		2.7	
F pr.	0.235		0.471		0.011	

NB: Means with same subscript are not significantly different at the P = 0.050 level

Table 10 shows tree measurements and fruit numbers for 470-2 on four rootstock selections four years after planting. Again, trees grafted on dwarf cherimoya produced the largest trunk circumference ($P<0.05$). These trees also produced the lowest vigour and the largest number of fruit per tree ($P>0.05$, Figure 11). Trees on 450 clonal rootstocks produced a similar number of fruit per tree when compared to the industry standard cherimoya rootstock. These trees achieved a significant difference ($P<0.05$) between the trunk and scion, with average scion circumference being larger than the trunk circumference below the graft. There was no significant difference in fruit number per tree between the four rootstocks ($P>0.05$).

Table 10 - 2021 tree measurements for 470-2 on four rootstock selections

Rootstock	Shoot length (cm)		Vigour rating		Trunk circ. (cm)		Trunk circ. Difference (cm)*		Fruit number	
450 clonal	93.9a	a	3.5	a	28.53a	a	-1.93	c	44	a
Cherimoya	105.6a	a	3.93	a	33.34a	a	1.8b	b	44.9	a
GEF	90.7a	a	3.25	a	30.45a	a	1.05bc	bc	48.5	a
Dwarf cherimoya	83.5a	a	3.25	a	34.9a	a	6.95a	a	54	a
Lsd	26.3		1.0		6.6		2.8		50.6	
F pr.	0.21		0.258		0.199		<.001		0.965	

NB: Means with same subscript are not significantly different at the P = 0.050 level

Figure 11 - Selection 470-2 grafted on clonal 450 (left), seedling cherimoya (middle) and dwarf cherimoya (right)

Clone vs graft trial – Maroochy Research Facility

Tables 11 to 13 shows tree measurements for selections 453-1 and 464-1 grown as cuttings on their own roots compared with the same selections grafted on the industry standard cherimoya rootstock. Between 2019 and 2021 trees grafted on cherimoya rootstock achieved larger trunk circumference than trees growing on their own roots. In 2019 there was a significant difference in trunk circumference between grafted and clonal 453-1 trees ($P<0.05$), however this was not observed in subsequent years. There was no significant difference in shoot length or fruit number per tree between grafted and cloned trees in each season. The performance of all trees in this trial was generally poor as tree growth was very slow. Differences in tree structure were observed with clonal trees branching at a higher point than grafted trees (Figure 12). Grafted trees generally had a more spreading habit compared to the more upright clonal trees.

Table 11 - 2019 tree measurements and fruit counts

Clone/rootstock	Trunk Circ (cm)		Shoot length (cm)		Fruit	
453-1 grafted	16.1	a	45.5	a	3.17	a
453-1 clonal	10.68	b	35.9	a	1.26	a
464-1 grafted	9.35	b	37	a	2.22	a
464-1clonal	12.68	ab	42	a	0.4	a
Lsd	4.9		11		2.6	
F pr	0.018		0.063		0.96	

NB: Means with same subscript are not significantly different at the P = 0.050 level

Table 12 - 2020 tree measurements and fruit counts

Clone/rootstock	Trunk Circ (cm)		Shoot length (cm)		Fruit	
453-1 grafted	19.1	a	57.7	a	5	a
453-1 clonal	14.6	a	51.8	a	6	a
464-1 grafted	19.3	a	63.3	a	4.63	a
464-1clonal	15.7	a	41	a	7	a
Lsd	4.964		18.98		4.5	
F pr	0.769		0.191		0.624	

NB: Means with same subscript are not significantly different at the P = 0.050 level

Table 13 - 2021 tree measurements and fruit counts

Clone/rootstock	Trunk Circ (cm)		Shoot length (cm)		Fruit	
453-1 grafted	17.12	a	44.3	a	13	a
453-1 clonal	15.13	a	41.8	a	8	a
464-1 grafted	20.72	a	62.2	a	0	a
464-1clonal	18.04	a	61	a	0	a
Lsd	5.3		8.11		25.39	
F pr	0.825		0.794		0.393	

NB: Means with same subscript are not significantly different at the P = 0.050 level

Figure 12 - Selection 453-1 grafted on cherimoya rootstock (left) and growing as a cutting on own roots (right)

Clonal propagation

Clonal propagation of rootstocks was carried out by Turkinje Nursery between September 2018 and May 2021. The nursery reported successful clonal replication of two rootstock selections, Cherimoya and 450 (Table 14). Cherimoya and selection 450 have shown an increased strike rate in each generation produced. Some of the successfully cloned rootstocks have been reported to show a decline in tree and root health if left too long before repotting. This issue was addressed in May 2021 when DAF officers visited the nursery and provided advice on irrigation scheduling and potting media. The nursery investigated critical times to initiate the cuttings so they were ready for the growth period and subsequent grafting, which resulted in an incremental increase in strike rate in each generation.

The nursery expressed concern over the tree habit of cherimoya clones, indicating that the trees had developed a weeping habit rather than the upright habit observed in 450 clones (Figure 13). This impacted the vigour of the rootstock as well as the availability of cuttings for propagation. Following discussions with DAF staff it was decided that all future propagation would be focused on developing large numbers of selection 450.

Table 14 – Results from clonal propagation trial conducted at Turkinje Nursery

Clone ID	Generation	Total cuttings collected	No. Rooted plants	Strike Rate %
450	1	124	71	57%
450	2	547	326	60%
450	3	468	359	77%
Total		**1139**	**756**	**66%**
Cherimoya	1	169	76	45%
Cherimoya	2	195	93	48%
Cherimoya	3	130	81	62%
Total		**494**	**250**	**51%**

Available rootstocks were delivered to Maroochy Research Facility for grafting and field evaluation (Figure 13).

Figure 13 - Clonal 450 (left) and clonal cherimoya (right) at Maroochy Research Facility

Extension

Newsletter articles

12 articles were published in 'The Custard Apple' industry newsletter between 2018 and 2021. Details of the articles are outlined in Table 15 and an example is provided in Appendix 2.

Table 15 - Articles published in industry newsletter between 2018 and 2021

Newsletter edition	Location	Topic
Autumn 2018	Pages 10-12	R&D update
Winter 2018	Pages 8-12	R&D update
Autumn 2019	Pages 16-18	R&D update
Winter 2019	Pages 16-19	Red custard apples
Spring 2019	Pages 10-12	Basic concepts of pruning
Summer 2019	Pages 11-13	What to do over the next three months
Autumn 2020	Web version	R&D update
Winter 2020	Web version	Custard apple breeding - behind the scenes
Summer 2021	Web version	What to do over the next three months
Autumn 2021	Web version	R&D update
Winter 2021	Web version	R&D update
Spring 2021	Web version	Fundamentals of pruning custard apples

Field days

DAF staff Grant Bignell and David Bruun attended all industry field days wherever possible (Figure 14). Face to face meetings were limited in the final two years of the project due to COVID-19 restrictions. Table 16 outlines industry events attended and R&D presentations delivered to growers.

Table 16 - Presentations delivered at industry field days between 2018 and 2021

Region	Date
Glasshouse Mountains	25/02/2018
Bundaberg	23/03/2018
Mareeba	3/03/2018
Alstonville	21/04/2018
Alstonville	10/10/2018
Glasshouse Mountains	2/02/2019
Glasshouse Mountains	19/08/2019
Bundaberg	9/02/2019
Alstonville	22/03/2019
Alstonville	19/09/2019
Glasshouse Mountains	15/02/2020
Alstonville	17/11/2020
Glasshouse Mountains	9/11/2021
Duranbah	9/12/2021

Figure 14 - DAF technical officer David Bruun conducting a pruning demonstration in Glasshouse Mountains (left) and research scientist Grant Bignell providing a project update at a CAA field day (right).

Outcomes

Progeny

Over 1,800 mature hybrid progeny (>3 years old) have been evaluated over the course of the project, resulting in 45 new selections being identified for further evaluation and testing. These new selections offer high fruit set, novel flavour, skin colour and flesh types and in some cases very low seed numbers. With no further hybridisation planned for this project these new selections will need to be evaluated over the next three years.

Additionally, the project has produced over 1,000 new hybrid progeny between 2018 and 2020 that will be suitable for evaluation over the next three years. These populations may produce more promising selections for testing and commercialisation.

Elite selections and regional testing

A key outcome outlined in the project was to successfully develop and commercialise new high-yielding green skin custard apple varieties to increase the reliability of fruit production and quality, resulting in a more profitable industry. Regional evaluation of three elite green skin selections has characterised their regional performance and informed recommendations for commercialisation. Although these varieties have not been commercialised prior to the finalisation of the project, the information produced through the project will allow commercialisation to progress quickly in 2022. Industry adoption of new green skin selections was estimated at 20% when the project commenced in 2018. A 2021 grower survey supported this estimate, with 20% of respondents indicating they were 'very likely' to adopt these new varieties when released.

Another outcome identified at the start of the project was the development of a commercial red skin variety to diversify the industry, attract a premium price in the market and boost potential for exports. While promising red skin selections have been identified during this project, only a limited number of trees have been evaluated in major production regions. The red skin selection 649-1 appears most suited to the Sunshine Coast and Wide Bay regions at this stage, although more evaluation will be required prior to commercialisation. Selection 591 has also been identified as a potential commercial red skin variety and has subsequently been distributed for further regional on-farm testing.

Potential adoption of red skin varieties was estimated at 5-10% of industry at the start of the project. Higher potential adoption rates were subsequently identified in a 2021 grower survey, with more than 30% of respondents indicating they were 'very likely' to adopt new red skin varieties once commercialised. Development and extension of information on these new varieties through this project has increased grower awareness, which has potentially increased interest in their adoption. Collaboration with 16 growers in three states has also strengthened recommendations and confidence in new varieties.

Rootstocks

The project aimed to identify new seedling and clonal rootstock selections that reduce tree vigour and increase the uniformity of custard apple orchards. Industry standard cherimoya rootstock was compared to a range of atemoya, cherimoya and squamosa rootstocks. A series of rootstock trials in Queensland identified alternative rootstock selections that can reduce tree vigour. Dwarf cherimoya performed well in trials, producing trees with a large trunk circumference and reduced shoot elongation and vigour. Trials also identified variability in atemoya rootstock selections Gefner and African Pride. The performance of the industry standard cherimoya rootstock in trials has confirmed its suitability in most regions. Taiwanese squamosa rootstock has shown to significantly reduce tree vigour in North Queensland and Bundaberg.

Clonal rootstock selection cherimoya and 450 have performed well in trials and differences in tree vigour have been identified. Trials have shown clonal rootstock has performed similarly to seedling rootstocks and could be an alternative for industry in the future, particularly for trellised growing systems.

Clonal propagation

The development of a clonal propagation program through collaboration with a trusted nursery was a key outcome of the project that aimed to guarantee the supply of rootstock material for industry expansion and reduce the reliance on seedling rootstock. Turkinje Nursery in North Queensland has successfully developed a system for clonal replication of custard apple rootstock. The nursery has achieved strike rates of over 70% on rootstock selection 450 and has developed a large collection of mother stock for future propagation. Material has been delivered to Maroochy Research Facility for grafting and on-farm testing. Following consultation with the nursery only propagation of selection 450 will continue, after undesirable (weeping) tree habits were observed in cherimoya clones. The nursery has agreed to continue the propagation of selection 450 so that commercial quantities can subsequently be trialled by propagation nurseries and ultimately growers.

Extension

Regular project updates were provided at field days and in the industry newsletter 'The Custard Apple' throughout the project. Face to face communication with growers was impacted by COVID 19 in the last two years of the project. Despite this, the project achieved high levels of engagement with industry as outlined in 'Monitoring and Evaluation'.

Growers were directly supported by project staff to adopt a range of management practices throughout the project. Approximately 69% of survey respondents indicated they had received advice from DAF project staff, which shows the high level of engagement with industry. Viewing of new rootstocks and varieties at field days also provided growers with the opportunity to see some of the outputs of the project.

Further promotion of the project was achieved thorough social media and other commercial media opportunities. These extended the reach of the project beyond custard apple growers and attracted significant interest from potential commercial partners through to consumers.

Monitoring and evaluation

The following key evaluation questions (KEQ) from the project monitoring and evaluation plan have been addressed. A survey was sent to all Custard Apples Australia members in October 2021 to evaluate the effectiveness of the project and the level engagement with growers (Appendix 3). 37 growers completed the survey representing growing regions in north Queensland (2), Bundaberg/Wide Bay (6), Sunshine Coast (10), Brisbane (2), Northern NSW (16) and Western Australia (1). The 37 grower responses represented 18 farms with >700 trees, 13 with between 200 and 700 trees and six with less than 200 trees.

KEQ- Has the project developed new varieties and rootstocks that are now available for industry uptake?

The project has successfully developed and evaluated three green skin selections that will be recommended for commercialisation. The project has also developed 2 red skin selections with strong potential for commercialisation following further evaluation. Additionally, promising selections identified in new progeny populations will provide industry with new varieties into the future. Shortages of rootstock experienced during the project have limited the extent of testing and may be a limitation for industry uptake once varieties are commercialised. Testing of new varieties and rootstocks has involved close collaboration with 16 growers spread across growing regions in Queensland (10), New South Wales (5), and Western Australia (1).

A grower survey in 2021 provided a snapshot of anticipated uptake of new varieties by existing growers. 20% of growers were 'very likely' to adopt new green skin varieties once commercialised with a further 31% responding as 'possibly' and 23% 'unsure'. Those that were very likely to adopt new green skin varieties had less than 700 trees. 31% of respondents were 'very likely' to adopt new red skin varieties once commercialised and a further 20% indicated 'possibly'. 11% were 'unsure' and 37% were 'unlikely' to adopt red skin varieties. Over 70% of those who responded as 'very likely' to adopt red skin varieties were larger farms (>700 trees).

KEQ- To what extent has the project met the needs of industry levy payers?

The Strategic Investment Plan (SIP) developed in 2017 listed **"**Measurable growth in production volumes and improved production efficiency and product consistency leading to increased grower profitability" as a key outcome between 2017 and 2021. The project's core activities of new variety and rootstock development and extension aimed to address this outcome between 2018 and 2021.

The 2021 grower survey measured the usefulness of information extended to growers on a range of topics and outputs of the project. 75% of respondents found the information on new green and red skin varieties as useful (28% 'very useful', 47% 'somewhat useful'). 72% of respondents found information on new seedling and clonal rootstocks as useful (19% 'very useful, 53% 'somewhat useful').

KEQ- To what extent were the target engagement levels of industry levy payers achieved?

A survey conducted in 2021 measured the project's extent of engagement with levy payers. Over 75% of respondents felt as though they were engaged with the project, with 40% somewhat engaged and a further 37% being very engaged. Queensland growers felt more engaged with the project with 80% of respondents being somewhat to very engaged compared to 66% in NSW. Larger growers had the highest level of engagement with the project with 100% of survey respondents with >700 trees ranging between somewhat and very engaged. Lower levels of engagement were recorded for smaller farm sizes with respondents with 200 to 700 trees recording 54% engagement and growers with less than 200 trees indicating 33% engagement. Additionally, 16 growers (11% of farms) were directly engaged with the project through on-farm testing of varieties and rootstocks.

KEQ- Have regular project updates been provided through linkage with the industry communication project?

12 newsletter articles and 13 presentations delivered at field days provided industry with regular updates on the progress of the project as well as information on orchard management practices. The 2021 grower survey identified that over 80% of respondents had received project updates throughout the project, with 47% receiving 'regular' updates and a further 36% receiving 'somewhat regular' updates. 11% of respondents 'rarely' received project updates and 6% responded as 'never' receiving updates.

Around 90% of respondents received project updates through the industry newsletter 'The Custard Apple', 53% received updates at field days and 25% were updated through direct communication with DAF researchers.

KEQ- Did the project engage with industry levy payers through their preferred learning style?

Custard Apples Australia (CAA) has a long history of supporting its growers and has a close working relationship with DAF researchers. Regional field days and road shows have historically been well attended by growers. Throughout the project DAF researchers regularly communicated with CAA to deliver content that was relevant, including interactive presentations, fruit tasting, visual inspections of new varieties in the field and pruning demonstrations. The grower survey indicated that the industry newsletter was the most medium followed by field days and direct communication with project staff.

KEQ- How accessible were extension events to industry levy payers?

DAF researchers attended and presented at 13 industry field days and roadshows conducted by Custard Apples Australia throughout the project. Accessibility and delivery of these events was impacted by the discontinuation of the communication project in 2019 and also restrictions caused by the COVID 19 pandemic in 2020 and 2021. DAF researchers were accessible to all growers through participation at industry events and also directly via phone and e-mail, with contact details of project staff supplied through the industry newsletter. Approximately 69% of survey respondents indicated they had received advice from DAF researchers over the project on a range of custard apple management practices. Over 75% of those who did receive advice from project staff considered it useful (42% very useful, 35% somewhat useful).

KEQ- Did the project make changes to improve efficiency?

Opportunities to improve efficiency were reflected at the project level and were not used as a performance measure in the grower survey. Significant effort was required to source and germinate quantities of rootstock for propagation of selections in the absence of commercially available material. Top working of culled progeny was also used to multiply new selections and increase the quantity of available budwood for future propagation. Top working of mature trees was also employed for on-farm grower testing and, in some cases, has resulted in selections fruiting two years after propagation.

Social media posts

Table 17 shows social media posts that promoted outputs from the project between 2019 and 2021

Table 17 – Social medio posts

Source	Date	Reactions	Comments	Shares	Link
Facebook ABC Sunshine Coast	15/04/2019	73	51	17	Facebook
Facebook Queensland Agriculture	14/04/2019	374	112	157	Facebook
Facebook Queensland Agriculture	19/01/2020	997	112	183	Facebook
Facebook Queensland Agriculture	16/08/2020	161	16	30	Facebook
Facebook Queensland Agriculture	26/07/2021	481	73	123	Queensland Agriculture | Facebook

Web articles and video

Table 18 shows web-based articles and videos promoting the outputs of CU16002.

Table 18 – Web based articles and videos

Source	Date	Link
ABC News	30/07/2019	Quest for custard apple new varieties a long and difficult road, paved with misfires and mutants - ABC News
Hort Innovation My Market Kitchen	26/06/2020	My Market Kitchen Episode 1: Daniel Jackson and Tropical Smoothie Bowl - YouTube
Queensland Country Hour (47:09)	31/07/2019	Queensland Country Hour - Queensland Country Hour - ABC Radio
Fresh Plaza	24/12/2019	Queensland researchers developing red skin custard apple variety (freshplaza.com)

Recommendations

Progeny

- Approximately 1,000 new hybrid progeny will reach maturity over the next two years and will need to be maintained and evaluated during this period. These populations include hybrids between elite red skin selections that may potentially result in new, novel varieties for the custard apple industry.
- The 45 new selections identified from progeny populations between 2018 and 2021 require further evaluation at Maroochy Research Facility and throughout major growing regions via on-farm testing.

Elite selections and new varieties

- Green skin selections 453-1, 470-2 and 470-3 are recommended to progress to commercialisation.
- Red skin selections 649-1 and 591 require further evaluation before commercialisation, including further observations on mature trees and propagation of larger numbers of trees for inclusion in regional testing on a range of growing systems.
- The rootstock shortage experienced by the industry over the last several years needs to be rectified so that new custard apple varieties can be propagated and adopted by growers.
- A PBR trial should be established for the three new green skin selections to generate data to support the PBR application and evaluation process.

Rootstocks

- Dwarf cherimoya seedling rootstock can be recommended in Queensland growing regions. Trials have identified that trees grafted on dwarf cherimoya produce large trunks and reduced vigour when compared to the industry standard cherimoya. Research is required to increase germination rates of dwarf cherimoya seed.
- The industry standard cherimoya rootstock has performed well in trials and should continue to be used.
- African Pride (atemoya) rootstock can be used in the absence of cherimoya rootstock if screened at the seedling stage. This will eliminate low and high vigour types.
- Clonal rootstocks 450 and cherimoya can be recommended as an alternative to seedling cherimoya rootstock and should be trialled further by commercial nurseries and growers to increase commercial confidence.
- All rootstock trials should continue to be monitored and evaluated to observe vigour and fruit set as trees mature.

Clonal propagation

- The clonal propagation program should continue and collaboration with licensed commercial nurseries should be encouraged and facilitated.
- Material should be used in further regional grower trials to evaluate the performance of clonal rootstocks in a range of growing regions. Regionally relevant performance data will help support adoption across major growing regions.

Extension

- Extension of information relating to performance of new varieties should be continued to promote industry adoption and support the early adopters of new selections.
- Field days should be coordinated with Custard Apples Australia to allow growers and potential commercial partners to view new varieties and rootstocks.

Refereed scientific publications

N/A

References

de Moraes, M.R., Ryan, S.M., Godoy, H.T. *et al.* Phenolic Compounds and Metals in Some Edible Annonaceae Fruits. *Biol Trace Elem Res* **197,** 676–682 (2020)

Hort Innovation 2021, Australian Horticulture Statistics Handbook 2019/20, 126 – 129 (2021)

Intellectual property, commercialisation and confidentiality

New progeny populations and elite selections developed during this project remain a source of IP.

Acknowledgements

We would like to acknowledge the significant contribution of collaborating growers who have hosted rootstock and variety trials in all growing regions of Australia. We would also like to acknowledge Custard Apples Australia for their assistance and collaboration in extension activities such as the newsletter and field days. Thanks also to Turkinje Nursery for their collaboration, hard work and commitment to developing a clonal propagation program for the Australian custard apple industry.

Appendices

Appendix 1

Table 19 - Summary of progeny selected for further evaluation (2018-2021)

Year	Cross code	Skin colour	Yield score (1-9)	Taste (1-9)	Texture (1-9)	Seed	Seed/100g
2018	747	Red	5	6	4	Seedless	0
2018	758	Red	8	6	5	Low	4
2018	758	Red	8	5	5	High	15
2018	549	Red	9	7	5	Average	6
2018	758	Red	7	5	4	High	11
2018	544	Green	5	7	7	Low	4
2018	130	Red	3	7	5	Low	3
2018	732	Red	7	6	6	Low	4
2018	616	Red	8	6	5	Low	5
2018	737	Green	2	8	7	Low	2
2018	606	Green	3	6	5	Low	3
2018	695	Green	4	7	7	Low	5
2019	807	Green	8	6	6	Seedless	0
2019	596	Red	2	8	6	Low	4
2019	596	Red	2	7	5.5	Low	4
2019	807	Green	7	6	4	High	17
2019	807	Green	8	7.5	7	High	12
2019	737	Green	1	6	5	Low	3
2019	807	Green	7	7.5	6	Average	5
2019	744	Green	2	7	7	Low	3
2019	807	Green	8	6	6	Average	6
2019	791	Red	1	6	6	Low	4
2019	Unknown	Red	7	6.5	5	Low	4
2019	686	Red	5	4	2	Seedless	0
2020	807-1	Green	5	5	5	Seedless	0
2020	807-2	Green	7	7	8	Average	8
2020	799	Red	2	6	7	High	13
2020	821-1	Pink/red	4	8	8	Average	7
2020	821-2	Light pink	3	8	6	Low	4
2020	821-3	Pink	2	7	7	Average	7
2020	747	Red	6	6	5	Seedless	0
2021	821	Pink/red	3	6.5	8	Low	4
2021	821	Green	4	7	7	Low	5
2021	824	Red	3	7	8	Average	6
2021	824	Pink/red	3	7	7.5	Average	6
2021	824	Red	3	8.5	7.5	Low	5
2021	824	Pink/red	1	8.5	8	Low	3
2021	824	Red	3	9	7	Average	6
2021	824	Pink/red	3	8	8	Low	3
2021	836	Green	7	8	7	Average	6

Appendix 2
Example of newsletter article
Red-skinned custard apple on-farm testing

Grant Bignell – Department of Agriculture and Fisheries (DAF)

The red-skinned custard apple selection 649-1 has now been on grower testing sites for five years. Testing locations include North Queensland, Bundaberg, Glasshouse Mountains and Northern NSW. Most trees in these locations are producing commercial yields. While there are only 2 to 3 trees at each test location, the volume of fruit has now reached quantities that provide DAF staff and collaborating growers the opportunity to see how each selection performs through picking, packing and storage processes.

Harvesting

Maturity of selection 649-1 is quite easy to assess at harvest. The colour of the fruit changes from a dark maroon to a very bright red with cream edges between the interstices (Figure 1). Maturity indicators are very similar to Pinks Mammoth varieties.

Figure 1- Maturity stages of 649-1.

Handling and transferring fruit into crates requires care, as the thin skin of this selection is easily damaged (Figure 2).

Figure 2 – Fruit harvested from Glasshouse Mountains 28/04/2019 (*Photo courtesy of Jackson Agriculture*)

Washing, grading and packing

On some farms fruit has been processed through washing, grading and packing systems that are also used for the industry standard variety KJ Pinks (Figure 3). Growers have reported no significant damage to the red-skinned selection through each of these postharvest processes. This result is encouraging, however further trials will be required prior to commercial release. The uniform shape of 649-1 makes packing into trays quite easy as there are very few misshapen fruit.

Figure 3 – Postharvest washing and grading of selection 649-1 (*Photo courtesy of Jackson Agriculture)*.

Storage

In one small grower trial fruit was stored between 10 and 12^{o}C for seven days (Figure 4). While storage for prolonged periods is not recommended this gave an indication of the response to cooling and storage for this selection. Fruit colour did become less vibrant as storage progressed over the seven-day period, however fruit firmness and quality was maintained.

Figure 4 – 649-1 stored for three days (left) and seven days (right) between 10 and 12^{o}C (*Photo courtesy of Jackson Agriculture)*.

Fruit was removed from storage after seven days between 10 and 12^{o}C and left at room temperature (ambient) for a further four days (Figure 5). Fruit was of acceptable eating quality following cool and ambient storage however the appearance of the fruit was less attractive than when first picked. Other postharvest technologies such as modified atmosphere packaging may be required to maintain skin colour during storage.

Figure 5 – Fruit stored for seven days between 10 and 12^{o}C and one day (left) and three days (right) at room temperature (*Photo courtesy of Jackson Agriculture)*.

Small-scale testing of elite selections is an important step in the commercialisation of new custard apple varieties. Grower involvement and feedback plays a vital role in the progression of selections to the large-scale testing phase. The ability for other growers to see these selections on a commercial farm at field days also increases the enthusiasm of industry and potential adoption of new varieties.

Hort Innovation
Strategic levy investment
CUSTARD APPLE FUND

This project has been funded by Hort Innovation using the custard apple research and development levy and funds from the Australian Government. For more information on the fund and strategic levy investment visit horticulture.com.au

Appendix 3

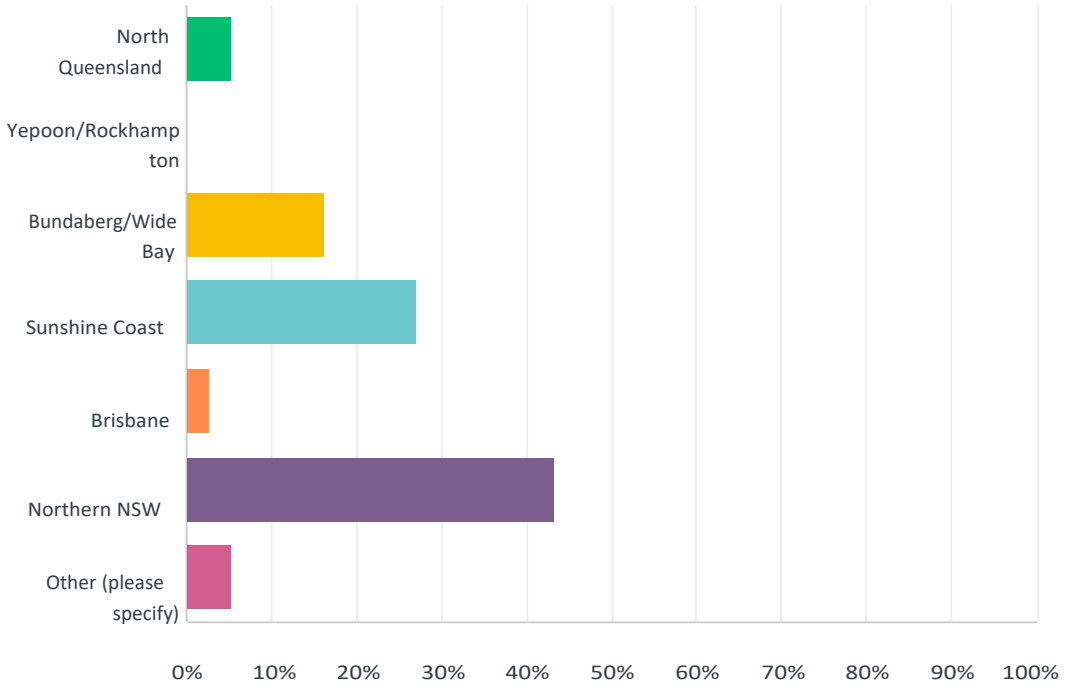
2021 grower survey

Introduction

The R&D project *New Custard Apple Varieties and Enhanced Industry productivity* carried out by the Department of Agriculture and Fisheries Queensland will end at the end of November 2021. This survey is designed to evaluate the effectiveness of the project in meeting your needs as a custard apple grower. Thanks for taking the time to do the survey, it should take less than five minutes complete.

Q1 Please select your growing region

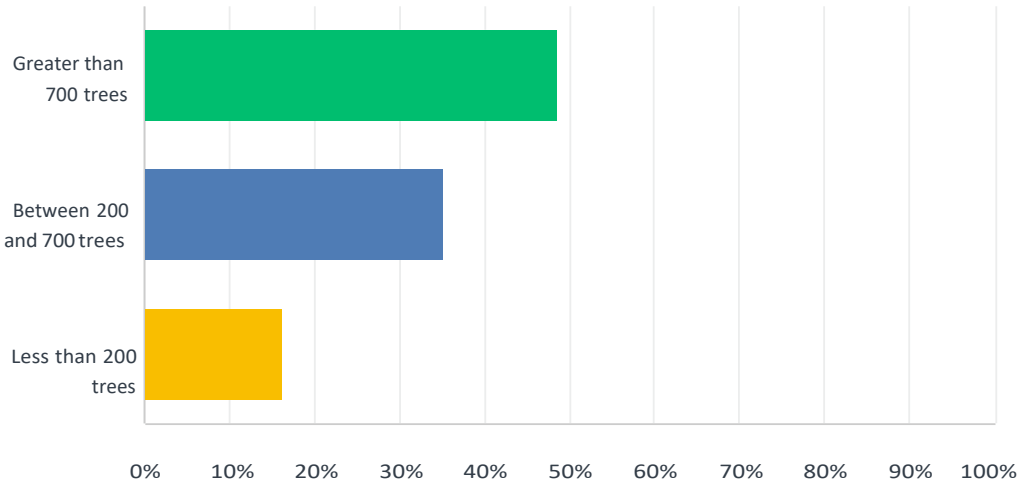
Answered: 37 Skipped: 1



ANSWER CHOICES	RESPONSES	
North Queensland	5.41%	2
Yepoon/Rockhampton	0.00%	0
Bundaberg/Wide Bay	16.22%	6
Sunshine Coast	27.03%	10
Brisbane	2.70%	1
Northern NSW	43.24%	16
Other (please specify)	5.41%	2
TOTAL		37

Q2 Approximately how many custard apple trees do you have on yourfarm?

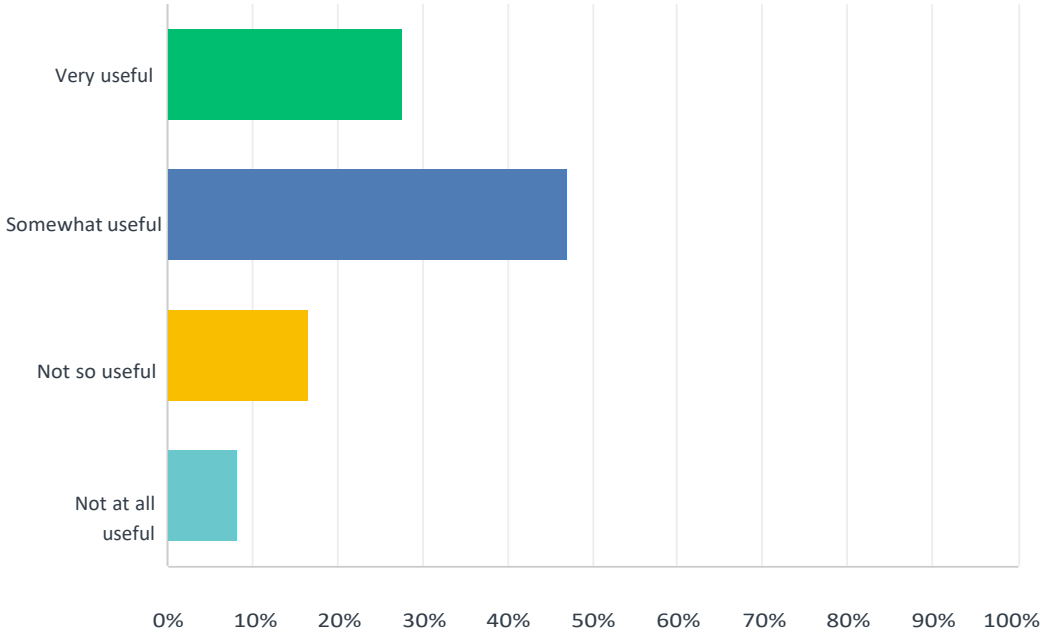
Answered: 37 Skipped: 1



ANSWER CHOICES	RESPONSES	
Greater than 700 trees	48.65%	18
Between 200 and 700 trees	35.14%	13
Less than 200 trees	16.22%	6
TOTAL		37

Q3 How useful have you found the information about new green and redskin varieties that has been developed during this project?

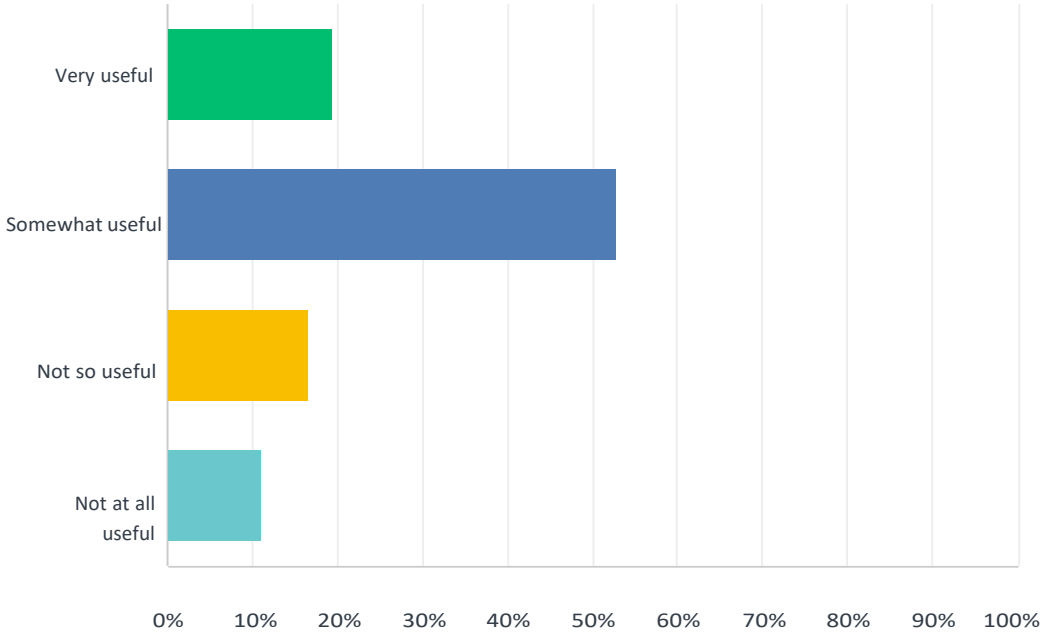
Answered: 36 Skipped: 2



ANSWER CHOICES	RESPONSES	
Very useful	27.78%	10
Somewhat useful	47.22%	17
Not so useful	16.67%	6
Not at all useful	8.33%	3
TOTAL		36

Q4 How useful have you found the information about new seedling andclonal rootstock selections being trialled/developed in this project?

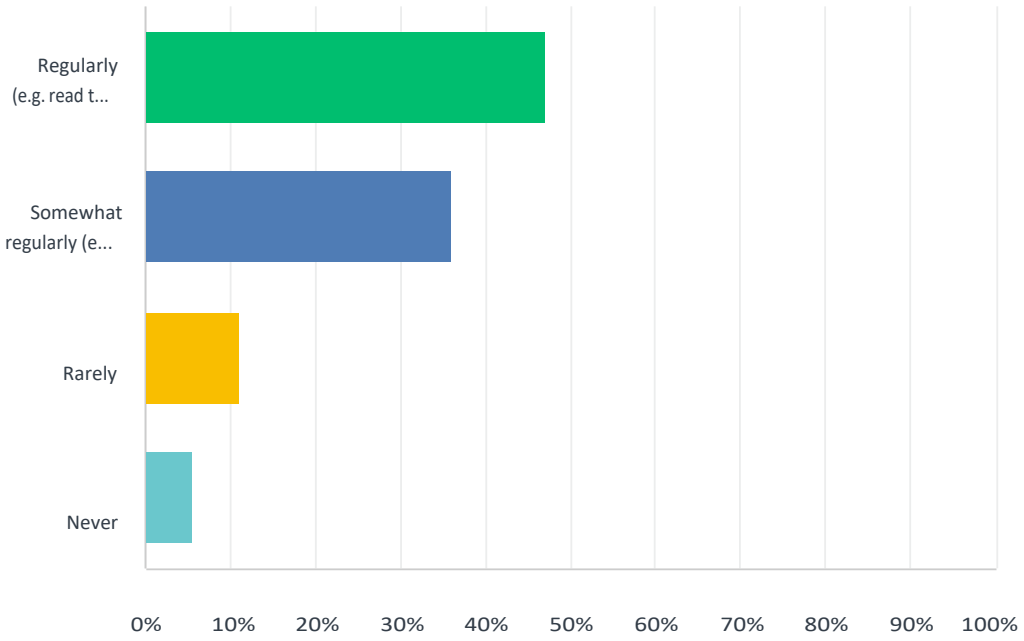
Answered: 36 Skipped: 2



ANSWER CHOICES	RESPONSES	
Very useful	19.44%	7
Somewhat useful	52.78%	19
Not so useful	16.67%	6
Not at all useful	11.11%	4
TOTAL		36

Q5 How often have you read project updates?

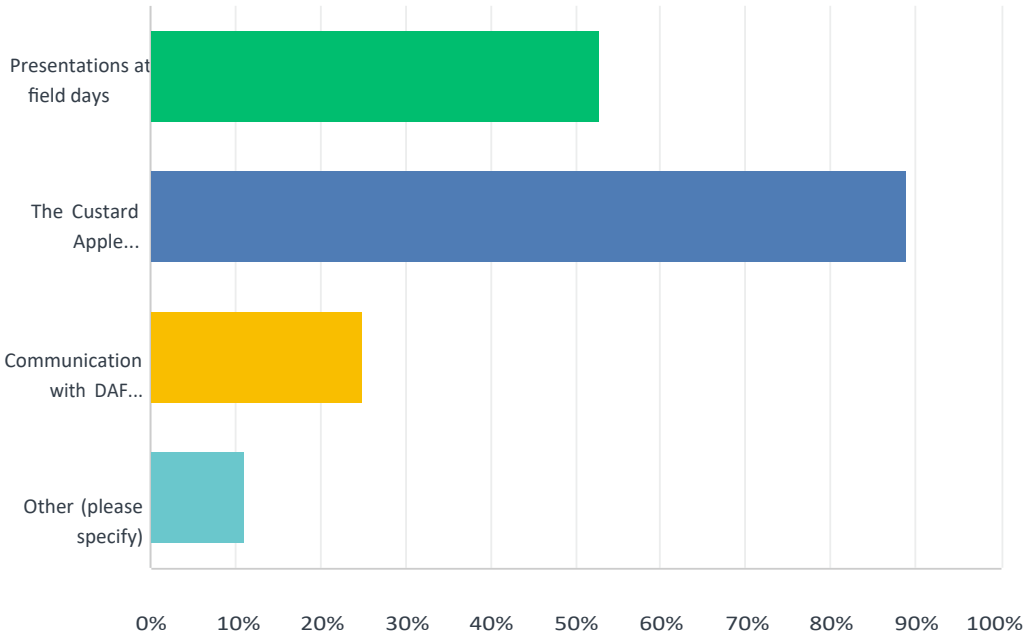
Answered: 36 Skipped: 2



ANSWER CHOICES	RESPONSES	
Regularly (e.g. read the quarterly newsletter articles, attended field days)	47.22%	17
Somewhat regularly (e.g. annually - field days)	36.11%	13
Rarely	11.11%	4
Never	5.56%	2
TOTAL		3

Q6 How did you receive project updates?

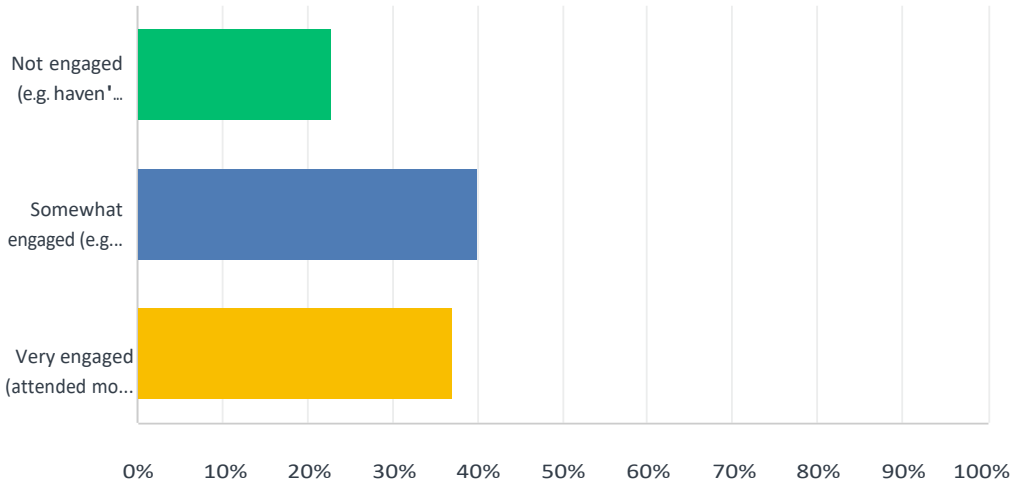
Answered: 36 Skipped: 2



ANSWER CHOICES	RESPONSES	
Presentations at field days	52.78%	19
The Custard Apple Newsletter	88.89%	32
Communication with DAF researchers	25.00%	9
Other (please specify)	11.11%	4
Total Respondents: 36		

Q7 How would you describe the extent of your engagement with project?

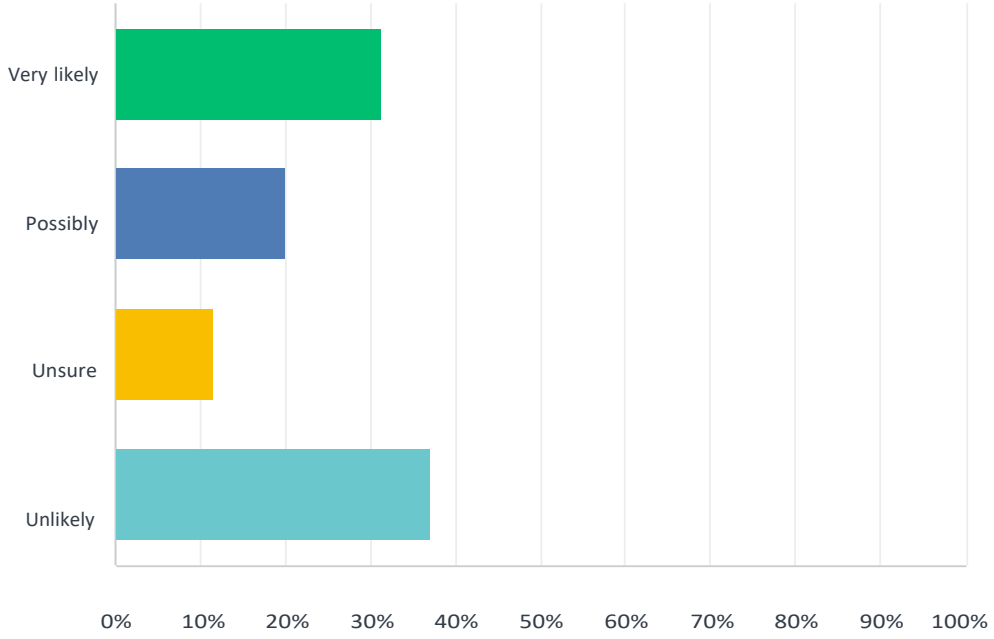
Answered: 35 Skipped: 3



ANSWER CHOICES	RESPONSES	
Not engaged (e.g. haven't attended any events or trialled new varieties)	22.86%	8
Somewhat engaged (e.g. attended some events)	40.00%	14
Very engaged (attended most events and/or trialled new varieties on my farm)	37.14%	13
TOTAL		3

Q8 Once they have been commercialised how likely are you to plant newred skin varieties on your farm?

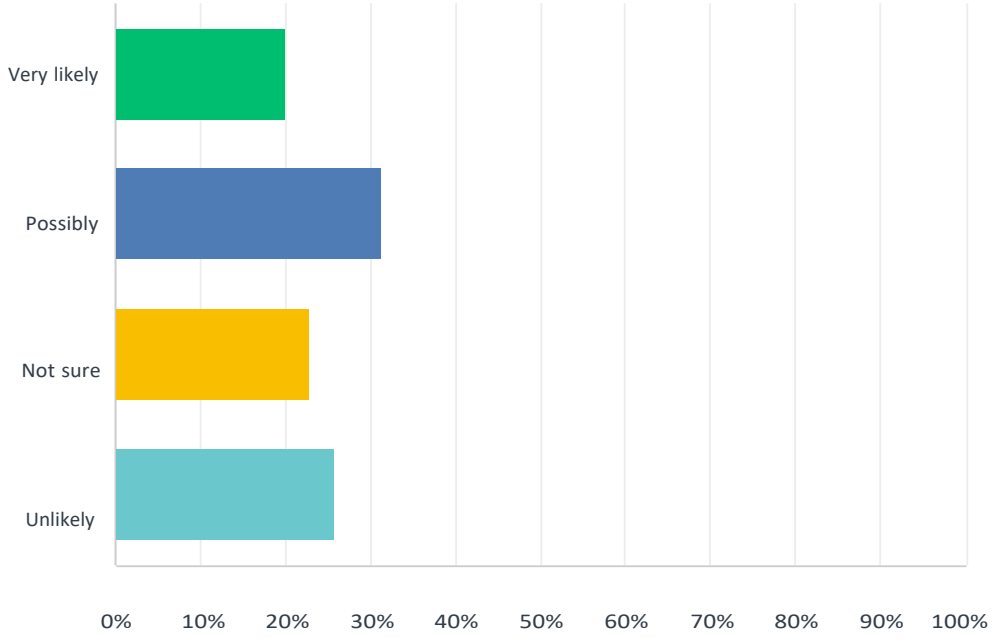
Answered: 35 Skipped: 3



ANSWER CHOICES	RESPONSES	
Very likely	31.43%	11
Possibly	20.00%	7
Unsure	11.43%	4
Unlikely	37.14%	13
TOTAL		35

Q9 Once they have been commercialised how likely are you to plant newgreen skin varieties on your farm?

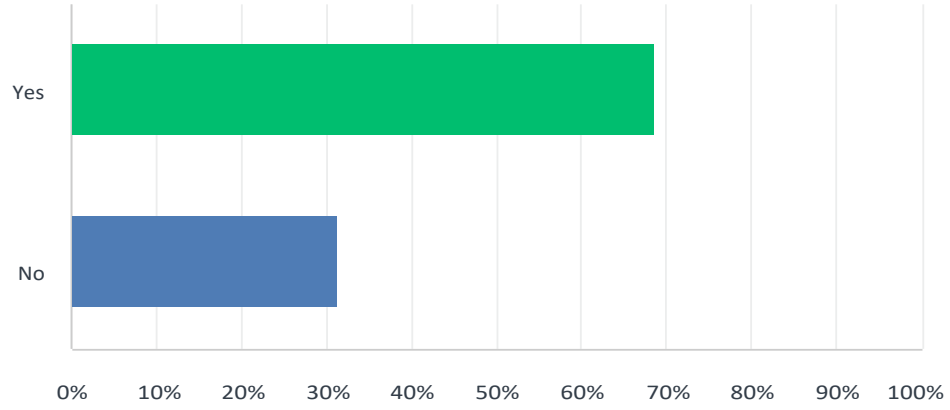
Answered: 35 Skipped: 3



ANSWER CHOICES	RESPONSES	
Very likely	20.00%	7
Possibly	31.43%	11
Not sure	22.86%	8
Unlikely	25.71%	9
TOTAL		35

Q10 Have you received advice on any aspect of custard apple production from the project team (Grant Bignell and David Bruun)?

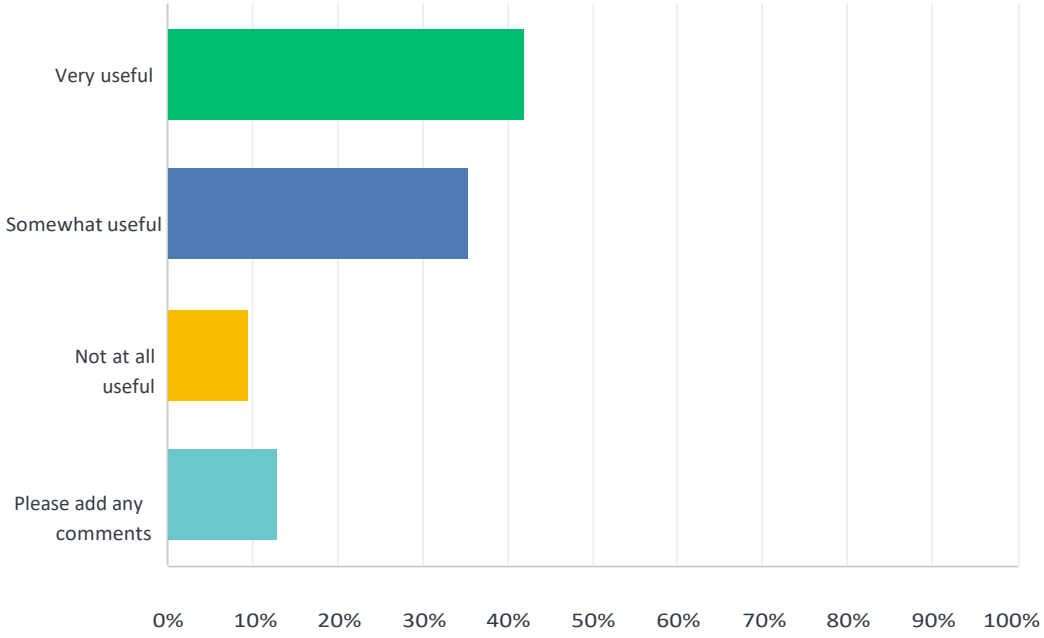
Answered: 35 Skipped: 3



ANSWER CHOICES	RESPONSES	
Yes	68.57%	24
No	31.43%	11
TOTAL		35

Q11 If 'yes' how useful was that advice?

Answered: 31 Skipped: 7



ANSWER CHOICES	RESPONSES	
Very useful	41.94%	13
Somewhat useful	35.48%	11
Not at all useful	9.68%	3
Please add any comments	12.90%	
TOTAL		31

Variety summary

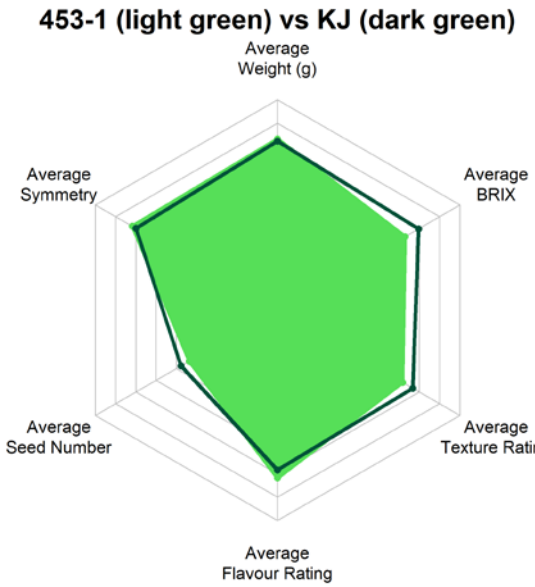
453-1

Testing locations

Mareeba, Wide Bay, Glasshouse Mountains, Northern NSW, Western Australia

453-1	Yield score*	Vigour score*	Avg Weight (g)	Avg Brix	Avg Flavour*	Avg Texture*	Seed no per 100g
QLD	7.1	4.1	574	16.5	6.5	6.8	4.9
NSW	4.8	4.1	555	11.3	5.3	5.9	4.1

*Table 1 – Averages for fruit and tree characteristics between 2019 and 2021. Qld and NSW regions have been combined. (*Yield score 1-9, vigour score 1-5, flavour and texture ratings 1-9)*



453-1 (green polygon) compared with KJ Pinks (green line) at Maroochy Research Facility 2021. The centre of the plot represents the lowest value for each trait, and the outside line represents the highest value.

Tree characteristics

Upright tree habit, moderate vigour, excellent lateral development with fruit bearing on the inner canopy.

Yield and fruit characteristics

Selection 453-1 produces medium sized light green fruit with pale green interstices. Fruit is very symmetrical and moderately tuberculate with white flesh. Flavour is different to Pinks Mammoth types. Commercial yields from planting are similar to KJ Pinks (4 years). Shelf life is approximately 5 days at ambient temperature

Variety summary

453-1

Growing system

Selection 453-1 is suitable for trellised, vase and hedgerow growing systems

Regional suitability

Selection 453-1 has performed well in Queensland and Western Australia and can be recommended for these growing regions. This selection can't be recommended for NSW due to low yield and fruit quality.

Management

Selection 453-1 has similar susceptibility to splitting as KJ Pinks. Fruit thinning is required to increase fruit size and fruit quality. Prune leaving laterals slightly longer than KJ Pinks. 453-1 has some susceptibility to Anthracnose, especially if fruit is left in bunches.

Harvesting

Selection 453-1 is an early to mid-season variety with fruit maturing from March/April onwards. Maturity is harder to determine as 'creaming' between interstices is less pronounced than other varieties. Shelf life is approximately 5 days at ambient temperature.

Plantings

Smaller numbers of this selection should be trialled to assess its suitability to individual growing locations.

Variety summary

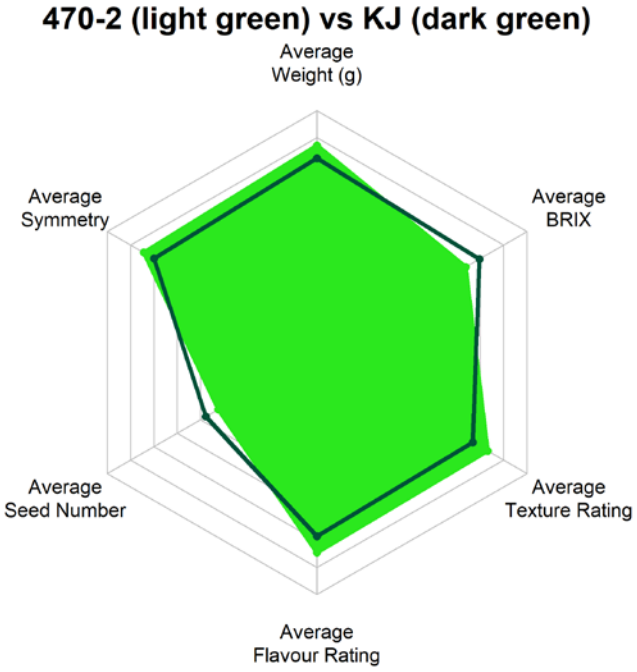
470-2

Testing locations

Mareeba, Wide Bay, Glasshouse Mountains, Northern NSW

470-2	Yield score*	Vigour score*	Avg Weight (g)	Avg Brix	Avg Flavour*	Avg Texture*	Seed no per 100g
QLD	7.5	3.6	568	18.1	7.4	7.2	6.0
NSW	5.7	3.8	817	14.6	7.1	7.1	3.4

*Table 1 – Averages for fruit and tree characteristics between 2019 and 2021. Qld and NSW regions have been combined. (*Yield score 1-9, vigour score 1-5, flavour and texture ratings 1-9)*



470-2 (green polygon) compared with KJ Pinks (green line) at Maroochy Research Facility 2021. The centre of the plot represents the lowest value for each trait, and the outside line represents the highest value.

Tree characteristics

Open/spreading tree habit, moderate vigour, lateral bearing with multiple fruit (bunching) on newly emerging laterals.

Yield and fruit characteristics

Selection 470-2 produces large green fruit with pale yellow interstices. Fruit is moderately symmetrical and tuberculate with white flesh and a Pinks Mammoth flavour. Shelf life is approximately 6 days at ambient temperature.

Variety summary

470-2

Growing system

Selection 470-2 is not suitable for trellised growing systems due to lack of lateral development on the inner canopy. Recommended for vase and hedge row growing systems.

Regional suitability

Selection 470-2 has performed well in Glasshouse Mountains, Bundaberg and Mareeba. This selection is not recommended for NSW growing regions.

Management

Selection 470-2 is susceptible to splitting in cooler climates due to its open tree habit. Early pruning (1st week in July) is recommended to allow fruit to develop before the end of April. Some fruit thinning is required to avoid bunching and increase fruit quality. Avoid excessive summer pruning. 470-2 has similar susceptibility to common pests and disease as KJ Pinks.

Harvesting

Selection 470-2 should be harvested before the end of April. Maturity is determined by the development of 'creaming' between the interstices similar to other Pinks Mammoth types.

Plantings

Small numbers of this selection should be trialled to assess its suitability to individual growing locations.

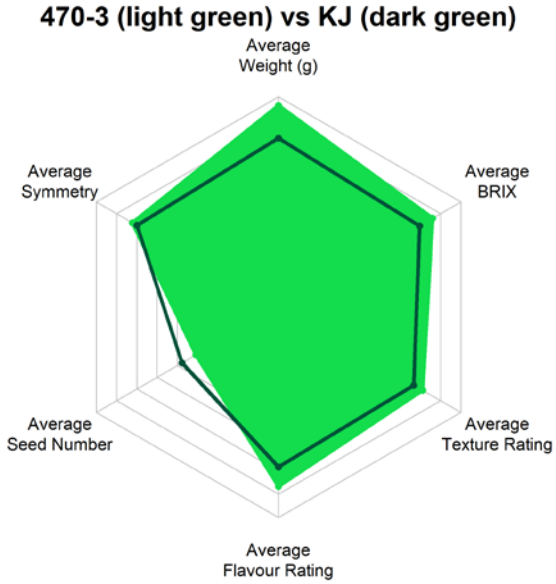
Variety summary

470-3

Testing locations
Mareeba, Wide Bay, Glasshouse Mountains, Northern NSW

470-3	Yield score*	Vigour score*	Avg Weight (g)	Avg Brix	Avg Flavour*	Avg Texture*	Seed no per 100g
QLD	5.8	3.7	662	19.4	7.5	7.3	3.9
NSW	6.7	3.8	532	16.4	7.2	7.2	4.7

*Table 1 – Averages for fruit and tree characteristics between 2019 and 2021. Qld and NSW regions have been combined. (*Yield score 1-9, vigour score 1-5, flavour and texture ratings 1-9)*



470-3 (green polygon) compared with KJ Pinks (green line) at Maroochy Research Facility 2021. The centre of the plot represents the lowest value for each trait, and the outside line represents the highest value.

Tree characteristics
Upright tree habit, moderate vigour, bearing fruit on the inner canopy.

Yield and fruit characteristics
Selection 470-3 produces large pale green fruit with pale yellow interstices. Fruit is moderately symmetrical and tuberculate with white flesh and a Pinks Mammoth flavour. Yield may take longer to reach commercial quantities when compared to KJ Pinks . Shelf life is approximately 6 days at ambient temperature.

Variety summary

470-3

Growing system

Selection 470-3 is suitable for trellised, vase and hedgerow growing systems.

Regional suitability

Selection 470-3 has performed well in most growing regions in eastern Australia. This selection can be recommended for NSW and Queensland growing regions.

Management

Selection 470-3 has shown resistance splitting. Some fruit thinning is required to increase fruit size and fruit quality. Prune leaving laterals slightly longer than KJ Pinks. 470-3 has similar susceptibility to common pests and diseases as KJ Pinks.

Harvesting

Selection 470-3 is a late harvest variety with fruit maturing from April/May onwards. Maturity is determined by the development of 'creaming' between the interstices similar to other Pinks Mammoth types. Shelf life is approximately 7 days at ambient temperature.

Plantings

Smaller numbers of this selection should be trialled to assess its suitability to individual growing locations.

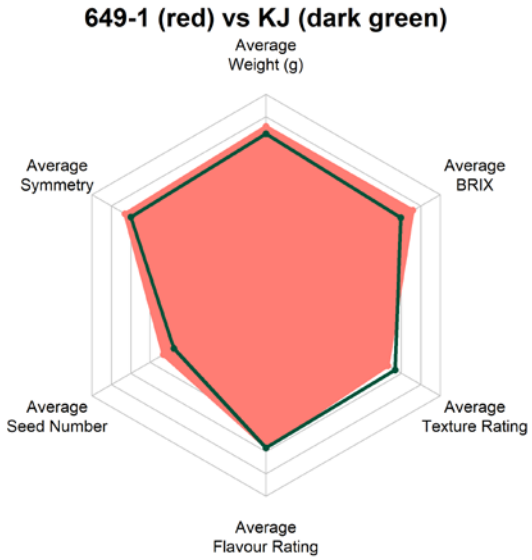
Variety summary

649-1

Testing locations
Mareeba, Wide Bay, Glasshouse Mountains, Northern NSW

649-1	Yield score*	Vigour score*	Avg Weight (g)	Avg Brix	Avg Flavour*	Avg Texture*	Seed no per 100g
QLD	5.5	3.9	526	19.4	6.8	7.0	4.9
NSW	3.5	3.8	378	16.4	5.0	6.3	7.6

*Table 1 – Averages for fruit and tree characteristics between 2019 and 2021. Qld and NSW regions have been combined. (*****Yield score 1-9, vigour score 1-5, flavour and texture ratings 1-9)*



649-1 (red polygon) compared with KJ Pinks (green line) at Maroochy Research Facility 2021. The centre of the plot represents the lowest value for each trait, and the outside line represents the highest value.

Tree characteristics
Spreading tree habit, moderate vigour, some vigorous water shoots, with fruit bearing on the inner canopy.

Yield and fruit characteristics
Selection 649-1 produces medium to large sized bright red fruit with pale interstices. Fruit is very symmetrical and moderately tuberculate with firm white flesh. Flavour is similar to Pinks Mammoth types. Commercial yields from planting are similar to KJ Pinks (4 years). Shelf life is approximately 5 days at ambient temperature.

Variety summary

649-1

Growing system

Selection 649-1 is suitable for vase and hedgerow growing systems. More information on suitability to trellised growing system needs to be developed.

Regional suitability

Selection 649-1 has performed well in Glasshouse Mountains and Wide Bay and can be recommended for these growing regions. This selection can't be recommended for north Queensland or NSW due to low yield and fruit quality.

Management

Selection 649-1 has does not appear to be susceptible to splitting. Minimal fruit thinning is required to increase fruit size and fruit quality. Prune leaving laterals slightly longer than KJ Pinks. 649-1 has similar susceptibility to common pest and disease as KJ Pinks. The thin skin of 649-1 requires care during the supply chain process and may be improved through management.

Harvesting

Selection 649-1 is a mid to late-season variety with fruit maturing from April/May onwards. Maturity is determined by 'creaming' between interstices. Shelf life is approximately 5 days at ambient temperature.

Plantings

Further observations of this selection in various growing regions and growing systems is required before plantings can be recommended.