Papaya breeding and variety development

Vern Hansen
QLD Department of Primary Industries and Fisheries

Project Number: FR99018

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This report is published by Horticulture Australia Ltd to pass on information concerning horticultural research and development undertaken for the papaya industry.

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FINAL REPORT

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FINAL REPORT – HAL PROJECT FR99018
(January 2005)

PAPAYA BREEDING AND VARIETY DEVELOPMENT

VERNON HANSEN

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DEPARTMENT OF PRIMARY INDUSTRIES AND FISHERIES
QUEENSLAND

HAL FR99018: PAPAYA BREEDING AND VARIETY DEVELOPMENT

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Purpose: The purpose of this project is to establish a long term papaya breeding project to provide improved cultivars for the Queensland papaya industry.

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A. MEDIA SUMMARY.

The papaya breeding and varietal development project has moved the industry significantly towards its objective of producing varieties with excellent flavour and appearance as well as good agronomic characteristics. Incremental improvements in fruit and plant characteristics has been achieved through recurrent selection using a breeding population based on parents with broad genetic variation.

The validation of the program design has been confirmed by investigation into general or specific combining ability of a range of genetic traits. The breeding strategy of incremental improvement, which has been adopted, is most applicable for papaya breeding. The strategy of using highly self-pollinated male lines and relying on specific trait combinations is not suitable for papaya breeding.

Through this program, the close relationship between musk flavour and winter spot has been broken so that new varieties with the desirable traits of fruit flavour and sweetness now also have reduced levels of winter spot.

Improved methodologies in assessment techniques and data collection have provided the groundwork to reduce future breeding costs. Similarly with the micro-propagation techniques, the laboratory turn around time has been significantly reduced due to improved practices. This is despite a major breakdown to the tissue culture laboratory at a critical stage through the project.

The benefits of micro-propagated plants over conventional seedling plants were demonstrated to industry.

The industry is encouraged to field evaluate the selected varieties form the last random cross population and move to the third crossing population.

B. TECHNICAL SUMMARY.

There are two major papaya varieties currently marketed. Hybrid 1B, (approximately 60% of production), a dioecious plant that has fruit of excellent appearance with a clear attractive skin but very poor taste (in the opinion of most people queried in consumer surveys).

The second variety, (approximately 30% of production), is Sunrise Solo. It is a bisexual, tastes great to most people, but suffers from severe skin blemishes, which give it a poor appearance on the market. Sunrise Solo is also the most important variety on the world export market.

This project was developed to do the groundwork necessary to establish a papaya breeding program capable of giving long–term, continuous variety improvement. It was implemented via a population breeding method (phenotypic recurrent selection) based on population breeding techniques that have been successfully used in annual cross-pollinated field crops such as maize, sunflower and sorghum.

Asexual micro-propagation by tissue culture was adopted as a key component of this project because it allows clonal propagation of selected genotypes.

Ten parents were selected that had fruit and production characteristics capable of fulfilling the industry's objectives. In constructing the base population, parents were broken into two groups and random pollination of female plants in one group were made from pollen of bisexual plants of the other group. The F1 hybrids within each group consisted of all possible crosses between the five parents, without reciprocals. The two sets of F1 crosses planted from the above were diallel cross series that were used to derive genetic information about the parents and the resulting population. Data on parent lines were analysed for general and specific combining ability and heritability.

Each individual parent line brought into the program strong positive and negative traits, providing evidence of broad genetic variation within the parent population. For the majority of characteristics there were significant positive or negative general combining effects. There was only one occurrence of a significant specific combining ability trait (ie days to first harvest for the female group of parents). This provides confidence the breeding strategy of incremental improvement, which has been adopted, is the most applicable for papaya breeding. The strategy of using highly self-pollinated male lines and relying on specific trait combinations is not suitable for papaya breeding.

An important concern about the parents selected for the project was an apparent genetic linkage between some important desirable characters and deleterious characters. The most important of these apparent linkages was an association between "musk" flavoured fruit and susceptibility to winter spot.

Two random intercross generations were conducted to attempt to break up these character associations and promote alternative character recombination. Over the period of 2001 and 2003 two random-mating populations were made. Population correlation data demonstrated that:

- Overall, there did not appear to be any major deleterious characteristics within the population.

- There was no evidence of the impact of increasing fruit TSS on the level of winter spot. This is a critical result to be achieved from this breeding program.

- There has been no relationship between brix levels and flesh colour, ie both yellow and red-fleshed fruit can have low or high TSS levels.

- Incremental improvements between the two random cross populations in a number of key fruit criteria were demonstrated, especially in brix, winter spot and fruit value index.

Efficiencies in trial design were identified in areas such as sample size and sampling period, number of criteria assessed, and data collection and maintenance. This will be beneficial in reducing the overall project costs (especially in labour), for future project work.

Micro-propagation techniques, developed in earlier projects, have been refined and measurable improvements in the efficiency in laboratory through-put have been demonstrated. Despite major electrical breakdown with the laboratory and serious losses of papaya plantlets, there is strong confidence that the systems will be successful.

Field demonstration plots and a cost benefit analysis between seedling and tissue culture production systems, provide evidence of the success of tissue culture practices.

Recommendation from the project are:

- All future random cross trials must be planted in the May to July period and harvested over summer winter summer period to avoid adverse environmental effects.
- For preliminary evaluations, all fruit physical characteristics, except for fruit weight, need not be collected as there are similar strong correlations to other major traits.
- The correlation between percentage total soluble solids and shelf life and flesh firmness needs further clarification.
- Selected hybrids from RC2 be evaluated in a large scale replicated trial to validate data.
- The next random cross planting (RC3) be planted before October 2005 as seed collected in November 2003, will begin to lose viability.

C. GENETICALLY BROAD BASED BREEDING POPULATION

1. INTRODUCTION

The objective of this project was to do the groundwork necessary to establish a papaya breeding project capable of giving long term continuous variety improvement. This objective was implemented via a population breeding method (phenotypic recurrent selection).

The population for long term selection was set up by intercrossing ten parents selected as having fruit and production characteristics capable of fulfilling the industries objectives. The strategic breeding objective addressed by this project is "the need to increase market opportunities on both the domestic and export markets through providing varieties that are more appealing to consumers and whose fruit can maintain it's quality during transport."

There are two major papaya varieties currently marketed. The first is Hybrid 1B, (approximately 60% of production). Hybrid 1B has an excellent appearance with a clear attractive skin, but, in the opinion of the majority of people queried in consumer surveys, has very poor taste.

The second major commercial variety, (approximately 30% of production), is Sunrise Solo. This variety tastes great to most people, but suffers from severe skin blemishes, which give it a poor appearance on the market. Sunrise Solo is also the most important variety on the world export market.

Consumer surveys have shown that although there are some domestic consumers who prefer the Hybrid 1B taste, the best chance for the industry to extend papaya sales to new consumers is via varieties with an attractive appearance and the Sunrise Solo taste. In addition, the evidence is that such varieties would give the Australian industry a competitive advantage on export markets.

As well as the consumer orientated characters (taste and appearance), a number of additional tree and fruit characters are of importance to growers to allow them to produce and market their crop profitably. Any varieties produced must also have these characters.

The above industry objectives are to be achieved through establishing a long term papaya breeding project to provide improved cultivars with the characteristics outlined above.

The project concentrates on providing a means of obtaining continued genetic advance in the long term. To do this it uses population-breeding techniques that have been successfully used in annual cross-pollinated field crops such as maize, sunflower and sorghum.

To make it economic to use the above techniques, a means must be found reduce the effect of the lengthy generation time of papaya on the time taken to produce and commercialise new varieties. This project aims to do this by commercialising new varieties through asexual reproduction by micro-propagation.

Important advantages of micro-propagation over propagation by seed are:

(a) Commercialisation of new varieties via micro-propagation will shorten the time needed to produce new varieties by 5-6 years, as it will not be necessary to select across generations until the varieties are genetically uniform.

(b) The planting material supplied to growers will be a clone of the parent plant and all plants in the crop will be genetically uniform. Currently commercial seed producers experience difficulty in maintaining uniform commercial seed.

(c) All plants will be of the same sex. It will not be necessary to plant a number of plants at each site and thin, at flowering, to a plant of the required sex as is necessary with seedlings. The benefits are lower labour costs through no thinning, faster early growth due to less competition and a lower disease risk due to the absence of the rotting stumps of thinned plants.

(d) Micro-propagated plants flower and fruit earlier and lower on the trunk than seedlings. The result will be a greater return before the crop is too tall for economic harvesting.

(e) New varieties will be commercialised as heterozygous material, thus maintaining the natural genetic state of the species and hopefully increased environmental stability.

(f) Micro-propagation has the potential to provide a more cost effective method of maintaining a papaya germplasm collection than by seed.
As explained above, the basic aims of the project were to set up a population to provide long-term genetic advance and selection of new varieties and to develop expertise in papaya micro-propagation to allow new selections to be commercialised asexually.

During work aimed at setting up the population, it was obvious that the plantings made contained material with commercial potential. This prompted a change in the objectives of the project to select material with commercial potential. The aim was to propagate enough plants of at least fifteen selections to plant a replicated variety trial at South Johnstone to obtain detailed performance data. At the same time it was agreed to do additional work to demonstrate the performance of micro-propagated plants to growers. This was achieved through field plantings of micro-propagated material, including an on farm commercial comparison of crops propagated from seed, micro-propagation and cuttings. A benefit/cost analysis of micro-propagated planting material versus seedlings and cutting material was also conducted.

Unfortunately, at the same time that these extensions to the project were agreed to, the budget for the final year of the project was cut by $20,000 due to a suspension and reorganisation of papaya levy collection. This funding situation significantly restricted the work that was possible during the final year of the project.

During the course of the project a number of a number of activities were conducted that were associated with the breeding project, but not officially part of it. These activities have been included in this report as the results are relevant to papaya breeding.

The associated activities were:

(a) The conduct of a replicated variety to test ten varieties at South Johnstone.

(b) Two seed production plantings to maintain viable seed of the variety collection maintained at South Johnstone.

(c) The development of effective data collection and experimental methods for papaya trials. This was achieved from data collected during construction of the random mated population and via a variety trial conducted during the course of the project.

(d) The commencement of the accumulation of character correlation and genetic data that will be important in helping to define the optimum selection, variety evaluation and

commercialisation strategy for the future. This was done through two diallel trials conducted during parent intercrossing and data collected during the two random intercrosses of the main breeding population.

2. MATERIALS AND METHODS

A flow chart of the project plan that shows the activities required to achieve the desired goals is attached in Appendix 1. There are two main parts of the project;

- development of a breeding population to provide a source of material for the selection of new varieties and long term genetic advance,
- and tissue culture work aimed at developing expertise in papaya micro-propagation to facilitate the testing and commercialisation of material selected from the population.

A summary of the milestone reports are presented in Appendix 2

The plant and fruit assessment methods were formulated from information provided by papaya industry representatives in meetings with the Papaya Extension Officer, Mr Phil Ross. The methods used in the project were used in the two preceding projects with modifications within the analysis where applicable to make all data on a 0 to 10 scale.

2.1. Development of the Breeding Population

The following steps were involved in the development of long term breeding population.

2.1.1. Parent Selection

The parents used for construction of the random mated population were selected with the aid of past data [FR97031] and the recommendations of various growers and industry representatives. Parents chosen and their main attributes are listed in Table 1 and 2.

The objective in setting up the population was to ensure that it included as much useful genetic variation as possible.

A number of additional plant and fruit characters were of interest to the industry. A selection index (Fruit Value Index) was used to resolve this rather complex selection exercise. Parent selection using this index was something of a balancing act between the need to include a reasonable number of parents that rated highly for taste and appearance and the need to ensure the diversity of parental origin to increase genetic variation.

Table 1. Parents Selected for the Project and Their Major Attributes

Parent	Origin	Major Attributes
BB9H	Queensland	Fair to poor eating quality, nasturtium flavour, thick bright yellow firm flesh, pear shaped, round to angular cavity, flat stalk end, sunken/flat teat shape, very low winter spot, shiny clean orange skin, high round female fruit shape.
Eksotika	Malaysia	Good eating quality, musk flavour, orange-red medium/soft flesh, elliptic shaped, star cavity, depressed stalk end, flat to slight teat, very good fruit size.
GD 3-1-9-2	Queensland	Very poor eating quality, nasturtium flavour, thick bright yellow medium firm flesh, oblong shaped, star cavity, flat stalk end, flat teat, low winter spot.
Kapoho	Hawaii	Good eating quality, sweet flavour, bright yellow medium firm flesh, pear shaped, round cavity, flat stalk end, sunken/flat teat, high sugar.
Maradol Roja	Mexico	Fair eating quality, smoky (frangipanni) flavour, red firm/medium flesh, oval bisexual and female fruit shape, depressed stalk end, slight teat, very low fruiting height, low winter spot.
Mission Beach	Canary Is	Fair eating quality, bland flavour, red, medium firm flesh, oval bisexual fruit shape, pentagon cavity, flat stalk end, slight teat, very low fruiting height, low winter spot.
NT Red	Malaysia	Good eating quality, musk flavour, orange-red medium firm flesh, oval bisexual fruit shape, pentagon cavity, depressed stalk end, high sugar level, moderate sized fruit.
Paris	Malaysia	Poor eating quality, bland flavour, red medium firm flesh, elongate bisexual and female fruit shape, pentagon cavity, depressed stalk end, pronounced teat, very low winter spot.
Subang	Malaysia	Poor eating quality, bland flavour, red medium firm flesh, elongate fruit, round/angular cavity, depressed stalk end, slight/pronounced teat, very low winter spot,
Sunrise Solo	Hawaii	Very good eating quality, musk flavour, orange-red medium firm flesh, pear shaped, round/angular cavity, depressed stalk end, sunken teat, high sugar level,.

Table 2. Some Characteristics of Selected Parents.

Parent	Sex	Fruit Weight (gm)	Brix	Winter Spot *	Eating Quality **	Flesh Firmness #
BB9H	F	515.9	9.9	0.6	3.5	2.6
BB9H	H	696.6	9.0	0.7	3.2	3.0
Eksotika	F	746.1	10.2	2.1	2.7	2.8
Eksotika	H	786.2	9.8	2.3	2.6	2.9
GD 3-1-9-2	F	944.9	7.9	0.7	3.9	2.8
Kapoho	F	476.7	12.3	1.1	2.0	2.8
Kapoho	H	368.5	13.0	1.1	2.1	3.0
Maradol Roja	H	1427.8	9.6	0.7	3.0	3.3
Mission Beach	H	118.0	11.6	2.0	2.0	2.0
NT Red	F	725.8	11.2	1.6	1.4	3.9
NT Red	H	620.3	11.3	2.3	1.1	4.0
Paris	H	2465.4	6.8	0.6	3.4	3.0
Subang	F	1167.0	9.5	0.3	3.3	2.8
Subang	H	1114.5	9.9	0.3	3.1	2.4
Sunrise Solo	F	529.5	12.0	1.1	1.9	3.2
Sunrise Solo	H	504.4	11.1	2.1	2.0	2.8

* Winter Spot: 0 = 0%, 4 = >50%
** Eating Quality: 0 = Very Good, 5 = Very Poor.
# Flesh Firmness: 1 = Hard, 2 = Firm Throughout, 3 = Firm, soft centre, 4 = Soft throughout

2.1.2. F1 Crossing of the Parents

All parent intercrossing was conducted at South Johnstone Research Station on plants planted in the previous project (FR97031) during November/December 1998 to avoid delays in the new project.

Two mating systems occur in papaya. Dioecious varieties consist of a mixture of female and male plants, while bisexual varieties consist of bisexual and female plants. Of the three sex types, both bisexual and female plants are commercially useful. Therefore, in setting up the population it was important to ensure that the resulting population consisted of only bisexual and female plants, as male plants were of no value as new asexual varieties. The ten parents chosen were divided into two groups of five (Groups A and B), as shown in Table 3. The base population was to be made up by pollinating female plants of F1 hybrids of Group B parents with pollen from bisexual plants of F1 hybrids of Group A parents.

The F1 hybrids within each group consisted of all possible crosses between the five parents, without reciprocals. Only one of the ten parents (GD 3-1-9-2) was a

dioecious variety. Male progeny of GD 3-1-9-2 were excluded from the population by using it only as a female parent in making the Group A F1 hybrids.

In the process of allowing for only the female parent of GD3-1-9-2, the cross between GD3-1-9-2 and Mission Beach was made but the fruit were lost through cyclone damage. In the analysis and presented data, missing plot values were calculated for the missing cross from means of all crosses that had either of the two missing parents. That being GD3-1-9-2 x Maradol Roja, GD3-1-9-2 x NT Red, GD3-1-9-2 x Paris, Mission Beach x Maradol Roja, Mission Beach x NT Red and Mission Beach x Paris. A value was calculated for each replication independently. To compensate for the effect of the missing cross on the gene frequency when the crosses were bulked to make up the starting population, the proportion of seed was increased of all the crosses that had the missing parents in an attempt to keep the gene frequency of all parent equal.

Table 3. Parent Groups

Group A		Group B	
Parent	**Sex Type**	**Group B**	**Sex Type**
BB9H	bisexual	GD 319-2	dioecious
Eksotika	bisexual	Maradol Roja	bisexual
Kapoho	bisexual	Mission Beach	bisexual
Subang	bisexual	NT Red	bisexual
Sunrise Solo	bisexual	Paris	bisexual

2.1.3 Intercrossing of the F1 Hybrids and Construction of the Base Population

The base population was constructed by allowing random pollination of female plants from Group B F1 hybrids with pollen from bisexual plants of Group A F1 hybrids. This planting was made at Southedge Research Station near Mareeba in September 1999 to reduce the chance of contamination with pollen from elsewhere. All male and bisexual plants growing on the research station were culled. The nearest commercial crop to the planting was four kilometres.

The two sets of F1 crosses planted from the above were diallel cross series that were used to derive genetic information about the parents and the resulting population.

The planting was set up to allow data to be collected and analysed by the method of Griffing (1956). As well as genetic information about the parents and population, this analysis also allowed a limited assessment of the commercial potential of the F1 hybrids.

Although the results of this analysis were useful, the value of the results was limited by; the need for the trial layout to be a randomised design, rather than a randomised

complete block, to ensure effective pollination, and, the need to restrict the planting to two plots of each F1 due to project budget constraints.

Another limitation on the value of the results was requirements for intercrossing only bisexual fruit from the Group A hybrids and only female fruit from Group B.

The data collected was minimum fruiting height and fruit value data. All data was collected from two, ten plant plots of each hybrid. All ten plants were included for the agronomic data. Data on parent lines were analysed for general and specific combining ability and heritability. Data are presented in Appendix 4.

All Group B fruit and opened flowers were stripped at the time that the Group A bisexuals were in full flower. This was to ensure that all Group A bisexuals had, as near as was possible, to an equal chance of contributing pollen.

After seed harvest, equal numbers of seed from each Group B hybrid was bulked to form the base breeding population (RC1).

2.1.4 Random Mating of the Base Population

An important concern about the parents selected for the project was apparent genetic linkages between some important desirable characters and deleterious characters. The most important of these apparent linkages was an association between "musk" flavoured fruit and susceptibility to winter spot.

Two random intercross generations were conducted to attempt to break up these character associations and promote character recombination.

The random intercrosses were done on two consecutive plantings transplanted into the field on 17-19th January 2001 and the 22nd May 2002. The first planting consisted of 4,504 plants and the second of 4,546 plants.

As a result of the crossing method used in constructing the base population for the first planting, these plantings should have consisted of half female and half bisexual plants. Any male plants present could only occur due to pollination during the random cross, done to produce the parent population. Therefore, among other data obtained, these populations (the proportion of male plants present) was be used as an indication of the effectiveness of Southedge Research Station's isolation on pollen contamination. In addition, a number of female plants were grown at various distances from the random cross plantings in an attempt to gain some indication of required isolation distances.

Any male and bisexual plants growing on Southedge were culled while these plantings were in progress.

All fruit and opened flowers were stripped from the female plants in the population when all bisexual plants had reached the flowering stage and had opened flowers. Any male plants that were detected in the population were culled before female fruit stripping. This was to ensure complete random mating.

Seed for the next generation was harvested from all female plants in each population. Twenty seeds from each female were bulked to form the new seed lot (RC2).

Data to document the performance of each population were collected from 719 and 504 random sample plants from the first and second plantings respectively. However, death of some selected plants and the removal of unwanted male plants reduced the actual data plants down to 626 and 448 respectively. Additionally, once plants had fruited a number of plants produced fruit that were very large (unacceptable) or had severe carpelloidy or winter spot. These trees where culled due to being unacceptable. No further assessments were made on these trees.

Data were also collected from a number of additional plants selected as having commercial potential. Initial selection of these plants was based on fruit set, fruit size, shape, and a low incidence of winter spot. Data collected from these additional plants were continually monitored. Any commercially unsuitable plants were culled as soon as they were detected.

Data collected for all plants were plant sex and plant death causes. Data collected from random sample and selected plants were minimum fruiting height, percentage fruit set, percentage carpelloid fruit and fruit value data. This data is presented in Appendix 5.

2.1.5 **Data Collection Methods**

2.1.5.1 Yield per Tree (kg)

Yield per tree is the total weight of fruit harvested per plot, less any classified as unsaleable, expressed as the mean per tree.

Fruit classified as unsaleable is a subjective judgement and includes misshapen carpelloid fruit, small fruit, misshapen or poorly developed fruit from poor pollination, fruit with blossom end defect and etcetera.

Data from the RC1 and RC2 populations were all collected from single plants. The means per plant were calculated for replicated trials on the number of trees per plot at the time of each harvest.

2.1.5.2 Unsaleable Fruit Yield

The total weight of fruit harvested per plot not classified as saleable, expressed as the mean per tree.

2.1.5.3 Saleable Fruit per Tree

Fruit per tree calculated in the same way, using the same fruit, as yield per tree.

2.1.5.4 Minimum Fruiting Height (cm)

Minimum fruiting height is the distance from the ground to the lowest fruit stalk, measured to the nearest centimetre.

In general, the lower the minimum fruiting height the better, as a low fruiting height indicates earlier fruiting and a greater yield of fruit before harvesting becomes uneconomical due to tree height. However, minimum fruiting height can be too low, particularly in high rainfall environments where fruit set too close to the ground may be heavily infected with Phytophthora fruit rot.

Industry requirements are for a minimum fruiting height of one metre.

2.1.5.5 Days to First harvest

Days to first harvest is the number of days from transplanting into the field to the date the first fruit was harvested. Fruit is harvested at the first sign of colour.

2.1.5.6 Side Shoot Rating (0-5)

The side shoot rating is a subjective assessment of the degree of side shooting from the main stem. Ratings are conducted when fruit set commences, at the same time that the minimum fruiting height is measured.

The ratings are;

0- no side shoots,
1- few weak side shoots all less than 3 cm long,
2- a number of side shoots all less than 5 cm long,
3- a number of side shoots all less than 10 cm long,
4- profuse side shooting with at least some side shoots more than 15 cm long and
5- profuse side shooting with most side shoots more than 15 cm long.

A rating below three is considered commercially acceptable. Commercial plantings with ratings above two would probably have the side shoots removed manually.

2.1.5.7 Fruit Weight (g)

This is the mean weight of saleable fruit in grams, measured when the fruit is ripe and suitable for eating.

2.1.5.8 Fruit Shelf Life (days)

This is the number of days between fruit harvest (at first colour) and fruit quality assessment, conducted when the fruit is ripe for eating. Where possible, the fruit is ripened at 22 degrees centigrade.

2.1.5.9 Percentage Fruit Set

Percentage fruit set is the percentage of the nodes inspected that have fruit set. It is assessed by counting the number of fruit set on the youngest five nodes that are sufficiently advanced to set fruit.

2.1.5.10 Percentage Carpelloid Fruit

Percentage Carpelloid set is the percentage of fruit that show distortion due to flower types other than elongata. It is assessed on the same nodes used for Percentage Fruit Set

2.1.5.11 Percentage Blossom End Defect Fruit

The percentage of blossom end defect fruit produced by a variety is a character of high economic importance. Susceptible varieties need special fruit fly treatment to access some markets.

Blossom end defect occurs in both bisexual and female fruit, but is much more prevalent in the fruit of bisexual trees. There is considerable variation between varieties for susceptibility.

The defect is present as a small hole in the blossom end of fruit, giving external organisms the opportunity access to the fruit cavity. It is detected during fruit assessment by a fungal and/or bacterial infection of the fruit cavity.

2.1.5.12 Fruit Value Index.

The fruit value index converts all fruit characters into a 1 –10 rating. It has been designed so that data from all past breeding projects can be converted into the fruit value index, so that results can be compared. The weightings for each character were derived from consultation with industry. The primary purpose of the index is to maintain useful genetic variation in the population during selection and increase the frequency of characters important to the industry and decrease the frequency of undesirable characters.

Table 4. Fruit Value Index: Fruit Character Weightings

Fruit Character	Weighting
Eating Quality	0.14
Brix Reading	0.14
Winter Spot	0.12
Fruit Shape	0.12
Fruit Size	0.12
Flesh Colour	0.08
Ripening Pattern	0.08
Teat Shape	0.06
Stalk Insertion	0.06
Shelf Life	0.06
Total	**1.00**

Allocation of points for each character is follows:

(a) Eating Quality Points. Eating quality points equal *Flavour Rating* + *Eating Quality Rating* where;

Flavour Rating		*Eating Quality*	
5	Bland	5	Very Poor
4	Sweet	4	Poor
3	Musk	3	Fair
2	Smoky	2	Good
1	Nasturtium	1	Very Good

(b) Brix Reading Points. Brix reading points equal 10 – ((12 – *Brix Reading*) * 1.5). A Brix reading of 12 being the industry target.

(c) Winter Spot Points. Winter spot points equal 10 – (*Winter Spot Rating* * 2.5) where the *Winter Spot Rating* is;

0 = where winter spot covers less than 1% of the surface,

1 = where it covers 1 to 15%,

2 = where it covers 16 to 30%,

3 = where it covers 30 to 50%

4 = where it covers more than 50%.

(d) Fruit Shape Points. Fruit shape points equal *Shape Rating* – (*Ridging Rating* - 1) where

Shape Rating (see Appendix 3)		Ridging Rating	
10	Elliptic", "Oblong", "Oblong ellipsoid" or "Oblong blocky"	1	None
8	"Elongate", "Lengthened cylindrical", "Plum shaped"	2	Slight
6	"High round", "Oval", "Blossom end tapered", "Acorn", "Turbinate inferior", "Pear shaped", "Globular" or "Turbinate superior"	3	Superficial
4	"Round"	4	Superficial plus
1	"Club shaped", "Reniform", or "Pumpkin shaped"	5	Moderate
0	Otherwise	6	Deep
		7	Very Deep

(e) Fruit Size Points. Fruit size points equal 10 – |(1,000 – *Fruit Weight*)/50)| where *Fruit Weight* is in grams.

(f) Flesh Colour Points. Flesh colour points are;

10 = Scarlet or Red

9 = Deep Yellow to Reddish Orange

8 = Bright Yellow

0 = Light Yellow or Other colours.

(g) Ripening Pattern Points. Ripening pattern points are

10 = Striping or Partial striping,

5 = Even all over and

0 = otherwise

(h) Teat Shape Points. (Appendix 3) Teat shape points for various ratings are

10 = Flat

5 = Depressed

3 = Moderate

0 = and otherwise

(i) Stalk Insertion Points. Stalk insertion points are 0 if the fruit is depressed around the stem, otherwise 10.

(j) Shelf Life Points. Shelf life points are Fruit Rot Points + Flesh Firmness Points + Days to Ripening Points where;

Presence of Fruit Rots		*Flesh Firmness*		*Days to Ripening*	
6	No Fruit Rots	4	Soft throughout	5	> 8 days
4	Trace of fruit or petal scar rot	3	Firm: soft centre	3	7 to 8 days
2	Moderate fruit or petal scar rot	2	Firm throughout	1	6 to 7 days
0	Severe fruit or petal scar rot	1	Hard	-3	5 to 6 days
				-5	<5 days

2.1.5.13 Data Collection

All data collected in this project is stored in a Microsoft Access database. Data from previous breeding projects has also been converted into Access, and is resident in one database for future retrieval.

2.2 Additional Project Activities

2.2.1 Disease Incidence and Desirable Trial Sites

It had been noted in previous breeding projects and some plant protection papaya trials, that plant losses, due to a range of diseases, had a significant impact on the quality of trial data. An analysis of the percentage plant losses from trials over a four years and three locations was conducted to determine the most secure site to conduct the basic breeding work for this project. Detailed final evaluation of any selected lines would be conducted in the various commercial production areas.

3.0 RESULTS AND DISCUSSION

Disease Incidence and Desirable Trial Sites

3.1 Disease Incidence and Desirable Trial Sites.

Disease incidence was recorded in detail for all plantings made from one year before the start of this project in seed increase plantings made in 1998. The data obtained are in Table 5.

Table 5. Disease losses recorded in plantings made during the project.

Place	Year	Planting Date	Purpose	Total Plants	Percentage Loss		
					Dieback	Yellow Crinkle	Phytophthora
SJ Phillips	1998	8th Dec	Seed Maintenance	554	59.2%	0.0%	25.9%
SJ Levee	1999	4th Aug	Seed Maintenance	185	2.7%	0.0%	30.3%
SJ Levee	2000	19th Jan	Seed Maintenance	68	0.0%	0.0%	17.6%
SJ Levee	2000	19th Jan	Replicated Variety Test	594	10.3%	0.0%	27.9%
SJ Levee	2000	19th Jan	Seed Maintenance	72	9.7%	0.0%	47.2%
SJ All				**1,473**	**27.2%**	**0.0%**	**28.0%**
SRS	1998	24th Nov	Seed Maintenance	321	0.3%	0.0%	0.0%
SRS	1999	23rd Sept	Crossing Block	305	0.3%	0.0%	0.0%
SRS	2001	29th Jan	Crossing Block	4,502	0.6%	0.6%	0.0%
SRS	2002	22nd May	Crossing Block	4,546	0.5%	1.5%	0.0%
SRS All				**9,764**	**0.5%**	**1.0%**	**0.0%**

The disease incidence data in indicate a serious risk management dilemma for the project. The chance of success from plant breeding is maximised if new varieties are bred and selected in the environments in which they are to be grown commercially.

However, this data indicates that there is a high risk of serious disease losses in coastal plantings made on both levee soils and basalt soils (Phillips Block) on South Johnstone Research Station (SJ), the only available trial site in the main commercial growing environment.

Resolution of this situation was to conduct of most of the basic breeding work for the project at Southedge Research Station (SRS) based west of Mareeba. Work at South Johnstone was and will be restricted to detailed final evaluation trials of material developed and selected at Southedge.

The advantages of Southedge Research Station are that there is a very low incidence of Phytophthora, and a lower incidence of dieback than at South Johnstone. There is also a significantly lower risk of cyclone damage at Southedge, but this is offset to a degree, by a higher risk of thunder and hail storms during the November-December period prior to the wet season. Additionally the proximity and density of

commercial papaya plantations to South Johnstone is much higher than at Southedge, potentially increasing the possibility of contamination with male pollen.

3.2 Evaluation of Hybrids from Parental Material – F1 Hybrid 1999, Tables 6, 7, 8 and 9 and Appendix 4

Table 6. Female Hybrids, Quantitative data.

Hybrid	Fruiting Height (cm)	Days to First Harvest	TSS (%)	Fruit Weight (g)	Fruit Length (mm)	Fruit Diameter (mm)	Fruit LB Ratio	Days to Ripening	Fruit Flesh Ratio	Flesh Variation (mm)
GD 319-2 x Maradol Roja	66	375	8.3	1,350	157	132	1.20	10.0	0.48	19
GD 319-2 x Mission Beach	91	375	8.7	1,300	172	129	1.33	10.5	0.47	17
GD 319-2 x NT Red	115	382	9.3	961	147	117	1.25	8.7	0.49	20
GD 319-2 x Paris	107	379	8.2	1,225	188	121	1.55	8.8	0.52	19
Maradol Roja x Mission Beach	70	380	8.8	1,567	174	144	1.20	12.8	0.45	14
Maradol Roja x NT Red	81	382	9.3	1,666	176	147	1.25	9.9	0.47	17
Maradol Roja x Paris	96	381	9.3	1,771	214	141	1.55	9.7	0.47	16
Mission Beach x NT Red	92	365	9.2	975	152	124	1.20	11.3	0.43	15
Mission Beach x Paris	96	370	8.6	1,723	217	138	1.60	11.7	0.48	16
NT Red x Paris	121	380	9.8	1,364	199	129	1.55	8.1	0.47	17
Mean	**93**	**377**	**8.9**	**1,390**	**179**	**132**	**1.37**	**10.1**	**0.47**	**17**
LSD 0.05	**18**	**6**	**1.0**	**741**	**39**	**25**	**0.15**	**2.4**	**0.02**	**3**
LSD 0.01	**26**	**9**	**1.4**	**1,064**	**57**	**36**	**0.22**	**3.5**	**0.04**	**5**
CV	**9%**	**1%**	**5%**	**24%**	**10%**	**9%**	**5%**	**11%**	**2%**	**9%**

3.2.1 Fruit Height

Hybrids from Maradol Roja and Mission Beach Red parents produced plants with fruit lower on the trunk, whilst those from parents of NT Red and Paris were significantly higher. Maradol Roja was very dominant in this character, having both very significant general combining ability and a strong trend in specific combining ability. NT Red and Paris hybrids were generally unfavourable.

All bisexual parents produced taller fruiting hybrids compared to the female parents with Kapoho lines being the most unacceptable. The added genetic variance of BB5H was acceptable, particularly when combined with Eksotika and Sunrise Solo parents.

3.2.2 Days to Harvest

Mission Beach Red (F) BB5H (H) and Sunrise Solo (H) displayed positive trends for shorter harvest intervals, with reasonably good general combining ability. Maradol Roja (F) Subang (H) and Kapoho (H) hybrids appeared to have harvest intervals, which would be unacceptable.

Data for specific combining ability appeared unreliable.

3.2.3 Total Soluble Solids.

Generally, the female parents had a lower level of soluble solids than the bisexuals. NT Red provided better combining ability over other female parents, whilst GD319-2 had a negative impact on sweetness.

Similarly, BB5H and Subang had unfavourable added genetic combining effects. However, Kapoho would appear to be acceptable. There was no significant specific combining ability for TSS.

Table 7. Bisexual Hybrids, Quantitative data.

Hybrid	Fruiting Height (cm)	Days to First Harvest	TSS (%)	Fruit Weight (g)	Fruit Length (mm)	Fruit Diameter (mm)	Fruit LB Ratio	Days to Ripening	Fruit Flesh Ratio	Flesh Variation (mm)
BB5H x Eksotika	118	335	9.8	646	153	87	1.80	7.9	0.53	11
BB5H x Kapoho	127	371	10.3	543	144	85	1.70	10.6	0.54	7
BB5H x Subang	132	364	8.8	1,040	198	101	2.00	10.4	0.53	9
BB5H x Sunrise	118	328	9.5	593	152	88	1.80	10.9	0.54	7
Eksotika x Kapoho	152	370	11.1	670	148	94	1.60	7.7	0.49	11
Eksotika x Subang	139	378	9.9	1,330	224	109	2.10	8.7	0.50	16
Eksotika x Sunrise	129	366	10.7	594	140	94	1.55	8.4	0.50	12
Kapoho x Subang	128	366	10.5	964	194	100	1.95	7.6	0.51	12
Kapoho x Sunrise	145	371	11.1	466	133	87	1.55	9.0	0.51	8
Subang x Sunrise	137	359	9.7	988	204	100	2.05	8.4	0.50	11
Mean	**132**	**361**	**10.1**	**783**	**169**	**94**	**1.81**	**8.9**	**0.51**	**10**
LSD 0.05	**33**	**29**	**1.1**	**386**	**19**	**15**	**0.20**	**1.4**	**0.04**	**3**
LSD 0.01	**47**	**42**	**1.6**	**554**	**27**	**22**	**0.28**	**2.0**	**0.06**	**4**
CV	**11%**	**4%**	**5%**	**22%**	**5%**	**7%**	**5%**	**7%**	**4%**	**11%**

Table 8. Female Hybrids, Qualitative Fruit data.

Hybrid	Fruit Value Index	Eating Quality Points	Sugar Level Points	Winter Spot Points	Fruit Shape Points	Fruit Size Points	Flesh Colour Points	Ripening Pattern Points	Teat Shape Points	Stalk End Points	Shelf Life Points
GD 319-2 x Maradol Roja	**3.3**	1.8	4.4	6.0	5.5	2.0	7.0	5.5	8.3	2.5	8.4
GD 319-2 x Mission Beach	**5.3**	3.1	5.1	6.3	5.0	3.7	8.2	8.3	6.3	3.9	9.3
GD 319-2 x NT Red	**5.9**	2.6	5.9	5.2	4.1	5.2	8.1	7.3	9.7	7.7	9.2
GD 319-2 x Paris	**6.2**	1.7	4.3	8.8	6.8	4.8	8.1	7.2	7.4	9.3	9.1
Maradol Roja x Mission Beach	**5.2**	3.6	5.2	5.1	4.6	2.8	9.3	10.0	4.6	0.0	9.9
Maradol Roja x NT Red	**4.7**	3.8	6.0	3.0	2.4	1.8	10.0	9.1	4.4	0.0	9.4
Maradol Roja x Paris	**5.2**	4.2	5.8	7.1	3.8	1.9	9.4	10.0	0.9	1.0	9.2
Mission Beach x NT Red	**6.3**	6.0	5.7	7.5	3.1	5.2	7.9	9.9	6.2	2.5	9.7
Mission Beach x Paris	**5.0**	2.8	4.9	5.3	5.9	2.2	9.1	9.8	1.9	1.4	9.6
NT Red x Paris	**6.1**	5.2	6.6	6.8	5.7	3.9	9.8	9.8	1.5	4.7	8.9
Mean	**5.3**	**3.5**	**5.4**	**6.1**	**4.7**	**3.3**	**8.7**	**8.7**	**5.1**	**3.3**	**9.3**
LSD 0.05	**1.7**	**1.4**	**1.5**	**6.0**	**2.7**	**2.3**	**1.9**	**1.9**	**2.7**	**3.4**	**1.6**
LSD 0.01	**2.4**	**2.0**	**2.2**	**8.6**	**3.8**	**3.2**	**2.7**	**2.8**	**3.8**	**4.8**	**2.3**
CV	**14%**	**17%**	**13%**	**44%**	**25%**	**30%**	**10%**	**10%**	**23%**	**45%**	**8%**

3.2.4 Fruit Weight and other Physical Characteristics

Female hybrids had larger fruit than bisexual hybrids within the female parents, although not significant, Maradol Roja developed much larger fruit and GD319-2 and NT Red smaller fruit.

The general combining ability of Subang to produce large fruit was very significant compared to other bisexual parents.

These trends for fruit weight were consistent across all fruit physical characteristics. The larger fruit characteristics of Maradol Roja and Subang were considered unacceptable.

There were no significant specific combining ability effects in any of the hybrids

3.2.3 Fruit Quality Index

Outside of the Fruit Value Index (combination of 10 critical characteristics), the key assessments for fruit quality are eating quality (flavour and eatibility), sugar and winter spot.

None of the parent hybrid combinations, assessed for fruit quality, displayed any specific combining ability effects, however a number proved positive and negative in general combining ability effects.

Eating quality. The eating quality of the bisexual group was generally higher than the female group. Hybrids from NT Red parents had significantly better general combining ability than those of GD319-2. Maradol Roja hybrids were generally less acceptable than NT Red.

Similarly, within the bisexual group, Sunrise Solo and Eksotika provided much better hybrids for eating quality than BB5H and to a lesser extent Subang.

Table 9: Bisexual Hybrids, Qualitative Fruit data.

Hybrid	Fruit Value Index	Eating Quality Points	Sugar Level Points	Winter Spot Points	Fruit Shape Points	Fruit Size Points	Flesh Colour Points	Ripening Pattern Points	Teat Shape Points	Stalk End Points	Shelf Life Points
BB5H x Eksotika	**5.3**	4.2	6.6	2.6	6.5	3.8	8.3	5.7	5.5	2.7	7.8
BB5H x Kapoho	**6.4**	4.0	7.5	7.2	6.8	5.3	7.8	5.9	5.6	6.2	9.3
BB5H x Subang	**5.1**	2.5	5.2	3.3	6.9	3.4	8.1	5.5	5.8	4.6	8.9
BB5H x Sunrise	**5.8**	4.4	6.3	2.6	6.1	6.0	7.8	5.7	5.6	7.9	9.4
Eksotika x Kapoho	**5.5**	6.7	8.5	0.3	5.8	6.2	7.3	5.4	4.9	0.4	7.9
Eksotika x Subang	**5.3**	5.0	6.9	0.9	6.3	2.7	9.8	6.9	5.4	0.7	9.5
Eksotika x Sunrise	**6.0**	8.5	7.9	0.6	6.3	6.3	9.2	6.0	4.6	0.7	8.8
Kapoho x Subang	**6.2**	4.6	7.8	5.4	6.7	4.4	8.0	7.8	5.7	4.0	8.5
Kapoho x Sunrise	**5.5**	6.3	8.5	0.8	7.2	4.5	6.1	5.5	4.9	1.9	8.5
Subang x Sunrise	**5.4**	5.9	6.5	1.1	6.5	3.3	9.4	6.6	4.1	3.5	9.0
Mean	**5.6**	**5.2**	**7.2**	**2.5**	**6.5**	**4.6**	**8.2**	**6.1**	**5.2**	**3.3**	**8.8**
LSD 0.05	**0.9**	**1.3**	**1.6**	**4.3**	**2.0**	**3.7**	**1.1**	**1.9**	**1.7**	**2.8**	**0.9**
LSD 0.01	**1.2**	**1.9**	**2.3**	**6.1**	**2.9**	**5.3**	**1.6**	**2.7**	**2.5**	**4.0**	**1.4**
CV	**7%**	**11%**	**10%**	**76%**	**14%**	**36%**	**6%**	**14%**	**15%**	**38%**	**5%**

Sugar Level Points. Sugar levels in the bisexual group were much higher than in the female group. NT Red (F) provided reasonably good added genetic variance over GD319-2 whilst Kapoho (H) dominated over BB5H.

Winter Spot. The female parent group provided much less incidence of winter spot than the bisexual parents. Within the female group, no parent dominated over another in regard to general combining ability. However, bisexual parents BB5H and Kapoho demonstrated significantly greater capacity than Eksotika and Sunrise Solo in providing progeny with less winter spot.

Fruit Value Index. Both parental groups had comparable average indices of about 5.5. Within the female group, NT Red provided greater general combining ability than Maradol Roja and GD319-2 for the key criteria. There was no significant difference between the bisexual parents.

3.2.4 Quantative Inheritance: Appendix 4 Table22

a. Flesh Colour. The reddish colour is recessive. There are exceptions and intermediates. For example a distinct band of yellow just under the skin (3-4mm) with the rest of the flesh red.

b. Taste. Nasturtium is dominant to all other tastes. The characteristic taste of Maradol Roja (Smoky) is dominant to all other tastes except nasturtium. Sweet is dominant to both musk and bland.

c. Eating Quality. Eating quality is around the average of the parents. Any deviation from the mean is usually downwards.

d. Flesh firmness. Around the mid point. Any deviation from the mid parent tends to be towards the firmer fleshed parent.

e. Fruit Shape. Equal to the mid parent (eg oval and elongate gives the intermediate elliptic)

f. Cavity Shape. Bisexual fruit floral, female fruit star.

g. End Shape. Inconsistent, but often around the mid parent.

h. Teat Shape. Sunken is dominant to flat is dominant to slight and pronounced.

3.2.4 Discussion on Parent Material

Each individual parent line clearly brings into the program strong positive and negative traits, providing evidence of broad genetic variation within the parent population. In the majority of characteristics there was a significant positive or negative general combining effect. There was only one occurrence of a significant specific combining ability trait (ie days to first harvest for the female group of parents). This provides confidence the breeding strategy of incremental improvement, which has been adopted, is the most applicable for papaya breeding. The strategy of using highly self-pollinated male lines and relying on specific trait combinations is not suitable for papaya breeding.

3.3 Evaluation of Selected Plants from Random Cross 1 and Random Cross 2 Appendix 5 & 6

Details of both trials are presented in Appendix 5and 6, with general information about some of the selections from both populations that could have potential.

More critical to the breeding program is an assessment of the correlation between characteristics that may be beneficial or deleterious to the outcome of the program. Also it provides an opportunity to analyse the appropriateness of the trial design eg sample size, and identify possible efficiencies that could be made in the program. There should be no genetic variation between the two populations apart from linkage break-up and character recombinations. All differences in quantitative characters (eg fruit height) will be due to environmental differences.

The sample size in RC1 was 1611 plants harvested over 152 days [13/9/01 to 01/02/02 or spring and summer] yielding 4614 fruit. In RC2 fewer plants were assessed, 1110, but harvested over a longer period of time, 284 days, covering summer/spring/summer [17/02/03 to 28/11/03] and yielding 7601 fruit.

Results and data is presented in Graphs 1 to 11 and Appendix 5 Tables 1 to 13. Eight of the 29 characteristics assessed are of particular interest.

3.3.1 Height of First Fruit Graph 1 Appendix 5 Table 7 & 8

The mean height to first fruit for the RC1 population was 82 cm (81 cm Female and 84 cm Bisexual), whilst in the RC2 it had decreased by about 20cm to 62 cm (61 cm Female and 64 Bisexual). This is a significant reduction in height and was one of the key objectives of the program. The times of planting of each population ie January for RC1 and May for RC2, would normally have seen RC2 plants shorter than RC1. However, RC1 plants, both female and bisexual, had a very wide distribution of plants heights, with the majority of plants being between 60 cm and 110 cm. The distribution of plant heights in RC2 was slightly more evenly spread reflecting the increased number of fruit sampled and not necessary an improvement in the population. To avoid this environmental effect on the population, it is recommended that future population be planted in May to July each year.

3.3.2 Fruit Flesh Ratio: Graph2 Appendix5 Table 7 & 8

This is the comparison between the circumference of the fruit and flesh thickness. Higher values are more acceptable.

There did not appear to be any increase or decrease in the flesh ratio between RC1 and RC2.

This criterion mirrored other fruit physical characteristics, where no changes were evident.

3.3.3 Brix graph 3 Appendix 5 Table 7 & 8

There was a significant improvement across both female and bisexual fruit in sugar levels between RC1 (9.5) and RC2 (10.7) population. An overall increase of 1.2 units in the RC2 population. This affect would not have been influenced by environmental conditions, as the harvest periods were long enough to negate these factors.

This increase has resulted from a move away from the lower brix levels and not necessarily at the higher brix level. In the RC1 population, there was a very wide distribution in brix readings from 6.5 to 13.5, but in RC2, this distribution was more concentrated to the higher level between 8.5 and 13.5. The improvement could be attributed to the sample size but also a shift in the population. Increased fruit total soluble solids was a major objective of the program.

3.3.4 Days to Ripening: Graph 4 Appendix 5 Table 7 & 8

Again, the progression from RC1 to RC2 has seen a narrowing of the frequency distribution of the populations fruit ripening habit. There would appear to be a significant reduction in the ripening interval ie 11 days down to 8 days. This however may not be commercially advantageous as it could lead to a shorter shelf life, depending on the level of management within the supply chain. This criterion will need to be monitored in future generations.

3.3.5 Winter Spot: Graphs 5 & 6 Appendix 5 Table 7 & 8

There was a slight overall reduction in Winter Spot level between RC1 and RC2 (2.2 down to 2.0), the major decline being in the bisexual lines (2.4 down to 1.9). However, with the female population in RC1, the distribution of winter spot appeared reasonably even across the five categories. Where as in the RC2 population, the trend would appear that the higher levels of winter spot are declining, and the lower levels are increasing, resulting in a concentration of fruit across the population with winter spot around the 30% level. Because trees with fruit displaying severe symptoms of winter spot have been culled in the RC1 population, this shift in the ratings can be attributed to both the increase in sample size and an improvement in the total population. It would be more desirable if the trend were more towards less than 30% coverage, which if the first assumption is correct, fruit from seed collected from the RC2 should display less symptoms than those in the RC2.

The reduction in winter spot level with the bisexual population was very encouraging considering the bisexual generally have a higher incidence of winter spot than females. Overall the presence of good tasting fruit with low winter spot is encouraging, indicating that the linkage has been broken.

3.3.6 Eating Quality: Graphs 7 & 8 Appendix 5 Table 7 & 8

Positive improvements in eating quality occurred in both female and bisexual fruit, with an average rating increment of 0.5 between the RC1 and RC2 populations. This also was a key objective of the project. Eating quality is very closely correlated to total soluble solids.

3.3.7 Shelf Life: Graphs 9 & 10 Appendix 5 Table 7 & 8

Both female and bisexual fruit in the RC1 Population demonstrated a large percentage of fruit having very good shelf life. However, groups resulted in a decline in potential shelf life in the RC2 population. The major influence on shelf life criteria has been the shortening of the days to ripen in the RC2 group. As mentioned above, this could be managed in the supply chain, but any additional reduction in shelf life maybe unsuitable.

3.3.8 Fruit Value Index Graph 11 Appendix 5 Table 7& 8

This considers 10 key fruit characteristics in one computation in an endeavour to provide an overall assessment of the fruit. The value is strongly influence by the characters of eating quality, brix and winter spot. Across the total population, there was an incremental improvement in the fruit index by about 0.4 units, which is about a 7% increase over the RC1 population. However, possibly of more relevance is that the population distribution has become less variable, in that the whole population has shifted. These criteria will need to be monitored in future generations

3.3.9 Population Correlations in RC1 and RC2 Appendix 5 Table 5 to 14

There are many closely associated characteristics that demonstrated similar trends.

Most of the fruit physical characteristics such as fruit length, circumference, flesh variance and flesh ratio, provided correlations similar to fruit weight. In the RC2 population there was a strong positive correlation between increase in fruit weight and the incidence of winter spot. Similarly, larger fruit also had more pronounced teat shape. These is not a desirable trends, however the consumer demand for large fruit is low and higher for small to medium fruit, which does tend to make the correlation meaningless.

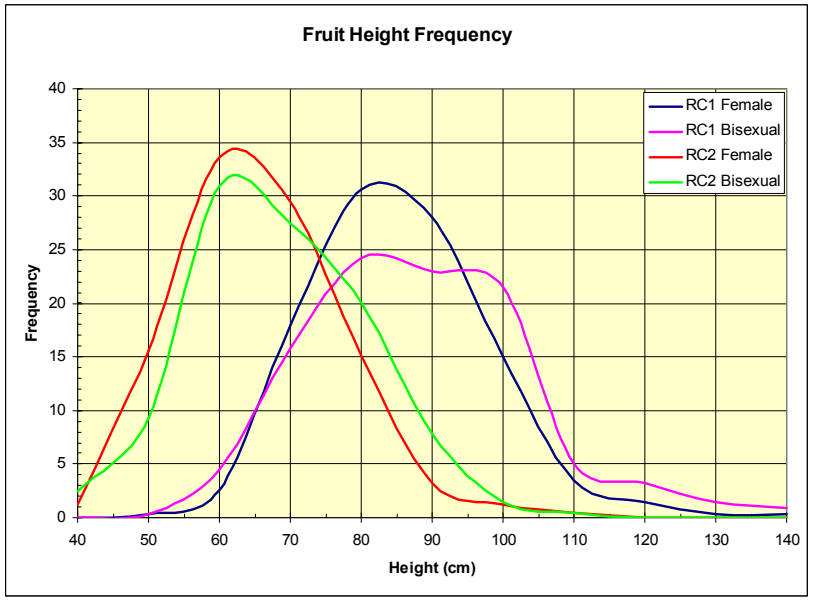
Fruit brix levels are a key determinant of many other critical criteria. There are demonstrated strong positive correlations with eating quality and in turn the fruit value index. However there are trends that increasing brix levels also result in a decline in days to ripening and an increase in fruit and scar rots. This trend occurred in the RC1 population but was not as evident in the RC2 population.

There was no evidence of the impact of increasing fruit TSS on the level of winter spot. This is a critical result to be achieved from this breeding program. Similarly, there has been no relationship between brix levels and flesh colour, ie both yellow and red-fleshed fruit can have low or high TSS levels.

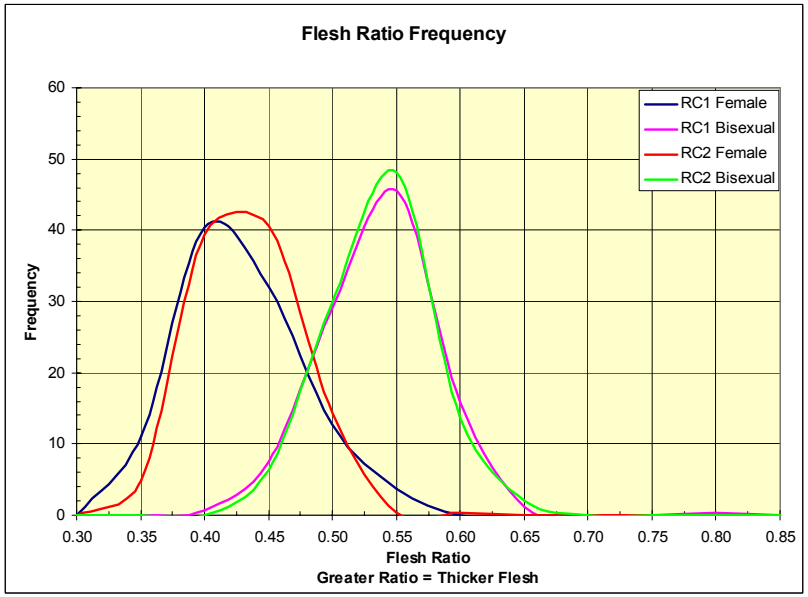
Increasing flesh firmness saw an increase in shelf life, but a small decline in brix and eating quality. This trend appeared to be stronger in the RC2 population.

Overall, there did not appear to be any major deleterious characteristics within the population.

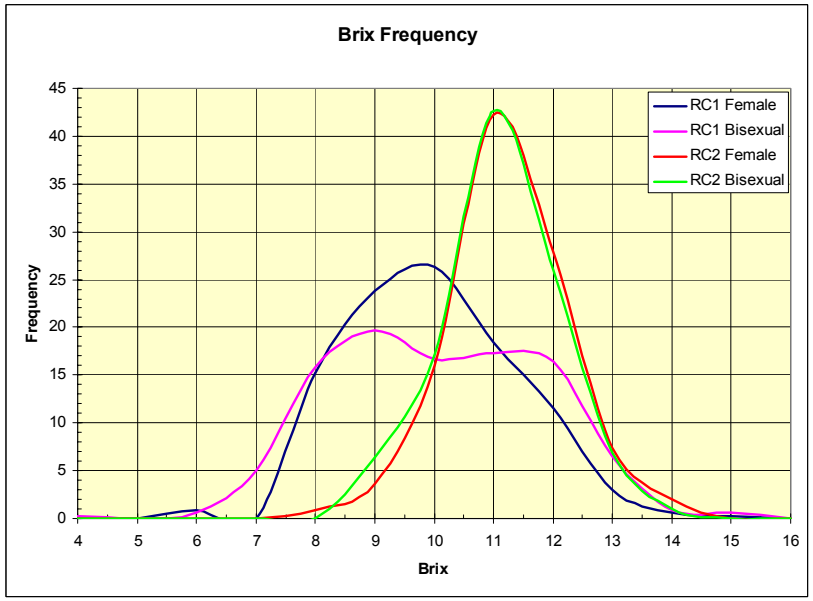
Graph 1



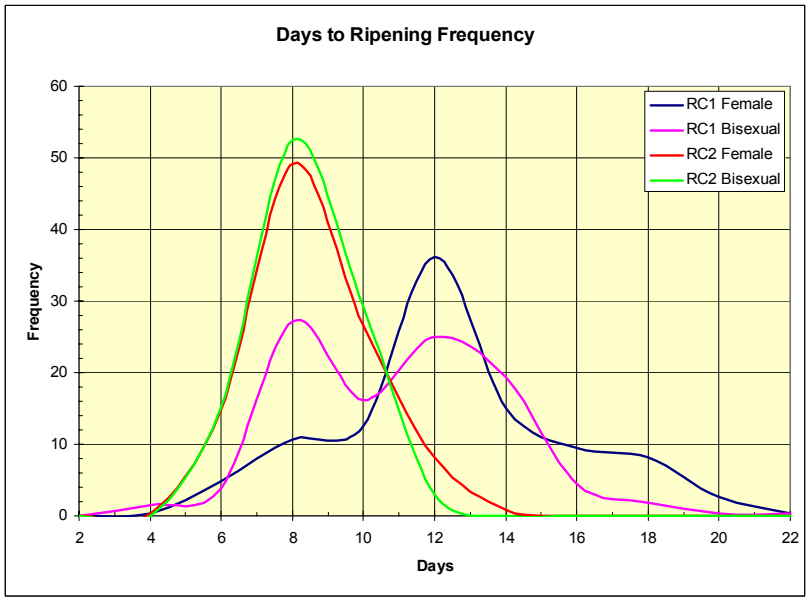
Graph 2



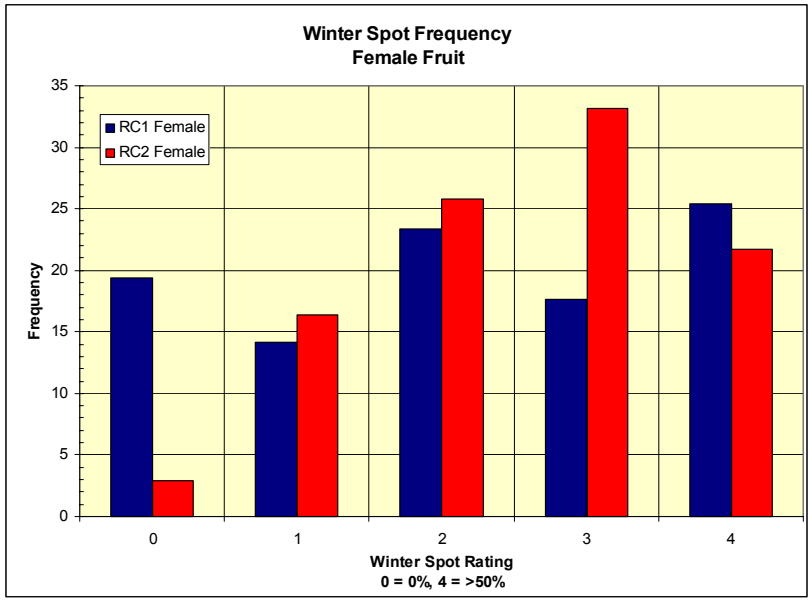
Graph 3



Graph 4



Graph 5



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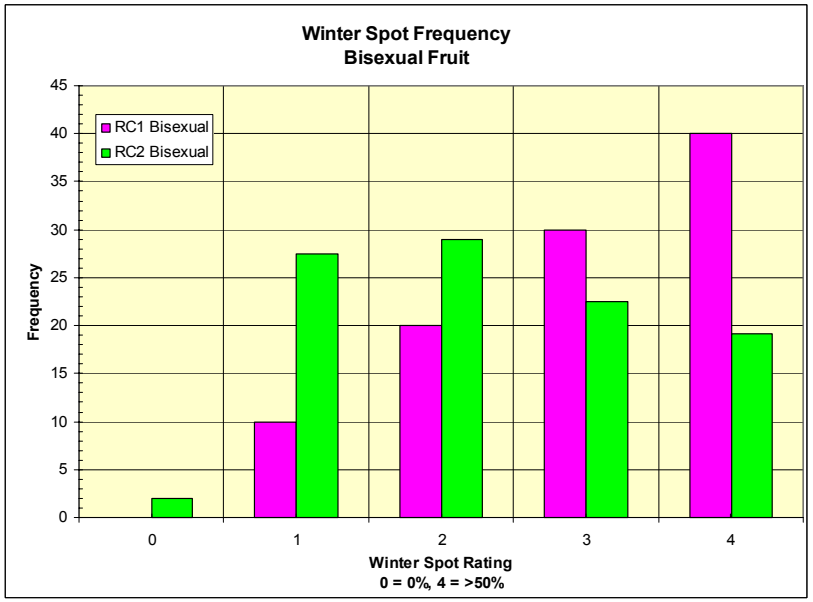
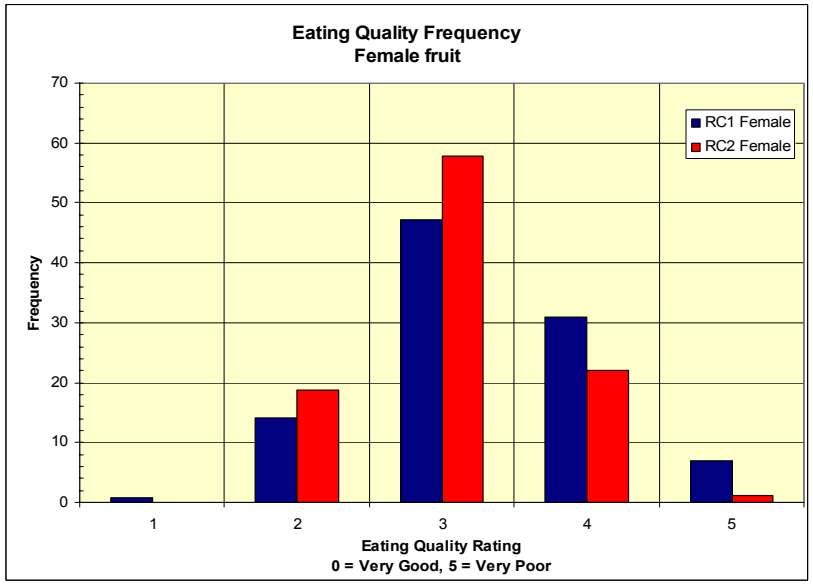
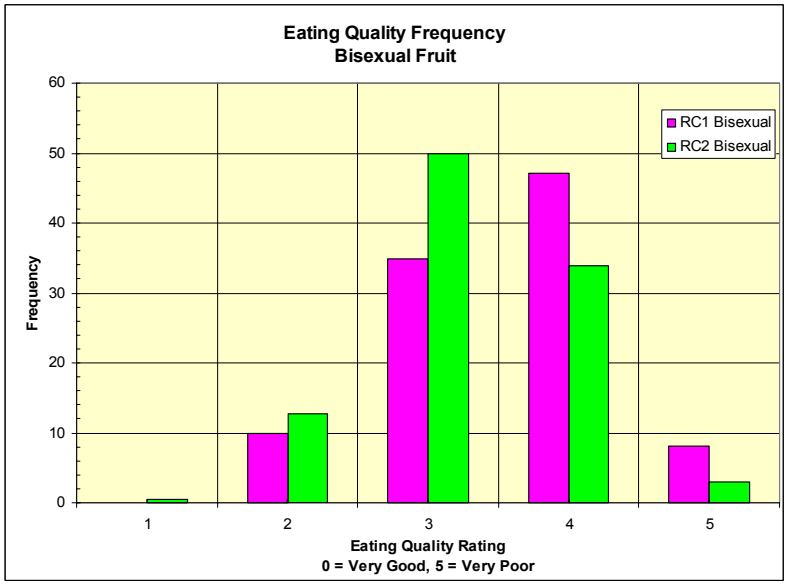


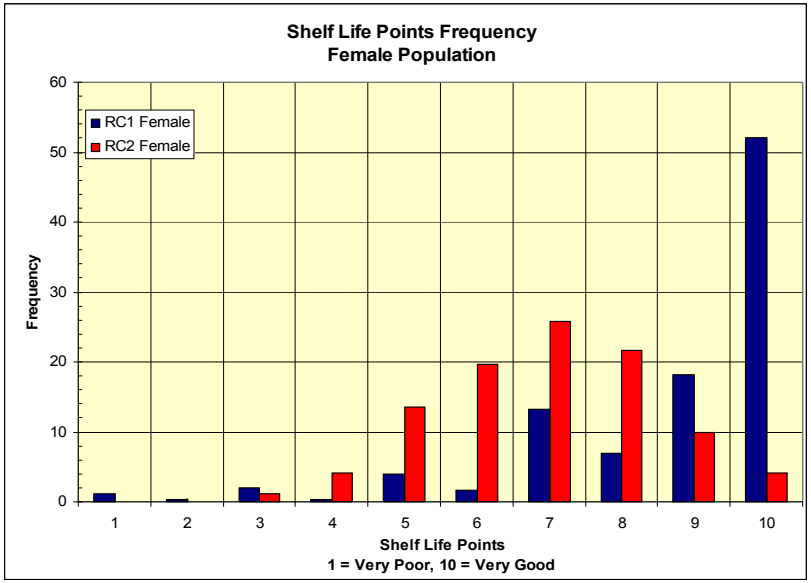
Graph 7



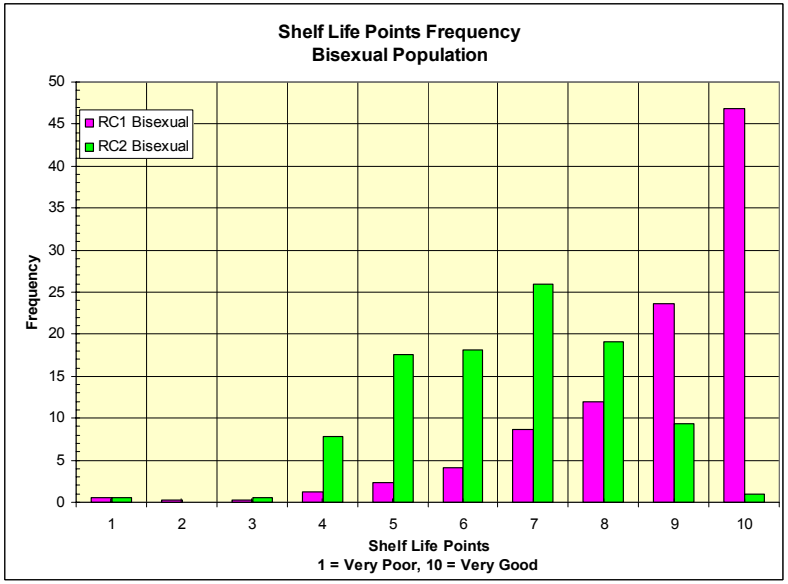
Graph 8



Graph 9



Graph 10



Graph 11

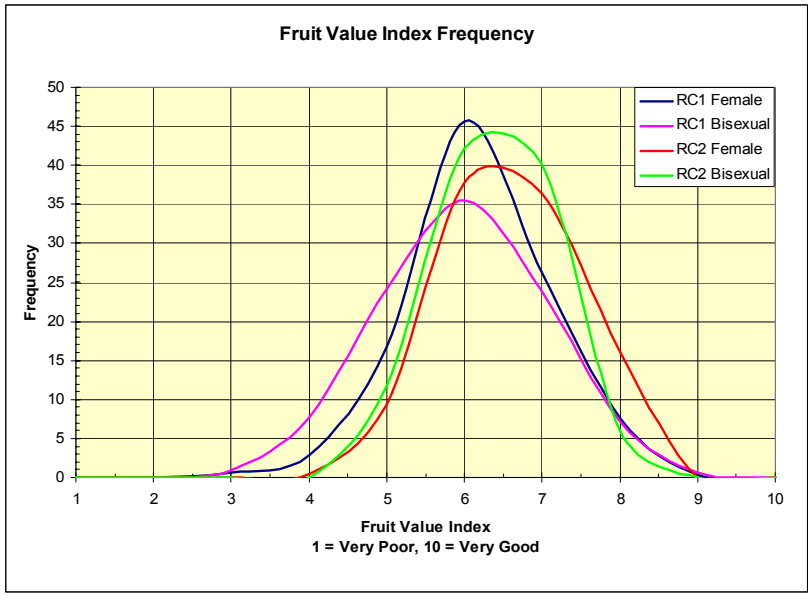


Table 9. RC1 and RC2 Populations: Summary Correlation Data.

		Value Index Points		Eating Quality Rating		Flesh Colour Rating		Fruit Rot Rating		Winter Spot Rating		Teat Size Rating		Days to Ripe		% TSS		Fruit Flesh Ratio	
		RC1	RC2	RC1	RC2	RC1	RC2	RC1	RC2	RC1	RC2	RC1	RC2	RC1	RC2	RC1	RC2	RC1	RC2
Side Shoot Rating	Female		-0.04		0.14		0.06		-0.08		-0.05		-0.06		-0.05		-0.10		0.04
	Bisexual		0.13		0.11		0.01		0.04		-0.28		-0.12		0.05		-0.02		-0.03
	All		0.02		0.13		0.03		-0.05		-0.16		-0.09		-0.01		-0.07		0.03
Fruiting Height	Female	-0.01	0.17	-0.16	-0.14	-0.19	0.06	-0.13	0.09	0.23	-0.05	-0.02	-0.03	-0.02	-0.02	0.20	0.10	-0.10	0.03
	Bisexual	0.26	-0.01	-0.18	-0.08	-0.18	-0.13	-0.21	-0.11	-0.17	0.13	0.07	-0.08	-0.40	0.11	0.41	0.07	-0.03	-0.01
	All	0.14	0.08	-0.16	-0.10	-0.19	-0.03	-0.17	-0.01	0.02	0.02	-0.03	-0.10	-0.23	0.03	0.33	0.07	0.04	0.10
Fruit Weight	Female	-0.39	-0.57	0.11	0.07	0.22	0.03	0.01	0.13	-0.11	0.28	0.35	0.18	0.14	-0.01	-0.16	-0.23	-0.35	-0.20
	Bisexual	-0.40	-0.54	0.20	-0.03	0.26	0.14	0.06	0.10	-0.11	0.41	0.20	0.18	-0.10	0.06	-0.11	-0.11	-0.28	-0.37
	All	-0.30	-0.49	0.10	-0.02	0.25	0.09	0.14	0.17	-0.15	0.36	0.48	0.30	0.15	0.04	-0.15	-0.15	-0.54	-0.40
Fruit Circum.	Female	-0.41	-0.57	0.07	-0.01	0.21	-0.02	0.06	0.12	-0.06	0.33	0.32	0.07	0.23	0.06	-0.16	-0.22	-0.54	-0.36
	Bisexual	-0.43	-0.49	0.22	-0.08	0.24	0.15	0.00	0.11	0.02	0.43	0.06	0.04	-0.01	0.14	-0.16	-0.10	-0.52	-0.49
	All	-0.18	-0.31	0.03	-0.11	0.20	0.06	0.23	0.23	-0.11	0.35	0.56	0.40	0.27	0.11	-0.14	-0.08	-0.81	-0.73
Fruit Length	Female	-0.31	-0.26	0.06	0.12	0.23	0.25	-0.10	0.00	-0.09	0.11	0.57	0.61	-0.02	-0.15	-0.10	-0.09	-0.21	-0.23
	Bisexual	-0.41	-0.55	0.17	0.08	0.29	0.21	0.04	0.01	-0.18	0.22	0.40	0.47	-0.18	-0.06	-0.06	-0.14	-0.06	-0.26
	All	-0.36	-0.39	0.12	0.14	0.21	0.19	-0.14	-0.09	-0.07	0.10	0.16	0.19	-0.18	-0.13	-0.05	-0.13	0.21	0.22
Fruit Flesh Variation	Female	-0.06	-0.21	0.16	0.01	-0.08	-0.14	-0.11	0.25	-0.03	0.19	-0.08	-0.03	0.05	0.19	-0.26	-0.23	0.50	0.38
	Bisexual	-0.24	-0.03	0.10	-0.15	0.17	-0.05	0.05	-0.07	0.31	0.13	-0.20	0.00	0.28	-0.05	-0.31	0.18	0.11	0.09
	All	-0.13	-0.16	0.12	-0.04	0.04	-0.11	-0.01	0.13	0.09	0.15	0.01	-0.07	0.19	0.10	-0.28	-0.08	0.05	0.24
Fruit Flesh Ratio	Female	0.21	0.07	0.07	0.06	-0.20	-0.13	-0.08	0.10	-0.07	-0.07	-0.38	-0.18	-0.18	0.06	-0.04	-0.10		
	Bisexual	0.09	0.39	0.03	0.06	-0.10	-0.30	0.05	-0.11	-0.03	-0.23	-0.28	-0.30	0.16	0.01	-0.07	0.12		
	All	0.03	0.04	0.08	0.13	-0.16	-0.15	-0.22	-0.15	0.06	-0.18	-0.61	-0.53	-0.20	-0.02	0.01	-0.04		
% TSS	Female	0.40	0.51	-0.71	-0.60	-0.06	0.10	-0.25	-0.12	0.19	-0.13	0.07	0.08	-0.39	-0.21				
	Bisexual	0.62	0.44	-0.59	-0.62	-0.19	0.04	-0.30	-0.11	-0.30	0.04	0.31	-0.04	-0.62	-0.17				
	All	0.52	0.48	-0.64	-0.61	-0.13	0.07	-0.25	-0.10	-0.06	-0.05	0.13	0.06	-0.50	-0.19				
Fruit Length/ Breadth	Female	-0.04	0.17	0.02	0.12	0.10	0.25	-0.16	-0.09	-0.03	-0.14	0.37	0.55	-0.22	-0.20				
	Bisexual	-0.09	-0.12	0.02	0.16	0.08	0.06	0.08	-0.09	-0.17	-0.19	0.27	0.47	-0.10	-0.21				
	All	-0.11	-0.07	0.05	0.18	-0.01	0.06	-0.22	-0.22	0.02	-0.19	-0.29	-0.17	-0.27	-0.17				
Days to Ripen	Female	-0.26	-0.01	0.25	0.02	0.08	-0.10	0.19	0.40	0.19	-0.01	0.00	-0.04						
	Bisexual	-0.35	0.00	0.27	0.03	0.06	-0.10	0.28	0.21	0.33	0.07	-0.38	-0.26						
	All	-0.27	0.00	0.24	0.02	0.09	-0.10	0.26	0.34	0.22	0.03	0.00	-0.07						
Teat Size	Female	-0.33	-0.25	-0.12	-0.02	0.30	0.25	-0.07	-0.04	0.09	0.17								
	Bisexual	0.09	-0.36	-0.15	0.01	0.06	0.20	-0.06	-0.07	-0.20	0.14								
	All	-0.04	-0.19	-0.14	-0.07	0.20	0.21	0.10	0.06	-0.11	0.19								
Fruit Ridging	Female	-0.29	-0.36	-0.21	-0.28	0.17	-0.09	-0.06	0.04	0.23	0.37								
	Bisexual	-0.16	-0.29	-0.02	-0.04	0.07	0.09	-0.04	0.07	-0.09	-0.04								
	All	-0.15	-0.27	-0.15	-0.22	0.15	-0.01	0.08	0.12	0.05	0.24								
Winter Spot	Female	-0.28	-0.60	-0.28	-0.13	0.09	0.06	-0.10	0.02										
	Bisexual	-0.43	-0.47	-0.06	-0.31	0.19	0.22	-0.03	0.03										
	All	-0.36	-0.52	-0.17	-0.23	0.13	0.14	-0.11	0.05										
Fruit Rot	Female	-0.14	-0.07	0.24	0.05	0.12	-0.03												
	Bisexual	-0.16	-0.04	0.15	0.04	0.01	0.07												
	All	-0.11	-0.04	0.18	0.02	0.10	0.01												
Scar Rot	Female	-0.15	0.14	0.23	0.05	0.06	-0.08												
	Bisexual	-0.28	0.09	0.11	0.02	0.02	-0.05												
	All	-0.20	0.11	0.18	0.05	0.05	-0.07												
Flesh Firmness	Female	-0.04	0.13	-0.20	-0.28	0.05	0.19												
	Bisexual	0.05	0.18	-0.27	-0.35	0.16	0.17												
	All	0.01	0.15	-0.23	-0.31	0.11	0.18												
Flesh Colour	Female	-0.07	0.15	0.00	0.02														
	Bisexual	-0.17	-0.03	0.12	-0.02														
	All	-0.11	0.08	0.05	0.00														
Eating Quality	Female	-0.41	-0.32																
	Bisexual	-0.50	-0.31																
	All	-0.46	-0.32																

3.3.10 Selected Plants for Commercial Evaluation. Appendix 5 & 6 Tables 1 to 6

Twenty-six hybrids were selected from the RC1 population based on the fruit value index, to progress into micro-propagation for further field evaluation. All had a assessment rating higher than the population average and all had a fruit value index greater than 6.4. The average %TSS for selected female was 10.8 (population 9.4) and for bisexuals 11.5 (population 9.6).

A high level of the foliar and fruit disease, black spot (Asperisporium caricae), was present throughout the trial, providing a good opportunity to assess levels of susceptibility to the disease with in the population. All 26 selected hybrids demonstrated either mild or severe symptoms of the disease, indicating a low level of resistance within the population.

Fifteen of the 26 hybrids were selected for field evaluation, however due to a major breakdown in the air conditioning unit in the tissue culture laboratory and a further failure of the electronic overload system, all plants were lost during the 2003/04 summer.

In the RC2 population, 39 hybrids were selected as being above the average of the total population. This number has been reduced down to 16 (14 bisexuals and 2 females), and following consultation with industry, 12 will be selected for field evaluation. The field evaluation will provide two sets of data. Firstly it will validate the single tree data collected form the random cross population and secondly identify potential commercial lines.

Table 10. Selected RC2 Taste Acceptance Test

Variety	% Acceptance	Eating Quality Rating
Sunrise	100	6.0
18-045	83	8.2
32-1-5	80	9.1
33-039	80	8.2
33-066	80	9.0
25-005	75	9.2
7-082	75	7.7
28-039	40	7.9
8-093	40	6.7
2-015	33	7.7
23-100	20	6.0
11-037	0	6.7
15-123	0	7.6
19-036	0	7.8
24-029	0	8.1
24-087	0	7.4

A preliminary grower evaluation of some of the fruit was conducted with a limited number of fruit and a limited number of Growers. Fruit were assessed just on like/dislike and the % of people who liked each line was calculated. This data was compared to the rating on eating quality made by the papaya breeding team (Table 10). Limited value can be placed on this data. Sunrise solo was the benchmark.

3.3.11 Validation of Trial Designs

The development of effective data collection and experimental methods for papaya trials was an objective, additional to the initial project submission. The outcomes of these assessments will provide greater efficiencies in term of labour and project cost. Two major areas of improvement have been identified.

Sample size and sampling period: The two random cross populations have provided significant insight into the volume of sampling that is required to achieved sound data, and also the period over which sampling should be completed. In RC1, 1611 plants (13% of the population) were assessed over a short period (152 days), whereas with RC2 population, fewer plants (10% of the population) were sampled, but over a longer period of time (284) days. As the data in the graphs 1 to 11 clearly indicate, variance in data was significantly less with the RC2 population, than RC1. Either indicating the higher number of fruit assessed from a smaller number of plants is better or the longer spread of the harvest period across summer and winter is the preferred option. Because the labour cost in harvesting and assessing is the major impediment to the breeding program, it is recommended, that a compromise between the two options be evaluated. This being a larger number of plants harvested over a period covering the full year, but only assessing fruit characteristics every second month. Fruit would still be harvested each week from the plant to obtain plant yield data, but no detailed fruit assessments would be made during each off month.

Assessment Criteria: Correlation data has indicated that for preliminary evaluations a number of criteria have very similar responses. Fruit weight for example could be representative of other fruit physical characteristics such as fruit length, circumference, flesh variance and flesh ratio.

Data Collation and Maintenance: All data from this project and some previous projects has been assembled onto a Microsoft Access data base by Mr Vern Hansen. This allows for easy retrieval and analysis. However, some small effort needs to be directed towards an operational manual on the database, particularly in the areas of inbuilt formulae based around the calculation of the Fruit Value Index, and correlation relationships. A practical example of a report generated from the database is presented in Appendix 6, providing a summary text of the performance of a range of hybrids as well as a general photograph of the tree and fruit.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Location of Breeding Program

All future breeding work is to be conducted at Southedge Research Station and evaluation of selections at each of the major commercial production areas. This is based on the lower incidence of disease, and the larger exclusion zone from near commercial papaya plantations.

4.2 FI Hybrid Parent Material Trial 1999

The assessments from this trial on agronomic and fruit characteristics of all parents selected for the breeding program demonstrated significant genetic variance. Each individual parent line clearly brings into the program strong positive and negative traits, providing evidence of broad genetic variation within the parent population. In the majority of characteristics there was a significant positive or negative general combining effect. This provides confidence the breeding strategy of incremental improvement, which has been adopted, is the most applicable for papaya breeding. The strategy of using highly self-pollinated male lines and relying on specific trait combinations is not suitable for papaya breeding.

4.3 RC1 and RC2 Populations

All future random cross trials must be planted in the May to July period and harvested over summer winter summer period to avoid adverse environmental effects.

For preliminary evaluations, all fruit physical characteristics, except for fruit weight need not be collected, as there are similar strong correlations to other major traits.

The correlation between percentage total soluble solids and shelf life and flesh firmness needs further clarification.

Selected hybrids from RC2 be evaluated in a large scale replicated trial to validate data.

The next random cross planting (RC3) be planted before October 2005 as seed collected in November 2003, will begin to lose viability.

5 REFERENCES

Griffing, B. (1956). Concept of general and specific combining ability in relation to diallel crossing systems. Australian Journal of Biological Sciences 9, 463-93.

D DEVELOPMENT OF MICRO-PROPAGATION CAPABILITY

1. MICRO PROPAGATION ACTIVITIES

Methodology, techniques and equipment developed by Dr Rod Drew at Redland Research Station in earlier papaya projects (mainly ACIAR funded projects) were duplicated at South Johnstone for the micro-propagation work in this project. Over the 4 years of the project, refinements of a number of steps with the total process have been made and a procedures manual has been developed. This has been particularly beneficial as unfortunately there has been considerable turn over in staff (four) within the tissue culture laboratory.

Key improvements to the Drew system has focused on improving the efficiency of through put. Two important areas of improvement were;

- It was identified that old stock (parent material), produced limited and slow side shoot development and resulted in a low percentage of survival through the initial root initiation stage. Cutting from healthy, actively growing stock, resulted in greater success through this phase.

- Low survival rates occurred when micro-propagated plants are deflasked from conventional agar media. Better survival and subsequent plant growth were achieved by moving to a perlite media. This however meant a double handling step, but the increase in percentage survival more than compensated for the increased cost in handling.

Outputs from the Tissue Culture laboratory:

- July 2001, a field planting of the commercial hybrids Sunrise Solo and Hybrid 1B were planted on a growers farm.

- December 2001, plants of the common hybrid parents (GD3-1-9, TVL-7, ER6-2 and ER6-4) were available to growers for planting.

- December 2001, a replicated plot of tissue cultured, cuttings and seedling plants of the commercial line, Sunrise Solo, had been established.

- July 2003. 18 hybrids from the RC1 population had been placed in culture, in preparation for field evaluation in May 2004.

Principal short comings to the tissue culture section of the project: In late December 2003 the laboratory suffered an equipment breakdown which was initially the air conditioner in the tissue culture growth room, this resulted in the temperature rising due to heat from the rooms lighting. An electricity cut off switch, designed to turn off all growth room electricity when the temperature went above 35 degrees failed to operate and allowed the temperature to rise to 50 degrees. This temperature killed approximately half the plants in the room out right. Much work was done in an attempt to rescue the remaining plants. However, almost all eventually died. All endeavours have been made to protect the electronic systems from these types of failures occurring again

2. COMPARISON BETWEEN TISSUE CULTURE AND SEEDLING PAPAYA PRODUCTION

This work was conducted and reported by Mr James Dunn, Extension Horticulturist, Department of Primary Industries and Fisheries at South Johnstone Research Station

2.1. Introduction

Papaya has been propagated by seed since it was first cultivated. Reasons for use of seed propagation are it is relatively inexpensive, readily and easily processed. The use of seed to propagate papaya has several disadvantages. The sex type of the papaya plant is not known before planting. Several seeds or seedlings have to be placed in a planting site and thinned to the required sex type. Countries that have high labour costs thinning for sex types add to the cost of production. Depending on the source of the seed, considerable variation in tree and fruit characteristics can occur within the crop. Having the ability to grow a uniform crop with the characters of an elite clone would be favourable.

There have been several approaches to producing different propagation systems in papaya. The main techniques that have been researched and used on a limited commercial basis are vegetative cuttings, micro-propagation, budding and grafting.

Techniques developed by Drew (1986), Fitch (2002) and Chan (2002), have allowed for further development of micro-propagation of papaya.

Propagation of papaya by vegetative cuttings by Allan, (1996) has development of a viable system to produce commercial cuttings. Commercial papaya growers in South Africa use vegetative papaya cuttings. The production of vegetative cuttings has been investigated to some extent in north Queensland, with the availability of plant material and high labour costs the main issues. Vegetative propagation systems in papaya have also used grafting and budding techniques. In Malaysia growers are reported to side graft hermaphrodite scion material to female papaya trees to increase the ratio of hermaphrodite trees in a seed propagated block.

Comparison of the performance of clonally propagated papaya to seed propagation there are some interesting points raised. Work in Malaysia on Eksotika papaya, which is a hermaphrodite sex type; have shown tissue cultured clones have performed better or at the same level as their mother plants. Supporting work in Hawaii demonstrated that cuttings and micro-propagated plants also provide increased fruit harvests in the first 9 months of plant growth. The research also stated that clonally propagated trees produced flowers earlier (3-4 months) and substantially lower on the tree (30cm). The increased yield of vegetative propagated plants provides an attractive incentive for commercial papaya growers to integrate vegetative propagation in their systems with an increase of 1.5 times the yield of seed propagated plants. Evaluation of different propagation types of papaya has been undertaken in Australia in Southern Queensland and even in the sub tropical conditions of this area micro-propagated plants outperformed seedling plants. The purpose of this investigation was to observe the performance of two different clonal propagation types in the tropical conditions of North Queensland Australia

2.2. Materials and Methods

The trial was planted on the 11th of October 2001 at Garradunga in Far North Queensland. The trial was of a completely randomised design. Four replication plots

per propagation type and 19 trees per plot giving 228 sample trees The trees were in 1.8 metre plant spacings in single row mounds. All plants were subjected to the same cultural practices within the trial design with no noticeable incursions of pest and disease occurring throughout the period of the trial.

The micro propagated plants used were sourced from the DPI&F laboratory at South Johnstone, and were approximately 8 weeks old when transplanted into the trial site. The vegetative cuttings were sourced from a local supply and were approximately the same age and size as the micro-propagated plants. The seedlings used were sourced from the DIP&F seed germ plasm and also were 8 weeks old at planting. All plants were of the Sunrise Solo variety.

Measurements were taken throughout the life of the trial so comparisons could be made on the three propagation types. Trunk girth measurements were taken over six months to assess the growth of the propagation types. First flower emergence dates were taken to compare earliness of flowering. Fruiting heights and time to first harvest were taken to measure harvest characteristics. Marketable yield was measured to assess the amount of papaya produced

2.3. Results

2.3.1. Trunk Growth. Table 11

As a gauge for the growth of the three different propagation types a trunk diameter measurement was taken. When analysing the data it is evident that the clonally propagated plants grew at a faster rate in the first 2 months of growth with micro propagated plants growing the fastest.

Table 11. Average Trunk Diameters (mm) of Seedling, Micro-propagation and Cutting Propagated Papaya Crops

Month	Crop Type		
	Seedling	Micro-propagation	Cutting
November	5.1	16.7	14.9
December	14.8	38.7	33.6
January	47.4	76.7	71.3
February	68.1	90.7	85.5
March	90.5	107.5	100.0
April	111.0	116.2	107.6

lsd (5%) Within crop types and between months = 6.2(mm)
Within crop types and between months = 3.6(mm)

Towards the end of the time period seedling propagated plants grew at a faster rate than the other two propagation types

Data after the first six sample times indicate an even growth between the three types with trunk growth increasing but not at the levels seen at the first six

occasions. It is evident from the results that both vegetative propagation types display superior early growth compared to seedling propagated papaya plants

2.3.2. Flower Emergence

The three types of propagated papaya plants produced fully developed flowers on the following dates;

Vegetative cutting produced flowers on the 20th November 2001,

Micro propagated 5th December 2001,

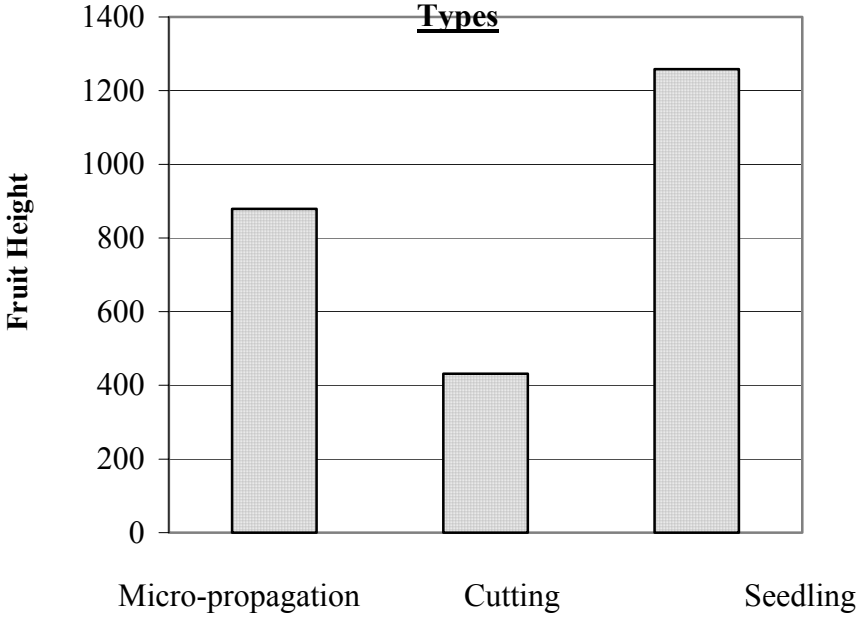
Seedling propagated on January 2nd 2002.

There were a total of 15 days between vegetative cuttings flowering and micro-propagated plants flowering while there were 43 days between vegetative cuttings and seedlings producing flowers.

2.3.3. Fruiting Height. Graph 12

A comparison was made between the fruiting heights of the three propagation types as a gauge of fruitfulness and probable harvest time. Seedling plants had the highest mean fruiting height at 125.8 cm, micro-propagated plants had mean a height of 87.8 cm and vegetative cutting plants had a mean fruiting height of 43.1 cm.

Figure 1. Fruiting Height (mm) of the Three Crop Types



2.3.4. Yield Table 12

Harvest data was collected in line with trial design. The first treatments to be harvested were that vegetative cutting 18th April 2002 189 days from planting, micro propagated plants were harvested on the 6th May 2002, 206 days from planting, Seedling plants were harvested on the 11th June 2002, 242 days from planting. Results from harvest records indicate that vegetative cutting plants are yielding far more than micro propagated plants and seedling plants. The total papaya weight data showed a significant treatment effect with the seed treatment significantly lower than tissue culture that was

significantly lower than the vegetative treatment. Apart from a period of time where all treatments were yielding quite low the seedling treatment was significantly lower in yield than the micro propagated and vegetative cutting treatments.

Table 12 Average Yield (Kg) for the Period 18th April 2002-17th August 2002

Crop Type	Yield
Seedling	41.9
Micro-propagation	144.0
Cutting	195.8

lsd (0.05) = 48.4

2.3.5. Discussion

The growth of the clonally propagated papaya, have better growth in the first three months. Seedling plants grew faster in the next three months to leave all three propagation types relatively even in trunk girth by the end of six months growth.

The time the propagation types took to first flower varied and the fact that vegetative cutting plants produced fully developed flowers 6 weeks before seedling. This earlier flowering also translated into earlier harvest times.

The fruiting heights of vegetative cuttings may have been too low attracting mechanical and spray damage from plantation management. Micro-propagated papaya's, fruiting at a height of 87 cm was satisfactory being neither uneconomically too high or low enough to attract damage or make harvesting difficult.

Clonally propagated papaya outperformed seedling papaya in the four parameters measured in this trial.

The main points from the trial is that the superior early growth of the clonal material has lead to earlier and lower fruiting and thus earlier and greater yields of papaya.

2.3.6. REFERENCES

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2.3.7. ACKNOWLEDGEMENTS

The assistance of Mr Allan Blair and Mr Charlie Loudon is acknowledged. Mr Blair grew the trial on his property at Garradunga as part of a commercial planting. Mr Loudon supplied the cutting based planting material used for the trial. The trial would not have been possible without their assistance.

3. BENEFIT COST ANALYSIS OF THE USE OF MICRO PROPAGATION IN PAPAYA

This work was conducted and reported by Mr James Dunn, Extension Horticulturist, Department of Primary Industries and Fisheries at South Johnstone Research Station and Mr Vern Hansen.

Summary *This analysis shows that at a price of $2.50 per plant, a micro-propagated crop of a dioecious variety has a 36% higher return per hectare than a conventional crop grown from seedlings. Higher yield, due to earlier fruiting was the only advantage of micro-propagation considered, as it could be accurately evaluated from real data. An additional advantage for the papaya industry, that is difficult to evaluate accurately, is that micro-propagation allows the faster production and commercialisation of new varieties.*

3.1 Introduction

Seedlings are the conventional means of establishing a papaya crop. The use of planting material produced by micro-propagation offers a number of practical advantages over seedlings.

With seedlings, a number of plants are planted in each tree position and later thinned to one plant of the required sex. Micro-propagation allows the production of plants of known sex. This means that only one plant needs to be planted per tree position.

A major advantage of micro-propagation is that it allows the speedy production and commercialisation of new varieties from breeding projects. Conventional seed propagated varieties need to be produced and maintained as genetically uniform pure line varieties. Such varieties are produced by selection over five or more generations of self-pollination, a process that takes from 6 to 10 years. Micro-propagation allows this process to be short-circuited. Commercial varieties can be obtained directly from genetically mixed populations, significantly reducing the time and money needed to produce new varieties.

The advantages of micro-propagation are summarised as follows:

(a) As the sex of the plants are known it is only necessary to plant one plant per tree site. This means that thinning is unnecessary. Early growth is faster due to the absence of competition.

(b) Micro-propagated plants fruit earlier and at a lower height than seedlings, giving a yield advantage over the life of the crop.

(c) As no thinning is done the rotting stumps of culled plants are not present to encourage soil borne diseases.

(d) Micro-propagation reduces time breeding projects take to produce and commercialise new varieties 6-8 years.

In this analysis only the first two of the above advantages are considered, as these can be clearly evaluated and are equally applicable to both existing varieties and any new varieties produced by the breeding project.

Only dioecious varieties are considered in the analysis. This is because the costs and advantages are considered to be fairly similar in both dioecious and bisexual varieties. Any differences between the two variety types will be in favour of bisexual varieties due to their higher number of productive plants per hectare. Ten percent of a dioecious planting consists of unproductive male pollinator plants.

The only disadvantage of using micro-propagation is an increase in the cost of planting material. The simple question answered by this analysis is whether crops grown from micro-propagated material provide a high enough increase in returns to out weigh the extra cost of planting material.

3.2 Production cost Data

Production costs were obtained from discussions with papaya growers and consultants. The price of micro-propagated plants used ($2.50) is an estimate based on the commercial price of other micro-propagated material. Cost data used in the analysis is shown in Table 1.

The data indicate that the growing costs of a micro-propagated crop are $1,912 per hectare higher than for a conventional crop. All the cost increase is due to the higher cost of planting material. The extra cost of planting material is offset, to a degree, by a reduction in pre-harvest labour costs as there is no need to remove excess male plants from the micro-propagated crop.

Table 13 Cost Data (per Hectare) for Conventional and Micro-propagated Papaya Crops

Operation	Crop Type		Comment
	Conventional	Micro-Propagated	
Land Preparation	$518	$518	
Planting	$1,385	$3,747	Micro-propagated plants $2.50, seedlings $0.60.
Weed control	$2,144	$2,144	
Fertilizer	$13,307	$13,307	
Pest & disease control	$2,898	$2,898	
Plantation management	$638	$188	No thinning required for the micro-propagated crop.
Irrigation	$1,268	$1,268	
Total growing cost	**$22,155**	**$24,067**	
Harvesting & marketing	$55,060	$66,074	Difference due to the 1,987 extra cartons from the micro-propagated crop.
Cost per Hectare	**$77,215**	**$90,140**	

3.3 Agronomic Data

The basic agronomic data used for the analysis are shown in Table 2. This data is from Ross et al (1998). Data were confirmed and updated by checking with growers and consultants.

The yield of micro-propagated plants shown in Table 2 was obtained from a trial conducted on a commercial farm at Garradunga. This trial compared conventional and micro-propagated crops and indicated a yield advantage of at least one carton per tree for micro-propagated plants.

The yield difference is due to faster early growth, earlier fruiting and a lower fruiting height for micro-propagated plants. There was no indication of differences between the two crop types in plant survival or the length of the cropping period.

3.4 Returns

The returns for conventional and micro-propagated crops, based on the data from Tables 1 and 2, are shown in Table 3.

The Table 3 data show an advantage for the micro-propagated crop of $5,871 per hectare, a 36% advantage over the conventional crop.

Table 14 **Agronomic Data for Conventional and Micro-propagated Dioecious Papaya Crops**

Data	Conventional Crop	Micro-propagated Crop
Trees per Hectare	1,700	1,700
Male pollinators (10%)	170	170
Bearing Female Trees	1,530	1,530
Assumed Mortality Rate (30%)	459	459
Remaining Bearing Trees	**1,071**	**1,071**
Average Crop Harvesting Period (months)	14	14
Average Yield (cartons per year per tree)	5.00	6.00
Average Yield per tree for 14 months	**5.83**	**7.00**
Average Price per Carton[1]	**$15**	**$15**

[1]average sale price from the start of 1999 to the end of 2000 in data supplied by Ausmarket Consultants

Table 15 **Production Data for Conventional and Micro-propagated Dioecious Papaya Crops based on the data from Tables 1 and 2**

Data	Conventional Crop	Micro-propagated Crop
Yield (cartons per hectare for 14 months)	6,244	7,497
Return per Hectare (14 months at $15 per carton)	$93,659	$112,455
Cost per Hectare (Table 1)	$77,215	$90,140
Net Return per Hectare	**$16,444**	**$22,315**

3.5 Discussion

The analysis shows that at a price of $2.50 per plant, a micro-propagated crop of a dioecious variety has a 36% higher return per hectare than a conventional crop grown from seedlings.

The only advantages considered in this analysis were those for which accurate data was available (increased yield) or that could be accurately estimated (the price of micro-propagated plants).

There are additional advantages of micro-propagated plants for the papaya industry that could have only been included in the analysis if debatable assumptions were made.

The most significant of these additional advantages is a time saving of 6-8 years for the breeding project in developing new varieties and getting them into commercial production.

A significant aspect of the higher yield of micro-propagated papaya is that the higher yield results from faster early growth and lower and earlier fruiting. This is important as it means that micro-propagated crops give growers an earlier return from their plantings.

3.6 References

Ausmarket Consultants - Ph. 07 33794576
Phil Ross; Greg Kelly; Joe Zappala; (1998) Papaya Industry Profile for North Queensland, Queensland Department of Primary Industries.

E. MID PROJECT REVIEW OF PAPAYA BREEDING PROJECT FR99018

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1.0 TERMS OF REFERENCE.

1. Assessment of project progress in relation to the original project proposal (including achievement against milestones)

2. Evaluate how well the Goals and Objectives of the project meet industry needs

3. Assess the likely timeframe for release of improved commercial varieties

4. Make recommendations on the final 2 years of the project inline with budget allocation

1.1 ITINERARY

Date	Location	Activity	Personnel
17 June	Southedge Research Station	Discussion with breeder	Review team Vern Hansen
	Southedge Research Station	Inspect field plantings and glasshouse facilities	As above Neil Bryde
	Garrandunga	Inspect tissue-cultured trial planting on grower site	James Dunn
18 June	South Johnstone Research Station	Continued discussions with industry and breeder	Vern Hansen
	South Johnstone Research Station	Inspect tissue culture laboratory	Vern Hansen James Dunn

1.2 EXECUTIVE SUMMARY

Most commercial papaya varieties in Australia are inbred lines (eg the bisexual Hawaiian variety Sunrise Solo) or F1 hybrids created from 2 inbred lines (many of the dioecious types). The difficulty with both these approaches, in breeding terms, is that it requires pedigree breeding through 5 to 7 generations to breed a new commercial inbred line or new parental inbred lines. The approach of this breeding project is to create a diverse breeding population through 2 cycles of random mating (to break linkages between traits like high sugar level and winter spotting); then to select out the best individuals and clonally propagate them by tissue culture. In breeding terms the upside is a saving in time and money in not having to genetically fix the outstanding individual by the production of inbred lines. The downside is that you need a cheap and efficient tissue culture system to provide the clones. In theory the system of selecting outstanding seedling individuals and propagating them by cloning also provides the advantage of capturing all the genetic variation compared with seed propagation of inbred papaw lines that will capture the additive genetic variance but none of the dominance variance. In this sense the rate of genetic gain should be greater. For the grower there are advantages related to knowing the sex of the tree at planting and hence saving in tree-thinning costs 7-9 months after planting.

The project has succeeded in developing the 2 random mated breeding populations and making a number of selections from the first generation of the breeding population. Clonal propagation has been developed to some extent but further work is needed particularly in the areas of efficient de-flasking techniques and a tissue culture system that is economically viable. Technology transfer to industry on the benefits of tissue culture versus seedling trees will be essential for uptake of new varieties developed in this project.

The development of a successful tissue culture system is fundamentally important for the current project to succeed as planned. However it should be recognised that if tissue culture is not successful, the value of the work to date would not be lost but rather, a commercial outcome would be significantly delayed and would require major additional resources. The value in the work that has been done thus far in breaking linkages and recombining genes cannot be ignored.

1.3 RECOMMENDATIONS

Recommendation 1. That future breeding project work and funding applications clearly identify tissue culture of papaw as a major objective. Specifically the development of an economical and efficient system that produces trees ready for successful field establishment.

Recommendation 2. The Papaw Industry through the QFVG Papaw Subcommittee, QDPI and HAL should decide if the PRSV resistant lines are to be incorporated into the South Johnstone breeding program.

Recommendation 3. The papaya breeding team should review the outcomes from the most recent papaw consumer research (conducted in 2002) and check that current target fruit characteristics fit with consumer requirements and modify breeding objectives as necessary.

Recommendation 4. To facilitate rapid uptake of the new papaw variety NT Red, QHI and industry should seek HAL funding for market chain evaluation of the fruit from the 2003-2004 field trials.

Recommendation 5. That Seed producers be provided with information and disease free material for commercial propagation of NT Red.

Recommendation 6. That QDPI and HAL, as owners of the project IP, in conjunction with the QFVG papaw subcommittee, should request the QHI Business Manager to prepare and present to industry a discussion paper that analyses different schemes for release, commercialisation and distribution of new varieties in relation to the Australian papaw industry requirements.

Recommendation 7. That the QHI industry manager organise for an ammended budget and workplan to reflect changes in work due to the project running well ahead of schedule. The new workplan should emphasis achieving an efficient and effective tissue culture system as a matter of priority.

Recommendation 8. That the breeding team establish strong working relationships with other Papaya breeders and tissue culture researchers. Specifically they should liase with QDPI staff at Redlands and Maroochy Research Station, search out overseas contacts using Dr Rod Drew's expertise and establish/participate in a papaya breeding email discussion group with overseas researchers.

Recommendation 9. That an economic analysis of tissue cultured papaw plantations be prepared as part of the extension work in the breeding project so that growers can compare growing tissue cultured versus seedling plants.

1.4 BACKGROUND

The Queensland papaw industry is based on female fruit from dioecious papaws. There has been some interest in bisexual "Solo" type fruit and this interest has increased in the past decade. Genetic improvement occurred in the 1960's when Mr Jim Waite of Kamerunga Research Station evaluated and selected a number of dioecious lines from the bisexual Waimanalo Solo variety. During the 1970's and early 1980's Mr Flav Aquilizan bred stable inbred lines by a technique based on use of highly self pollinated male plants and then used these inbred lines to create hybrid seed for commercial use. The majority of Queensland's papaws are produced from hybrid plants derived by intercrossing inbred dioecious lines.

The current project "Papaya Breeding and Variety Development" – FR99018 commenced in July 1999 with the main emphasis on the production of bisexual varieties suitable for the Innisfail production region but with some work on developing dioecious varieties more suited for cooler areas.

The current review is part of the original project plan; scheduled in the project to occur as part of milestone number 6 due on 31 December 2001

1.5 REVIEW OUTCOMES

As a general comment the review team were impressed with the planning in the original project proposal and the speed and efficiency with which the milestones had been accomplished. The breeding project has positioned itself so that it is able to

deliver significant benefits to industry in the next stage of the breeding, selection, evaluation and testing cycle. Industry has taken the initiative by deciding that market expansion is most likely to occur with an increase in production of new red-fleshed, musk flavoured papaws and by funding a breeding program to breed this type of variety. A key to delivering these outcomes will be the successful development of a tissue culture system to allow rapid production of clonally propagated selections that are available to industry at economic prices. The full implications are discussed in the specific terms of reference.

TOR 1
Assessment of project progress in relation to the original project proposal (including achievement against milestones).

The project has progressed rapidly in relation to achievement against the original milestones such that the final report should be completed by late 2003, 12 months ahead of schedule. The project team have created and field planted two populations of 5,000 seedling trees. These are random mated intercross populations designed to combine the characteristics of a selected parental group and to allow breaking of linkages between undesirable gene groups.

Micropropagation by tissue culture is a key component of this project that will allow clonal propagation of selections for testing and direct use in commercial orchards. To date, there is not an efficient tissue culture system developed for papaya. The main thrust of future research in this project must be to develop an efficient tissue culture system and demonstrate the benefits of tissue culture versus seedling trees to industry to ensure widespread adoption.

***Recommendation 1**. That future breeding project work and funding applications clearly identify tissue culture of papaw as a major objective. Specifically the development of an economical and efficient system that produces trees ready for successful field establishment.*

The philosophy of the original proposal is based on the premise that papaw market expansion is most likely to occur through increased consumption of red-fleshed, musk flavoured types of fruit. In the original project proposal this is stated as "Red fleshed sweet or musk flavoured fruit are preferred by a wide range of consumers and offer the best chance for market expansion". Consumer surveys conducted in 1997 and 1999 by Margaret Olsen support this conclusion (Papaw Consumer Research, Margaret Olsen 1999). Therefore breeding should concentrate on producing new varieties with this type of fruit rather than varieties that produce the more commonly marketed yellow flesh, nasturtium flavoured type fruit.

The project methodology is sound and draws on the following elements:

- Start with a wide genetic base and so increase the variability available for selection. The rate of genetic gain is directly proportional to the total phenotypic variance of the breeding population. Creating the original F1 population with 10 parents selected both for high levels of the desired characteristics and with the widest possible genetic diversity should ensure the breeding population has large variability and will increase rate of genetic improvement.

- Use cycles of random mating to break linkages between genes controlling desirable and undesirable characteristics.

- Select the outstanding individuals from the population and tissue culture them to provide a genetically stable variety.

- Propagate selections by tissue culture for clonal evaluation across locations and years.

Selection of outstanding individuals in each of the random mated populations will be on the basis of single plant selection and as such it should follow the maxim that heavy selection pressure should be put only on those traits with high heritability. Then in successive generations of clonal propagation, as the number of selected genotypes is reduced and the number of clones of each genotype is increased it will be possible to select for traits of lower heritability. This will involve testing a smaller number of genotypes over a wider range of environments and years.

TOR 2
Evaluate how well the Goals and Objectives of the project meet industry needs

The objectives of the project were determined in consultation with industry at the time of project submission so at the start of the project the objectives were well aligned with industry needs. Three years later in June 2002, the industry representatives present during this review considered the project objectives were still well aligned with industry needs. Of the five specific breeding objectives listed in the original proposal, three were considered as still important. ie

- Increased yield
- Fruit attachment on medium length stalks
- Fruit bearing height of less than 1 metre

The remaining two objectives were selection for specified fruit characteristics and resistance to Papaya Ring Spot Virus. The listed fruit traits of high TSS, musk flavour, low winter spot, oblong/oval/elongate shape, fruit size, bright yellow to scarlet flesh colour, flat or slight fruit teat shape, striping ripening pattern, firm for mechanical handling, shelf life and no stalk end depression were still considered important but it was noted that supermarket chains were demanding fruit with less blemish than had been required in previous years.

Breeding for PRSV was still considered important but there was doubt regarding the commercial acceptance of any new varieties classed as genetically modified organisms.

Recommendation 2. *The Papaw Industry through the QFVG Papaw Subcommittee, QDPI and HAL should decide if the PRSV resistant lines are to be incorporated into the South Johnstone breeding program.*

Alignment with Papaw Industry Strategic Plan

A broader issue is how the breeding of new varieties with characteristics of red flesh, sweet musk flavour fits into the overall papaw strategic plan.

The current industry strategic plan is being reviewed following the completion of papaw consumer research. The strategic plan will consider the findings of the research when developing strategies and activity plans.

Market Research

The papaya breeding project is aimed at producing a distinct type of fruit, the red fleshed, sweet musk flavoured type from bisexual varieties. The visual and eating characteristics of these fruit are distinct from the current industry standard which is a yellow fleshed, nasturtium flavoured fruit with the more rounded shape distinctive of dioecious varieties. It is important that these breeding objectives are verified with consumer market research. QFVG is commissioning a consumer market research project in spring 2002.

Recommendation 3.The papaya breeding team should review the outcomes from the most recent papaw consumer research (conducted in 2002) and check that current target fruit characteristics fit with consumer requirements and modify as necessary.

TOR 3
Assess the likely timeframe for release of improved commercial varieties

The current 5 year project did not aim to release new commercial varieties. FR99018 was aimed at producing a breeding population from which individual seedlings could be selected for clonal propagation and test as potential commercial candidate varieties.

However, in the process of setting up the original F1 population, the Malaysian derived variety NT Red was recommended for further evaluation in commercial farm plantings. In a trial at South Johnstone Research Station planted in February 2000 NT Red was identified as having commercial potential. Trial lots of seed have been bulked and were harvested in June 2002. These will be planted in spring 2002 at 12 to 15 grower sites in both the Mareeba and Innisfail regions with approximately 300 trees per site. It is expected that a decision on release of NT Red could be made by June 2004.

Recommendation 4. *To facilitate rapid uptake of the new papaw variety NT Red, QHI and industry should seek HAL funding for market chain evaluation of the fruit from the 2003-2004 field trials.*

Recommendation 5. *That Seed producers be provided with information and disease free material for commercial propagation of NT Red.*

In the longer term, there will be selections from the random mated populations that will be tested as potential variety releases. Twenty seedlings were selected in 2002 from the first random mated population. The papaw breeder estimates these will be clonally propagated and tested in replicated research station trials (1.5 years) the tested on farm trials (1.5 years) and then bulked up in tissue culture (1.5 years). If these selections continue to perform during the testing across locations and seasons it is anticipated there will be a release in 5 years ie 2007.

Commercialization and Distribution of New Varieties

With anticipated release of new varieties it is important that the industry consider the methods that will be used for distribution and commercialisation. This is a complex issue and involves questions of:

- Disease and pest certification of released material

- Release domestically only or also internationally
- Distribution by single or multiple propagators
- Production by all Australian growers or subsets of growers
- Control of marketing of fruit from new varieties or no marketing restrictions.

***Recommendation 6**. That QDPI and HAL, as owners of the IP, in conjunction with the QFVG papaw subcommittee should request the QHI Business Manager to prepare and present to industry a discussion paper that analyses different schemes for release, commercialisation and distribution of new varieties in relation to the Australian papaw industry requirements.*

TOR 4
Make recommendations on the final 2 years of the project inline with budget allocation

The papaya breeding and variety development project is running well ahead of schedule with regard to the development of the seedling breeding populations. It was planned that the second random cross generation would not be established until July 2003 (milestone number 9) but this has been achieved by June 2002. All that remains in this part of the project is to harvest the fruit from the second random mated population in preparation to enter the next stage of breeding, namely the first selection cycle. This fruit should be ready to harvest from May 2003. The review team considers this part of the project should continue to run to plan. The fact that the project is ahead of schedule in this regard means that the budget for the last 2 years of the project needs to be amended.

***Recommendation 7**. That the QHI industry manager organise for an ammended budget and workplan to reflect changes in work due to the project running well ahead of schedule. The new workplan should emphasis achieving an efficient and effective tissue culture system as a matter of priority.*

A key to the breeding strategy employed in this project is the rapid multiplication of papaw plants by tissue culture at a cost that is economically viable for growers and propagators. It is the review teams opinion that this is yet to be achieved and therefore the final 2 years of project work should concentrate on achieving this objective. There are 2 aspects to the tissue culture question. The first is to develop an efficient system that produces quality plants at economic prices. Our first recommendation relates to this issue. In this regard it may be useful to establish working linkages with other tissue culture groups or to strengthen those that already exist. Part of this process should include the formation of a Papaya breeding network (via email initially) with breeders and Papaya tissue culture researchers from Australia, South Africa, Malaysia, Hawaii, India, Taiwan, Brazil, Philippines, and Mexico.

***Recommendation 8**. That the breeding team establish strong working relationships with other Papaya breeders and tissue culture researchers. Specifically they should liase with QDPI staff at Redlands and Maroochy Research Station, search out overseas contacts using Dr Rod Drew's expertise and establish/participate in a papaya breeding email discussion group with overseas researchers.*

The second aspect is grower adoption of tissue cultured plants. There are costs and benefits in growing tissue cultured versus seedling plants. These relate to factors such as higher price of tissue cultured trees, higher early yields from tissue cultured trees, unknown sex of seedling trees and the associated costs of intra-site competition and costs of culling to one tree per site, rates of off-types from tissue cultured trees and ability of tissue cultured versus seedling trees to withstand high winds. Growers need to be informed of the relative advantages and disadvantages of tissue culture versus seedling plantations. The project team have commenced this process through a series of demonstration plantings and grower field days. This is an important part of the project and should continue. It would useful to economically quantify these factors to assist growers in decision making.

***Recommendation 9**. That an economic analysis of tissue cultured papaw plantations be prepared as part of the extension work in the breeding project so that growers can compare growing tissue cultured versus seedling plants.*

Finally, this project, as are most projects, is being conducted in a continually changing environment. The breeding team, the QFVG papaw industry sub-committee and QHI management need to consider and plan for foreseeable changes. In this regard the review panel was aware of the possible retirement of Mr Vern Hansen and the changes in industry funding that may result from loss of the QFVG grower levy system. The industry strategic planning workshop scheduled for mid December 2002 will provide information to all partners of the likelihood of a national levy and future source of industry research funding.

F. TECHNOLOGY TRANSFER.

Through out the project, the project team, as well as the papaya extension officer conducted a range of extension activates to keep the industry informed on the progress of the project. These activities covered areas such as

- Publication of articles in Papaya Post
- Publication in Good Fruit and Vegetables.
- Field walks though the plots at South Johnstone and Southedge Research Stations.
- Field walks through demonstration farm plots of tissue cultured plants.
- Presentations by the Project Leader at Grower Association meetings
- Taste panels at grower nights and field days.
- Seminars to other scientific staff on the progress of the trial work.

A comprehensive list of these activities is reported in the milestone reports presented in Appendix 2.

G. ADDITIONAL ACTIVITY OUTSIDE OF PROJECT.

A number of additional activities outside the project submission were conducted during the early stages, whilst parent combination were being constructed. These activities were considered valuable to outcomes of the total breeding program.

1. 0 Papaya Hybrid Evaluation Trial 1999

An outcome of a former project FR97031, a number of F1 hybrids were selected as having possible commercial potential. A trail was established in February 2001 at South Johnstone Research Station to evaluate the performance of these varieties. Initially 10 vatieties were included in the trial, however three of the lines selected (Claveria, Brunos Choice and NT Red x Paris Hybrid) were culled for obvious faults soon after harvesting started.

Harvesting commenced in September 2000 and continued until early March 2001. The trial was abandoned due to severe *Phytophthora* root damage. Although only five months harvest data were obtained, meaningful data was collected and a recommendation made.

1.1 Results

Table 16. Yield of Saleable Fruit and Productivity Data

Variety	Yield per Tree (kg)	Fruit Per Tree	Fruiting Height (cm)	Days to First Harvest	Side Shoots (0-none to 5 profuse)	% Blossom End Defect Fruit
NT Red	42.8 ++	64	98	267	3.4 --	0.43
Subang x Sunrise Solo	43.5 ++	55 --	123 ++	280 ++	4.7	0.00
Sunrise Solo x Paris	43.6 ++	38 --	95 -	264	3.3 --	3.17 ++
Sunrise Solo x Paris Sel 07	41.6 ++	43 --	97	282 ++	3.1 --	2.67 ++
Sunrise Solo x Paris Sel 22	36.9 ++	30 --	94 -	283 ++	2.4 --	4.37 ++
Sunrise Solo x Paris Sel 53	32.9 +	40 --	96 -	284 ++	2.8 --	3.23 ++
Sunrise Solo	25.5	69	106	267	4.4	0.63
Average	**38.1**	**48**	**101**	**275**	**3.4**	**2.07**
LSD 0.05	**5.4**	**6**	**10**	**6**	**0.5**	**1.34**
LSD 0.01	**7.6**	**8**	**14**	**9**	**0.6**	**1.88**
CV%	**8%**	**7%**	**5%**	**1%**	**7%**	**36%**

Table 17 Monthly Yield of Saleable Fruit

Variety	Yield/Tree Oct-2000 (kg)	Yield/Tree Nov-2000 (kg)	Yield/Tree Dec-2000 (kg)	Yield/Tree Jan-2001 (kg)	Yield/Tree Feb-2001 (kg)
NT Red	3.5 ++	6.3 ++	12.8 ++	10.5 ++	8.1 ++
Subang x Sunrise Solo	0.7	2.0 -	11.9 +	16.0 ++	10.9 ++
Sunrise Solo x Paris	6.5 ++	7.5 ++	16.1 ++	9.5 ++	3.5
Sunrise Solo x Paris Sel 07	1.4	2.2 -	12.1 ++	8.4 +	14.9 ++
Sunrise Solo x Paris Sel 22	0.7	3.7	9.5	7.5	13.9 ++
Sunrise Solo x Paris Sel 53	1.2	3.5	7.4	4.4 --	14.1 ++
Sunrise Solo	1.4	3.4	9.2	6.6	4.1
Average	**2.2**	**4.1**	**11.3**	**9.0**	**9.9**
LSD 0.05	**0.9**	**1.1**	**2.1**	**1.5**	**2.5**
LSD 0.01	**1.3**	**1.6**	**2.9**	**2.1**	**3.5**
CV%	**23%**	**16%**	**10%**	**10%**	**14%**

+ and ++ indicate larger values than those of Sunrise Solo at the 95% and 99% probability levels respectively

- and -- indicate smaller values than those of Sunrise Solo at the 95% and 99% probability levels respectively

Table 18 Fruit Data

Variety	Fruit Wt (g)	Fruit Diam. (mm)	Fruit Length (mm)	Fruit Length/ Breadth	Cavity Size Variation (mm)	Thinnest Flesh (mm)	Days from Harvest to Ripe	TSS (%)
NT Red	705 ++	95 ++	166 ++	1.8	16.0 ++	16.3	10.3	10.3 --
Subang x Sunrise Solo	816 ++	97 ++	190 ++	2.0 ++	8.7	18.3 ++	7.0 --	10.6 --
Sunrise Solo x Paris	1091 ++	106 ++	213 ++	2.0 ++	9.0 +	20.3 ++	8.3 -	10.8 --
Sunrise Solo x Paris Sel 07	907 ++	98 ++	204 ++	2.1 ++	6.7 -	21.7 ++	6.0 --	10.7 --
Sunrise Solo x Paris Sel 22	1193 ++	114 ++	201 ++	1.8	9.0 +	23.3 ++	7.3 --	9.3 --
Sunrise Solo x Paris Sel 53	855 ++	101 ++	185 ++	1.9 ++	8.0	21.0 ++	7.0 --	10.7 --
Sunrise Solo	376	78	133	1.7	8.0	16.0	10.0	11.6
Average	**849**	**98**	**185**	**1.9**	**9.3**	**19.6**	**8.0**	**10.6**
LSD 0.05	**79**	**4**	**4**	**0.1**	**1.0**	**0.8**	**1.2**	**0.5**
LSD 0.01	**111**	**5**	**5**	**0.1**	**1.4**	**1.1**	**1.7**	**0.8**
CV%	**5%**	**2%**	**2%**	**3%**	**6%**	**2%**	**9%**	**3%**

Table 19 Fruit Value Index Points Score of 0 (poor) to 10 (excellent) for each Character

Variety	Value Index Points	Eating Quality Points	TSS Points	Winter Spot Points	Shelf Life Points	Fruit Shape Points	Fruit Size Points	Ripe Pattern Points
NT Red	6.3 +	8.6	7.0 --	0.6	8.5	7.9	5.4 ++	7.2 -
Subang x Sunrise Solo	6.5 ++	5.8 --	7.2 --	3.9 ++	7.0	7.4	6.0 ++	8.6
Sunrise Solo x Paris	6.5 ++	6.2 --	7.4 --	3.1 ++	8.2	4.5 --	8.4 ++	9.4 ++
Sunrise Solo x Paris Sel 07	6.1	6.6 --	7.4 --	5.2 ++	5.3 --	5.8 --	6.2 ++	5.9 --
Sunrise Solo x Paris Sel 22	5.8	5.4 --	5.4 --	3.8 ++	6.5 -	5.9 --	8.3 ++	6.6 --
Sunrise Solo x Paris Sel 53	6.3 +	6.9 --	7.4 --	4.3 ++	6.5 -	7.2 --	6.6 ++	6.0 --
Sunrise Solo	6.0	8.2	8.5	1.1	8.7	7.8	0.5	8.1
Average	**6.2**	**6.8**	**7.2**	**3.1**	**7.2**	**6.6**	**5.9**	**7.4**
LSD 0.05	**0.2**	**0.6**	**0.7**	**0.9**	**1.9**	**0.4**	**0.9**	**0.7**
LSD 0.01	**0.3**	**0.9**	**1.0**	**1.3**	**2.7**	**0.5**	**1.3**	**1.0**
CV%	**2%**	**5%**	**5%**	**16%**	**15%**	**3%**	**9%**	**5%**

+ and ++ indicate larger values than those of Sunrise Solo at the 95% and 99% probability levels respectively

and -- indicate smaller values than those of Sunrise Solo at the 95% and 99% probability levels respectively

1.2 Discussion

1.2.1 NT Red

NT Red is a red fleshed bisexual variety. It is a genetically uniform variety that can be grown from self pollinated seed.

NT Red out-yielded Sunrise Solo by a significant margin over the whole harvest period (Tables 1 and 2). The higher yield of saleable fruit was due to larger fruit (Table 3) and less unsaleable misshapen fruit.

The fruit have a distinct musk flavour. Eating quality was very similar to Sunrise Solo, despite slightly lower sugar levels (Table 3).

NT Red fruit were pear shaped, but less narrowed at the stalk end than Sunrise Solo fruit and were more suitable for packing. The fruit had a similar shelf life to Sunrise Solo with an average of ten days from harvest to full ripeness.

No differences were noticed between NT Red and Sunrise Solo in disease or pest susceptibility. Damage from Phytophthora root and fruit rot, dieback and two spotted mite were similar.

NT Red is susceptible to winter spot and received a similar rating to Sunrise Solo.

This variety is considered to have definite commercial potential. The trial data indicate that it offers significantly higher returns than Sunrise Solo due to higher yield. It has similar eating quality to Sunrise Solo.

1.2.2 Sunrise Solo x Paris Hybrid

This variety is a red fleshed bisexual variety. It is a hybrid variety and must be grown from seed produced by crossing the parent varieties.

Sunrise Solo x Paris Hybrid out-yielded Sunrise Solo by a significant margin (Tables 1 and 2).

Although Sunrise Solo x Paris Hybrid yielded well, some of its fruit were too long for convenient packing. It's average fruit length was two hundred and thirteen millimetres (Table 3). This means that a number of fruit exceeded two hundred and forty millimetres, the height of the largest fruit cartons.

The fruit were sweet flavoured with only a small proportion of fruit with a musk taste. Eating quality was good, but the taste was inferior to that of Sunrise Solo.

Sunrise Solo x Paris Hybrid was less susceptible to winter spot than Sunrise Solo, but suffered some damage early in the harvest period (September-October).

It had a higher proportion of fruit with blossom end defect than Sunrise Solo.

This is a high yielding variety that produces a relatively small number of large fruit. It may have commercial potential where large fruit are required.

1.2.3 Claveria

This is a yellow fleshed bisexual variety. It produced a very high proportion of carpelloid fruit (sixty percent) and had an extremely crowded fruit column. It is not a suitable commercial variety.

1.2.4 Paris x NT Red Hybrid

This is a red fleshed bisexual variety. It is a hybrid variety and must be grown from seed produced by crossing the parents.

The fruit of this variety were too large for packing. It is not a suitable commercial variety.

This is a red fleshed bisexual variety. It is a hybrid variety and must be grown from seed produced by crossing the parents.

The fruit of this variety were too large for packing. It is not a suitable commercial variety.

This variety was low yielding because of wide spacing of the fruit on the fruit column. It is not a suitable commercial variety.

2 EVALUATION OF PAPAYA GERMPLASM FOR SUSCEPTIBILITY TO PHYTOPHTHORA ROOT ROT

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Department of Primary Industries and Fisheries

2.1 Introduction

Sixty-two papaya cultivars and breeding lines were examined under glasshouse conditions for susceptibility to *Phytophthora* root rot of papaya.

2.2 Methods

2.2.1 Seedling establishment and experimental design

The experiment was established in the plant pathology glasshouse at South Johnstone Research Station near Innisfail, Queensland Australia. Seed of the various cultivars and breeding lines was sown into 90 (5x18) cell Speedling® trays containing pasteurised potting mix. Each tray was divided into 5 plant plots with a single guard row separating adjacent datum rows. Each treatment was replicated 4 times in a completely randomised design. Seedlings were fertilised weekly with Aquasol® foliar fertilizer.

2.2.2 Inoculum preparation and seedling inoculation

A modification of the method of Tsao (1971) was used to produce chlamydospores of P. palmivora in liquid culture. Two inoculum plugs (5 mm diam.) of a papaya isolate of P. palmivora, taken from the margin of a 4 day-old culture grown on cornmeal agar (CMA), were transferred to 125 mL Ehrlenmyer flasks containing 25 mL of a liquid medium. The broth medium used was reported by Mircetich et al. (1968); it consisted of 100 mL of Campbell's V-8 juice, 2g CaCO3, and 900 mL distilled water. The V-8 broth (Miller 1955) was cleared by filtering twice through 3 layers of muslin, then vacuum filtered through Whatman No. 54 filter paper. Prior to the addition of the inoculum plugs, the liquid medium was sterilised in an autoclave for 15 min at 1210 C.

Cultures grown in the liquid broth were incubated at 220C in the dark resulting in the formation of mycelial mats. After 14 days incubation, the mycelial mats were submerged under aseptic conditions with 75 mL of sterile distilled water before being incubated at 180 C (Tsao 1971) for a further 28 days. The resultant chlamydospore-bearing mycelial mats were placed in 100 mL sterile distilled water and mascerated at high speed for 1 min in a Waring blender. The mycelial fragments and chlamydospores were separated by passing the suspension 3 times through a nest of sieves (106, 75 and 38 µm in diameter) with the chlamydospores being collected on a 38 µm sieve before being suspended in a small quantity of water. The mean concentration per mL of a chlamydospore suspension was assessed from spore counts of 3 replicate samples. Eight-week-old seedlings were inoculated by pipetting a 2

mL suspension of 200 chlamydospores of Phytophthora palmivora at the base of each plant.

2.2.3 Disease assessment

Seedlings were evaluated for root rot incidence as plants died, or 3 weeks after inoculation. Roots of plants were washed free of potting mix and examined for root rot. The susceptibility of each cultivar or breeding line was assessed as the percentage plant mortality. Sections of diseased roots from affected plants were surface sterilized in 70% ethanol for 1 min, rinsed in sterile distilled water and blotted dry with sterile paper then transferred to P10ARP selective medium. The plates were observed for the growth of P. palmivora from the root sections after incubation in the dark at 260 C.

2.2.4 Results and Discussion

Of the 62 papaya cultivars and breeding lines tested, the seed of 12 of these failed to germinate. The percentage plant mortality in the 50 cultivars and breeding lines assessed for root rot ranged between 5 and 100% (Table 1). The papaya lines Subang 6, Subang*Sunrise, Paris*Sunrise, Paris*NT Red and Saipan Red were less susceptible to root rot than the remaining germplasm tested. The high tolerance level of this germplasm to root rot should be useful in a breeding program. Work is required to clarify the inheritance of the resistance to root rot. Tolerant cultivars are seen as an important component in the integrated management of Phytophthora root rot of papaya.

2.2.5 References

Miller PM (1955) V-8 juice agar as a general purpose medium for fungi and bacteria. *Phytopathology* 45:461-462.

Mircetich SM, Zentmyer GA and Kendrick JB (1968) Physiology of germination of chlamydospores of *Phytophthora cinnamomi*. *Phytopathology* 68: 666-671.

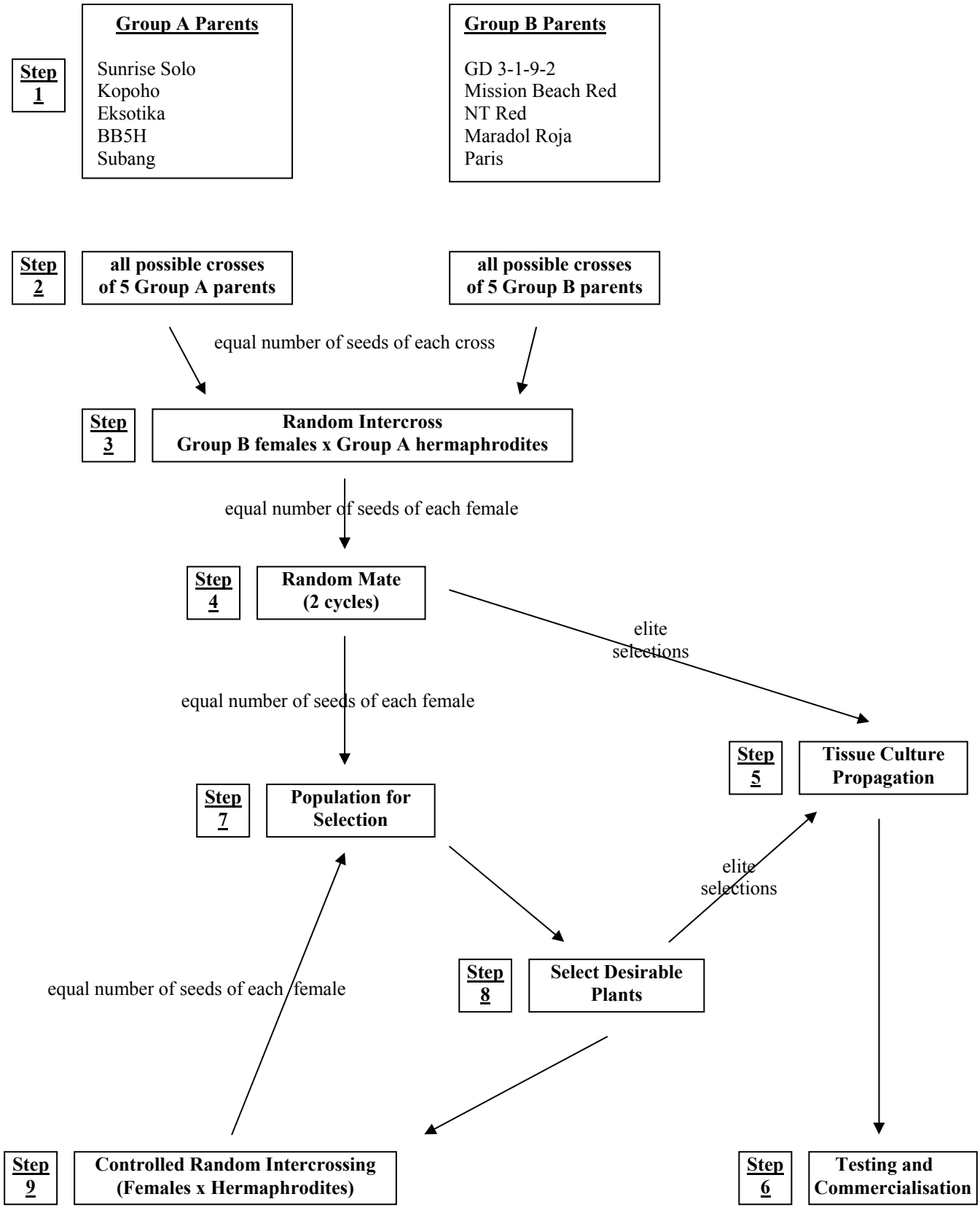
Tsao PH (1971) Chlamydospore formation in sporangium-free liquid cultures of *Phytophthora parasitica*. *Phytopathology* 61:1412-1413.

Table 20 Evaluation Of Papaya Germplasm For Susceptibility To *Phytophthora Palmivora*

Accession No.	Papaw Germplasm	Mortality (%)
54	Paris*NT Red	5
45	Subang 6	11
55	Paris*Sunrise	15
56	Subang*Sunrise	15
43	Saipan Red	30
4	C. cauliflora	45
7	Claveria	50
23	Kapoho	50
35	Paris	50
58	Sunrise gold	50
21	HCAR36	55
46	Sunrise Solo	60
42	Red Lady	61
17	Giant Panama EET	63
49	Tropical Dream	63
30	Mareeba Red	65
48	Thai Red	65
57	Boxinho de Santa Amalia	65
33	Mission Beach Red	70
50	TVL7	70
13	GD3-1-9	72
41	R7T4	74
37	PC 93-1	76
14	GD3-1-9 (R. Wiltshire)	79
11	GD3-1-19	80
27	Line 40	80
41	Line 1B	80
52	H29 (TVL7*GD3-1-9) R. Wiltshire	80
28	Line 5	81
9	ER6-2	83
3	BB9H-5-1	85
24	KC 90-1-2	85
25	Khag Dam (sirikul)	85
32	MG9	85
47	Tainung 5	85
10	ER6-4	87
15	GD3-1-9-2 (G. Grant)	87
6	Carica querciflora	88
8	Eksotika	89
A	Jacaratia Spinosa	89
B	C. goudotiana	89
12	GD3-1-19-2-1	90
29	Maradol Roja	90
39	PNG 1	90
22	JS92-1-1	95
16	GD3-1-9-5	95
19	HCAR 16	100
34	NT Red	100
26	KM 93-5-1	100
31	MCK	100
1	BB5H	Nil germination
2	BB9H-5	Nil germination
5	NIL	Nil germination
18	GN 93	Nil germination
20	HCAR 218	Nil germination
36	Paris (C. Barbagallo)	Nil germination
38	Pitsanulok	Nil germination
40	Puerto Rico 6-65	Nil germination
44	Subang	Nil germination
51	Waimanolo	Nil germination
53	MCK*ER64	Nil germination
59	Eksotike II	Nil germination

Appendix 1

PAPAYA BREEDING PROJECT
Flow Chart



MILESTONE REPORTS

Milestone Number: 2,

Due date 31/01/2000

Seed of initial inter-parent crosses harvested

This milestone has been achieved.

The 10 parents selected for the project are Sunrise Solo, Eksotika, Kopoho, BB5H, Subang, Mission Beach Red, Paris, NT Red, Maradol Roja, and GD 319-2.

Data from the previous breeding project and seed increase plantings were used for parent selection. Selection was aimed at obtaining a group of genetically diverse parents that are best able to meet the objectives of the project. The parents selected include varieties originating in Hawaii, Malaysia, The Philippines, Canary Islands, Mexico and Australia.

Seed of all the crosses between the parents needed to set up the base population for the project has been harvested. This seed has been planted and the plants are growing in the field at Southedge Research Station.

Start Micro-propagation Work

This milestone has been achieved.

All equipment required for the tissue culture laboratory at South Johnstone has been obtained and is installed and operating with the exception of a roller drum. The delay in obtaining the roller drum was due advice not to transport it via commercial transport. It will be transported from Brisbane by car during the second week of February.

The first step in getting papaya material into tissue culture is to obtain rooted cuttings. Several glasshouse trials have been conducted to develop potting mixes and techniques for rooting cuttings. These trials have given high success rates with vermiculite and vermiculate/peat moss mixes. Cuttings of Hybrid 1B, Sunrise Solo, ER 6-2, GD 3-1-9 and TVL 7 are currently growing. This will be extended to the full range of commercial hybrids and hybrid parents as soon as suitable side shoots are obtained from current field plantings.

The success of the project depends largely on the acceptance of micro-propagation by papaya growers. Papaya industry representatives have been exposed to field plantings of micro-propagated material originating from Redlands Research Station in both south and north Queensland. In addition, field plantings micro-propagated material from Dr Rod Drew's breeding project have been demonstrated to industry representatives in north Queensland.

Milestone Number: 3,

Due date 1st July 2000

Southedge Research Station planting of F1 hybrids for first random intercross established

This milestone has been achieved.

F1 hybrids from the ten parents selected for the project (Sunrise Solo, Eksotika, Kapoho, BB5H, Subang, Mission Beach Red, Paris, NT Red, Maradol Roja, and GD 319-2) are growing at Southedge Research Station to provide random intercross seed to produce the main starting population for the project.

The parents were divided into two groups to make the F1 hybrids, Group A (Sunrise Solo, Eksotika, Kapoho, BB5H and Subang) and Group B (Mission Beach Red, Paris, NT Red, Maradol Roja and GD 319-2).

The F1 hybrids between the Group B parents are being used as female parents for seed production and those between the Group A parents as male parents.

All the Group B hybrids are carrying sufficient fruit to provide the required seed for the first random intercross generation. Seed harvesting should be completed in late September 2000.

Three of the F1 hybrid varieties in the planting are considered to have immediate commercial potential. These are Sunrise Solo x Paris, NT Red x Paris and Subang x Sunrise Solo. These, plus several other promising varieties have been planted in a trial on South Johnstone Research Station to obtain performance data in the main papaya producing area.

Demonstrated progress with micro-propagation.

This milestone has been achieved.

There are four steps in propagating papaya by tissue culture:

1. Growing cuttings of the plants to be propagated.
2. Planting the apical buds from cuttings on agar media.
3. Encouraging the apical buds to produce roots.
4. Producing the required number of plants from the rooted material.

All the above steps have now been undertaken successfully.

Step 3, the rooting of apical buds, is the most difficult stage of papaya tissue culture propagation. It is done by alternating apical buds between roller drum media and single shoot or rooting media until roots are produced. Roots have been obtained on Sunrise Solo material after 3 months treatment. This step usually takes 6 or more months in other laboratories.

At present the main emphasis is being placed on obtaining further reductions in the time taken for root production. A review of work done to date is being used to find the most effective treatment combination.

Another approach being tested to speed up root production is the use of juvenile material from seedlings. A disadvantage of this method is that the sex of the plants will not be known until flowering plants are grown. However, the technique will be useful for the maintenance of hybrid parents where both male and female plants are required.

Varieties in culture at present are the main commercial varieties, Hybrid 1B and Sunrise Solo, and the commercial hybrid parents, ER 6-2, GD 3-1-9 and TVL 7.

Cuttings of a range of varieties are being grown to provide further tissue culture material. The varieties include additional commercial hybrid parents, selected F1 hybrids from the planting at Southedge Research Station and a number of advanced generation selections from the cross Sunrise Solo x Paris.

Milestone number: 4,

Due date 31st December 2000

Harvesting of fruit from F1 hybrid intercrosses underway.

This milestone has been achieved.

Harvesting of all required seed from the F1 hybrid intercross planting has been completed. Equal quantities of seed from each of the female parents have been bulked to give seed for planting the first random cross generation.

Five thousand plants of the first random cross generation are established in a planting on Southedge Research Station.

Fruit quality and agronomic data was collected for all the F1 hybrids grown. This data will be used for determining the mode of inheritance of various fruit characters and for assessing the commercial potential of the F1 hybrids.

Three of the F1 hybrid varieties in the planting are considered to have immediate commercial potential. These are Sunrise Solo x Paris, NT Red x Paris and Subang x Sunrise Solo. These, plus several other promising varieties are under test in a trial on South Johnstone Research Station to obtain performance data in the main papaya producing area.

Common commercial hybrid parents and commercial varieties under micro-propagation

This milestone has been achieved.

Varieties in culture at present are the two main commercial varieties, Hybrid 1B and Sunrise Solo, and the commercial hybrid parents, ER 6-2, ER 6-4, GD 3-1-9, GD 319-2 and TVL 7.

At present Sunrise Solo and Hybrid 1B material is being multiplied to provide material for field planting.

Current work is concentrating on getting a wider range of varieties into culture and on developing more efficient methods for preparing tissue cultured material for field planting.

Milestone number 5

Due Date: 31st july 2001

F1 hybrid random intercross planting completed.

This milestone has been achieved.

The F1 hybrid random intercross seed harvest has been completed. All required data (agronomic and fruit quality data) were collected from this population and forwarded with the report for milestone 4.

The F1 hybrids, Sunrise Solo x Paris, NT Red x Paris and Subang x Sunrise Solo were selected as having commercial potential in that report. They were among a group of varieties tested in a variety trial on South Johnstone Research Station. A report on this trial is in the attached file, Appendix 1.

This report recommends that the variety NT Red (one of the parent varieties used in this project) be further evaluated in commercial farm plantings. It also identifies the hybrid, Sunrise Solo x Paris as having some commercial potential.

5,000 plants of the first random cross generation are growing in the field at Southedge Research Station. The trees in this planting have reached approximately 2 metres.

A change that has been made to the project is that the minimum fruiting height is being measured as an index of population variation instead of flowering time as specified in the project proposal. This change has been made as both characters are considered to be equally good measures of population variation, but minimum fruiting height has the advantage of being of greater commercial value.

Seed harvesting from female fruit of the first random population will commence about November. This means that this part of the project is at present about 6 months ahead of schedule.

Micro-propagation of all common hybrid parents and commercial parents completed.

This milestone has been achieved.

The most popular commercial varieties, Sunrise Solo and Hybrid 1B and the common commercial hybrid parents GD 3-1-9, TVL 7, ER 6-2 and ER 6-4 are being maintained in culture. These parents will make the common hybrids 1B, 11B and 29.

The new variety, NT Red, is currently being cultured to allow true to type parent material to be maintained.

Emphasis is currently on propagating plants of the commercial varieties Sunrise Solo and Hybrid 1B. These plants are being prepared for a field planting to demonstrate the performance of micro-propagated to growers and nursery operators.

One planting of 50 Sunrise Solo plants has recently been made on a farm at Utchee Creek. Early growth of these plants has been impressive in comparison with the farmers normal crop propagated from seed.

Although the micro-propagation technique is working well, some problems have been experienced with low survival rates when plants are deflasked. A review of work done to date has indicated transplanting techniques that offer higher survival rates. These will be tested over the next couple of months.

Next Steps in Project

Random Cross Population

The next step in this part of the project is to harvest seed from the female plants of the population growing on Southedge Research Station. It is expected that this will start in November.

Data will be collected from the fruit of sample plants in the population to allow the study of the relationship between various fruit characters. This will allow efficient selection methods to be devised for the future.

Some plants in the current field planting appear to have commercial potential. The fruit characteristics of these plants will be assessed and the plants vegetatively propagated to provide material for detailed field trials, if this appears justified by their fruit characteristics.

Micro-propagation

Work in this part of the project over the next 6 months will concentrate on the following:

The production of Sunrise Solo and Hybrid 1B plants for farm demonstration plantings.

The culture of a greater range of varieties and hybrid parents.

Intensive work on de-flasking to develop more highly productive methods.

Extension Activities

Project staff under took the following extension activities over the last 6 months:

V. Hansen: attended various local Papaw Improvement Group meetings to update growers on project progress.

V. Hansen: attended Fruit and Vegetable Growers Association Papaw Sub-Committee Meetings to update committee members on project progress.

V. Hansen: interviewed for article on the project published in “Good Fruit and Vegetables”, May 2001.

V. Hansen: talks on papaya breeding and seed production techniques to a papaya seed producers certification course.

N. Bryde: talk and display on identifying papaya sex types at the North Queensland Rotary Field Day, 1st and 2nd June 2001 at Mareeba.

C. Kuhn and V. Hansen: regular contact with the operators of commercial tissue culture laboratories and nurseries to exchange information on papaya propagation methods.

Milestone number:6

Due date: 31st december 2001

First random intercross generation established. Plants past the f lowering stage and flowering time data collected.

This milestone has been achieved. However, a change that was made to the project is that minimum fruiting height was measured as an index of population variation instead of flowering time as specified in the project proposal. This change was indicated in the report for milestone 5 and was made as both characters are considered to be equally good measures of population variation, but minimum fruiting height has the advantages of being of greater commercial value and easier to measure.

The plants have reached the fruiting stage and seed harvesting from female plants is currently underway. Harvesting will be finished by mid January. This will allow the second random intercross planting to be transplanted into the field around April. It means that this part of the project is more than 6 months ahead of schedule.

Some data additional to that specified in the project proposal is being collected. This data consists of fruit set and carpelloid fruit data and fruit quality data and is intended for use to select potentially commercial plants from the population.

Further sub-culturing of micro-propagated plants completed to provide material of hybrid parents and commercial varieties to seed producers. Demonstration field planting of micro-propagated plants established.

This milestone has been achieved.

Material of the common commercial hybrid parents (GD 3-1-9, TVL 7, ER 6-2 and ER 6-4) have been sub-cultured and is available for planting. These parents will make the common hybrids 1B, 11B and 29.

Material of the commercial varieties Sunrise Solo and Hybrid 1B is also available.

The planting of micro-propagated Sunrise Solo plants on a farm at Utchee Creek that was reported in the previous milestone report has reached the fruiting stage. Fruit set on the micro-propagated plants is at a significantly lower height than the farmers seedling plants, and will produce close to an additional carton of fruit per plant. Growth and development of the micro-propagated plants is superior to that of the seedling plants.

A second farm demonstration planting of micro-propagated plants is being conducted by the Papaya Extension Officer, James Dunn. This planting is on a farm at Garradunga. It consists of a replicated trial comparison of seedling, cutting and micro-propagated material of Sunrise Solo. This planting is at present about 1 metre tall.

Additional plantings of micro-propagated plants will be made on farms as material becomes available.

Some difficulties were reported in the last milestone report with low survival rates when micro-propagated are deflasked. Experience with de-flasking has allowed the type of plants most likely to survive to be identified and for production techniques to concentrate on producing this type of plant. This, plus culling of unsuitable plants at de-flasking has improved survival rates and produced more uniform material.

Some reports in the literature suggest that the roots of papaya plants grown on agar media tend to have defects that reduce survival at de-flasking. Culture methods that use perlite and vermiculite as media are being tried to overcome this problem. Plants grown on perlite media have shown better survival and growth than plants from conventional agar media.

FIRST PROJECT REVIEW COMPLETED.

This milestone has not been completed.

The purpose of this review is to use knowledge gained during the first two years of the project to fine tune the methods and objectives of the project prior to the large scale selection of material for commercial testing.

This project review has coincided with a separate review of industry funded papaya breeding projects by the Queensland Fruit and Vegetable Growers Association.

After discussions with the HAL Project Leader for the project, it was decided to delay the project review until after the Queensland Fruit and Vegetable Growers Association review has been conducted.

Next Steps in Project

Project Review

This will be completed as soon as possible after the Queensland Fruit and Vegetable Growers Association review has been done.

Random Cross Population

The next step in this part of the project is to complete seed harvest from the female plants of the population growing on Southedge Research Station. It is expected that seed harvest will be completed in mid January 2002.

Once seed harvest is complete the second random cross population of 5,000 plants will be planted.

Data is being collected from the fruit of sample plants in the population to allow the study of the relationship between various fruit characters. This will allow efficient selection methods to be devised.

Some plants in the current field planting appear to have commercial potential. The fruit characteristics of these plants are being assessed. Any with fruit that appears to offer commercial potential will be vegetatively propagated to provide material for detailed field trials.

Micro-propagation

Work in this part of the project over the next 6 months will concentrate on the following:

Field walks to demonstrate farm plantings of micro-propagated plants to growers, industry representatives and commercial nursery operators.

The production of Sunrise Solo, Hybrid 1B and NT Red plants for further farm demonstration plantings.

Propagation of any useful plants selected from the Southedge random cross population.

More work on de-flasking methods and the means of producing plants best suited to successful de-flasking.

Extension Activities

Project staff under took the following extension activities over the last 6 months:

V. Hansen: TV interview about the new variety NT Red for screening on local channel 9 news. October 2001.

V. Hansen: attended an Innisfail Papaw Improvement Group meetings to discuss possible future changes to the project with growers as a preliminary to the project review. October 2001.

V. Hansen, N Bryde and C Kuhn: gave talks on various aspects of the project at the 2001 Papaya Field Day at Southedge Research Station. October 2001.

Milestone Number: 7

Due date: 31st July 2002

Harvesting of fruit from the first random intercross generation underway.

This milestone has been achieved.

Harvesting of fruit from the first random cross generation was completed in January, 2002. This means that this part of the project is more than 6 months ahead of schedule.

Fruit quality, fruit set, carpelloid fruit and fruiting height data were collected from a group of 700 random plants. These data will give information on the weaknesses and strengths of the population and character correlation and will be used to design an efficient future selection strategy for the project.

The above data were also collected from plants whose fruit were within commercial limits for size and visible fruit characters. These data were used to select plants with commercial potential. Cuttings are being taken from the selected plants as a source of material for tissue culture propagation. It is intended to use the tissue cultured material to establish detailed field trials.

There was considerable variation between plants in the population for the degree of black spot infection. It could not be determined if this variation was due to chance or genetic differences, in the current population.

Therefore a number of heavily and lightly infected plants were selected. These plants will be vegetatively propagated to allow a replicated trial to be planted with the treatments derived from each of the selected plants.

This trial will determine if there are genetic differences in the population for black spot susceptibility.

Investigate various methods of improving micro-propagation efficiency.

This milestone has been achieved.

Further work has been done with culture methods that use perlite as a media instead of the agar media.

While the use of perlite media has significantly improved de-flasking survival rates, it is necessary to replant the de-flasked plants into a traditional potting mix to grow the plants on to transplanting size. This double handling will increase the cost of tissue culture material.

A recently reported propagation method that uses a mixture of peat moss, perlite and sand will be tried as an alternative to perlite for the root initiation step. This potting will be suitable for growing the plants to transplanting size and will reduce the cost of tissue culture propagation.

Field walk to demonstrate field plantings of micro-propagated plants.

This milestone has been achieved.

This field walk, organised by the papaw extension officer James Dunn, was held on the 14th June, 2002. A trial on a growers property where normal seedlings were compared with plants derived from tissue culture and cuttings was inspected.

Approximately 15 growers attended the field walk. They were impressed by the lower fruiting and earlier fruiting of the vegetatively propagated material, but were concerned about the potential cost of tissue culture derived planting material.

First project review completed.

This milestone has been completed.

The review was conducted on the 17th to 21st June, 2002, by D. Walker and J. Zapalla (Growers Representatives), J. Tyas (Horticulture Australia Limited), T Dunmall (Queensland Fruit and Vegetable Growers Association) and B. Topp (Queensland Department of Primary Industries).

The report from the review has not yet been received.

Next Steps in Project

Project Review

Any recommendations made in the review will be considered when a new project proposal is submitted for the continuation of the breeding project after the current project is completed.

Random Cross Population

The second random cross generation was transplanted into the field on 23rd May, 2002. Operations on this population will be similar to those conducted on the first random cross generation.

Seed harvesting will be completed around August 2003. This will complete the current project, approximately 6 months ahead of schedule.

Work to get material from the selections made from the first random cross generation into tissue culture will continue.

Micro-propagation

Work in this part of the project over the next 6 months will concentrate on developing propagation methods aimed at reducing production costs.

Material produced will be used to establish further demonstration plantings on farms in both the Innisfail and Mareeba districts

Milestone Number: 8

Due Date: 31st December 2002

First random cross generation fruit harvest completed.

This milestone has been achieved.

Harvesting of fruit from the first random cross generation was completed in January, 2002. This means that this part of the project is more than 6 months ahead of schedule.

5,000 plants of the second random cross generation have been planted at Southedge Research Station. This planting has reached approximately 2.5 metres. Almost all trees have now set fruit.

Fruit harvesting will commence in February 2002.

Field planting of micro-propagated plants established.

This milestone has been achieved.

This field planting has been established and is being evaluated by papaw extension officer James Dunn. It consists of a trial on a growers property where normal seedlings are being compared with plants derived from tissue culture and cuttings. The planting consists of the varieties Hybrid 1B and Sunrise Solo.

This planting has reached fruit harvest.

The data collected to date show a significant advantage for both tissue culture and cutting derived plants in yield, lower fruiting height and earliness of fruiting.

Fruit harvesting and data collection will continue.

Next Steps in Project

Second random cross population

The second random cross generation was transplanted into the field on 23rd May, 2002. Operations on this population will be similar to those conducted on the first random cross generation.

Seed harvesting will be completed around April 2003. This will complete the current project.

Selections from the first random cross population

Material from 26 fruit quality selections from the first random cross population is currently being tissue cultured. The aim of this work is to generate enough material for a detailed field test of the selections.

Micro-propagation

Work will continue with the aim developing propagation methods aimed at reducing production costs.

Material produced will be used to establish further demonstration plantings on farms in both the Innisfail and Mareeba districts.

Progress made over the last 6 months is the development of a method to hold material in culture for an extended period. This is done by setting up the culture tubes to allow gas exchange and hence reduce ethylene concentration and by using fructose as the sugar source.

The use of perlite as a rooting media has improved root development and growth and reduced root induction time. The root induction for newly cultured material has been reduced to as little as 8 weeks (approximately 6 months with the original method).

Milestone number: 10

Due date 31st July 2003

(Note Milestone 9 is no longer present. Due to an adjustment in the project budget, project milestones were amended, resulting in no milestone 9)

Second random cross generation (RC2) field planting established. RC2 plants past flowering and fruiting height data collected.

This milestone has been achieved.

Plants of the RC2 population are well past flowering and the required fruiting height data has been collected.

Farm trial to compare tissue culture plants and seedlings completed. Report on farm tissue culture trial and tissue culture benefit/cost analysis completed.

This milestone has been achieved.

The micro-propagation farm trial has been completed. A report for the trial is attached.

A benefit/cost analysis of crops grown from micro-propagated material has been completed and is attached

Tissue culture multiplication of first random cross generation (RC1) selections underway. Material from at least 15 RC1 selections in culture.

This milestone has been achieved.

Eighteen RC1 plants are now in culture.

Next Steps in Project

The next steps in the project will be restricted by cuts made to the project's budget because of a suspension of levy collection.

A planned planting of the project's variety collection, including the parents of commercial hybrids, that was planned has been suspended because of a shortage of funds. This is of some concern as there is a danger of the loss of some material if this planting is not done soon. A planting of this material is the first activity planned when the project resumes normal operations.

RC1 Population Selections

These selections are being propagated to provide material for a detailed replicated trial to be planted on South Johnstone Research Station in April 2004.

RC2 Population

All required seed from female plants has now been harvested.

Plants considered to have commercial potential are being selected. After selection they will be propagated from cuttings to provide source material for tissue culture. Current data indicate that 25 to 30 plants will be selected. Papaya industry representatives and growers are assisting with selection.

As with the RC1 population, most selections will be bisexual plants.

Micro-propagation

As stated in section 2.1, the main activity for some time will be to propagate RC1 selections.

RC2 selections will also be cultured and propagated as material becomes available.

Extension Activities

Project staff under took the following extension activities over the last 6 months:

All project staff: Field walk to inspect and evaluate potential selections from the RC2 population at Southedge Research Station. 10th May 2003.

V Hansen and N Bryde: Follow up to Southedge Field Walk for several industry representatives unable to attend the original field walk. 28th May 2003.

V. Hansen: Judging of the papaw exhibits at the Innisfail Show. 10th July 2003.

V Hansen and N Bryde: Second Southedge Field Walk to allow industry representatives to make a second evaluation of potential RC2 selections.19th July 2003.

V Hansen: Talk to visiting HAL board members about the project. 23rd July 2003.

Milestone number 11:

Due date: 31st December 2003

Harvesting of Random Cross 2 (RC2) fruit and the selection of plants with commercial potential completed. RC2 data analysis and plant selection completed.

This milestone has been achieved.

Seed has been harvested from all female plants. Twenty seeds from each female were bulked to form the next generation population for selection.

Selection of plants with commercial potential was conducted with the assistance of growers at two field walks and one fruit tasting evening.

Thirty-four bisexual plants and five female plants have been selected from the population as commercial prospects.

Several of the selected plants appear to have excellent commercial potential, but need to be intensively tested in the Innisfail district to be certain.

Rooting of cuttings and tissue culturing of selected RC2 plants underway. At least some selected RC2 plants in tissue culture.

This milestone has been achieved.

Shoots from ten of the selected RC2 plants are in tissue culture. Cuttings from eight plants have been rooted to provide clean shoots for tissue culture.

Multiplication of RC1 selections to produce material for a replicated field trial well advanced. Enough material from at least 15 RC1 selections and control varieties (Sunrise Solo and Hybrid 1B) available to plant a replicated field trial.

This milestone has not been achieved.

The milestone was not achieved because of a breakdown in laboratory equipment and the departure of a staff member experienced in tissue culture.

The equipment breakdown was initially the air conditioner in the tissue culture growth room, which resulted in the temperature rising due to heat from the rooms lighting. An electricity cut off, designed to turn off all growth room electricity when the temperature went above 35 degrees failed to operate and allowed the temperature to rise to 50 degrees. This temperature killed approximately half the plants in the room out right. Much work was done in an attempt to rescue the remaining plants. However, almost all eventually died.

Recovery from the above diaster was complicated by the departure at short notice of Ms Teresa Venables, the project staff member experienced in papaya tissue culture. It proved to be difficult to find a replacement with experience in plant tissue culture. Eventually a person with experience in banana tissue culture was appointed.

The consequences of the above are that work for this milestone is approximately six months behind schedule.

Next Steps in Project

All work on the project is virtually finished, except for the micro-propagation work reported in 1.3 above, the production of a commercialisation plan and the writing of a final report.

The main emphasis in the immediate future will be to propagate planting material for the replicated trial. More work will also be done to get further RC2 selections into culture.

Communications and extension activities

V Hansen: Outline of project progress to Mareeba and Mossman papaya growers attending a nutrition workshop. 12th November 2003.

V Hansen: Talk to visiting DPI Senior Managers about the project. 21st November 2003.

V Hansen: Outline of project progress to Innisfail growers and grower fruit tasting to assist with plant selection. 10th December 2003.

Other issues

Some precautions have been taken to ensure that the tissue culture growth room over heating does not happen again.

The electricity cut off switch has been set at a constant setting that cannot be changed. An alarm connected to the growth room has been installed in the manager's house to alert him of any significant growth room temperature rises.

Appendix 3.

Female Fruit Description

Fruit Shape:


1.Globular


2.Round


3.High Round


4. Eliptic


5. Oval


6.Oblong


7.Oplong-elipsoid


8.Oblong-Blocky


9.Elongate


10.Lengthened cylindrical


11.Pear shaped


12.Club


13.Blossom and tapered


14.Acorn


15.Reinform


16.Turbinate inferior


17.Plum Shaped


18. Pumpkin


19.Rounded globular


20.Carpelloid

Teats:


1.Sunken


3.Flat


5.Slight


7.Pronounced

Stalk End Fruit Shape:


1.Depressed


3Flattened


5.Inflated


7.Pointed

Shape of Central Cavity:


1.Round


2.Angular


3.Pentagon


4.Slightly Star Shape


5Star Shape


6.Flower

F1 Hybrid for Parent Material 1999.

Appendix 4

Location: Southedge Research Station
Planting Date: 23/09/1999
Trial Design: 10 treatments (One Missing plot combination), 2 sex types, 2 replications, 10 plants per plot.
Fruit Harvest data: Collection period 04/07/2000 to 02/11/2000 (121 days)

PlotID	Rep	HybridID
21	I	Kapoho x Sunrise Solo
22	I	Eksotika x Sunrise Solo
23	I	BB5H x Sunrise Solo
24	I	Subang x Sunrise Solo
25	I	Eksotika x Kapoho
26	I	BB5H x Kapoho
27	I	Kapoho x Subang
28	I	BB5H x Eksotika
29	I	Eksotika x Subang
30	I	BB5H x Subang
31	I	GD 3-1-9-2 x NT Red
32	I	GD 3-1-9-2 x Maradol Roja
33	I	GD 3-1-9-2 x Paris
34	I	Mission Beach Red x NT Red
35	I	Maradol Roja x Mission Beach Red
36	I	Mission Beach Red x Paris
37	I	Maradol Roja x NT Red
38	I	NT Red x Paris
39	I	Maradol Roja x Paris
40	II	Kapoho x Sunrise Solo
41	II	Eksotika x Sunrise Solo
42	II	BB5H x Sunrise Solo
43	II	Subang x Sunrise Solo
44	II	Eksotika x Kapoho
45	II	BB5H x Kapoho
46	II	Kapoho x Subang
47	II	BB5H x Eksotika
48	II	Eksotika x Subang
49	II	BB5H x Subang
50	II	GD 3-1-9-2 x NT Red
51	II	GD 3-1-9-2 x Maradol Roja
52	II	GD 3-1-9-2 x Paris
53	II	Mission Beach Red x NT Red
54	II	Maradol Roja x Mission Beach Red
55	II	Mission Beach Red x Paris
56	II	Maradol Roja x NT Red
57	II	NT Red x Paris
58	II	Maradol Roja x Paris

F1 Hybrid Trial 1999
Fruit Quality and Agronomic Data

Table 1 - Performance of Female Hybrid Group: Quantitative Fruit Data

Hybrid	Fruiting Height (cm)	Days to First Harvest	TSS (%)	Fruit Weight (g)	Fruit Length (mm)	Fruit Diameter (mm)	Fruit LB Ratio	Days to Ripening	Fruit Flesh Ratio	Flesh Variation (mm)
GD 319-2 x Maradol Roja	66	375	8.3	1,350	157	132	1.20	10.0	0.48	19
GD 319-2 x Mission Beach	91	375	8.7	1,300	172	129	1.33	10.5	0.47	17
GD 319-2 x NT Red	115	382	9.3	961	147	117	1.25	8.7	0.49	20
GD 319-2 x Paris	107	379	8.2	1,225	188	121	1.55	8.8	0.52	19
Maradol Roja x Mission Beach	70	380	8.8	1,567	174	144	1.20	12.8	0.45	14
Maradol Roja x NT Red	81	382	9.3	1,666	176	147	1.25	9.9	0.47	17
Maradol Roja x Paris	96	381	9.3	1,771	214	141	1.55	9.7	0.47	16
Mission Beach x NT Red	92	365	9.2	975	152	124	1.20	11.3	0.43	15
Mission Beach x Paris	96	370	8.6	1,723	217	138	1.60	11.7	0.48	16
NT Red x Paris	121	380	9.8	1,364	199	129	1.55	8.1	0.47	17
Mean	**93**	**377**	**8.9**	**1,390**	**179**	**132**	**1.37**	**10.1**	**0.47**	**17**
LSD 0.05	**18**	**6**	**1.0**	**741**	**39**	**25**	**0.15**	**2.4**	**0.02**	**3**
LSD 0.01	**26**	**9**	**1.4**	**1,064**	**57**	**36**	**0.22**	**3.5**	**0.04**	**5**
CV	**9%**	**1%**	**5%**	**24%**	**10%**	**9%**	**5%**	**11%**	**2%**	**9%**

Table 2 - Performance of the Bisexual Hybrid Group: Quantitative Fruit Data

Hybrid	Fruiting Height (cm)	Days to First Harvest	TSS (%)	Fruit Weight (g)	Fruit Length (mm)	Fruit Diameter (mm)	Fruit LB Ratio	Days to Ripening	Fruit Flesh Ratio	Flesh Variation (mm)
BB5H x Eksotika	118	335	9.8	646	153	87	1.80	7.9	0.53	11
BB5H x Kapoho	127	371	10.3	543	144	85	1.70	10.6	0.54	7
BB5H x Subang	132	364	8.8	1,040	198	101	2.00	10.4	0.53	9
BB5H x Sunrise	118	328	9.5	593	152	88	1.80	10.9	0.54	7
Eksotika x Kapoho	152	370	11.1	670	148	94	1.60	7.7	0.49	11
Eksotika x Subang	139	378	9.9	1,330	224	109	2.10	8.7	0.50	16
Eksotika x Sunrise	129	366	10.7	594	140	94	1.55	8.4	0.50	12
Kapoho x Subang	128	366	10.5	964	194	100	1.95	7.6	0.51	12
Kapoho x Sunrise	145	371	11.1	466	133	87	1.55	9.0	0.51	8
Subang x Sunrise	137	359	9.7	988	204	100	2.05	8.4	0.50	11
Mean	**132**	**361**	**10.1**	**783**	**169**	**94**	**1.81**	**8.9**	**0.51**	**10**
LSD 0.05	**33**	**29**	**1.1**	**386**	**19**	**15**	**0.20**	**1.4**	**0.04**	**3**
LSD 0.01	**47**	**42**	**1.6**	**554**	**27**	**22**	**0.28**	**2.0**	**0.06**	**4**
CV	**11%**	**4%**	**5%**	**22%**	**5%**	**7%**	**5%**	**7%**	**4%**	**11%**

Table 3 - General Combining Ability Effects: Quantitative Fruit Data

Parent	Fruiting Height (cm)	Days to First Harvest	TSS (%)	Fruit Weight (g)	Fruit Length (mm)	Fruit Diameter (mm)	Fruit LB Ratio	Days to Ripening	Fruit Flesh Ratio	Flesh Variation (mm)
Female Group										
GD 319-2	1.55	0.98	-0.42	-242	-18.20	-9.68	-0.05	-0.85	0.02	2.42
Maradol Roja	-20.37	3.57	-0.04	264	1.02	11.73	-0.09	0.57	-0.01	-0.72
Mission Beach	-8.28	-5.85	-0.15	1	-0.87	2.15	-0.05	1.93	-0.02	-2.08
NT Red	11.63	0.57	0.58	-198	-14.98	-4.10	-0.07	-0.88	-0.01	0.28
Paris	15.47	0.73	0.03	174	33.02	-0.10	0.26	-0.76	0.02	0.11
gca F	**20.75**	**10.60**	**4.38**	**2.77**	**8.15**	**3.02**	**28.76**	**7.93**	**17.26**	**7.90**
variance component	**819**	**44**	**0.42**	**126,522**	**1,446**	**169**	**0.08**	**5.36**	**0.00**	**9.43**
	20.47	**1.1**	**.01**	**3163**	**36.15**	**4.22**	**.002**	**.134**	**0**	
Bisexual Group										
BB5H	-11.63	-14.83	-0.8	-122	-10.2	-18.8	0.02	1.3	0.03	-2.5
Eksotika	2.70	1.67	0.4	44	-2.7	5.9	-0.06	-1.0	-0.01	2.7
Kapoho	7.37	11.67	1.0	-184	-20.5	-14.6	-0.15	-0.4	0.00	-1.5
Subang	2.03	7.83	-0.7	426	49.5	34.6	0.29	-0.3	-0.01	1.9
Sunrise	-0.47	-6.33	0.2	-163	-16.2	-7.1	-0.10	0.3	0.00	-0.6
gca F	**1.42**	**4.08**	**9.68**	**11.47**	**65.62**	**5.76**	**23.32**	**12.37**	**4.37**	**25.45**
variance component	**59**	**348**	**0.11**	**202,849**	**2,975**	**144**	**0.11**	**2.80**	**0.00**	**20.01**

$F_{[(p-1)\ m]} = M_g/M_{e'}$. **F** 0.05 = 3.18 **F** 0.01 = 5.35

Table 4 - Specific Combining Ability Effects: Quantitative Fruit Data

Hybrid	Fruiting Height (cm)	Days to First Harvest	TSS (%)	Fruit Weight (g)	Fruit Length (mm)	Fruit Diameter (mm)	Fruit LB Ratio	Days to Ripening	Fruit Flesh Ratio	Flesh Variation (mm)
Female Group										
GD 319-2 x Maradol Roja	-8.96	-6.63	-0.16	-63	-5.31	-2.13	-0.03	0.11	-0.01	0.51
GD 319-2 x Mission	4.21	3.04	0.36	150	11.92	4.71	0.06	-0.67	0.00	-0.21
GD 319-2 x NT Red	8.54	3.38	0.18	11	0.19	-1.29	0.00	0.26	0.01	0.01
GD 319-2 x Paris	-3.79	0.21	-0.38	-98	-6.81	-1.29	-0.03	0.30	0.00	-0.32
Maradol Roja x Mission	5.38	5.21	0.03	-89	-5.64	-1.96	-0.03	0.13	0.01	-0.49
Maradol Roja x NT Red	-4.04	1.29	-0.21	209	10.47	6.79	0.05	0.04	0.01	0.15
Maradol Roja x Paris	7.63	0.13	0.34	-58	0.47	-2.71	0.01	-0.28	-0.01	-0.18
Mission Beach x NT Red	-5.13	-6.29	-0.19	-218	-11.64	-6.13	-0.05	0.13	-0.02	0.01
Mission Beach x Paris	-4.46	-1.96	-0.19	157	5.36	3.38	0.02	0.41	0.01	0.68
NT Red x Paris	0.63	1.63	0.23	-2	0.97	0.63	0.00	-0.43	-0.01	-0.18
sca F	**2.16**	**8.08**	**1.32**	**0.61**	**0.69**	**0.43**	**1.01**	**0.37**	**3.12**	**0.23**
variance component	**180**	**122**	**0.15**	**0**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Bisexual Group										
BB5H x Eksotika	-5.67	-12.83	0.2	-87	-2.42	-16.3	0.03	-1.3	0.00	-0.1
BB5H x Kapoho	-0.83	13.67	0.0	27	3.42	-1.3	0.02	0.6	0.00	0.6
BB5H x Subang	9.00	10.50	-0.3	-59	-9.08	4.5	-0.12	0.3	-0.01	-0.8
BB5H x Sunrise	-2.50	-11.33	0.1	118	8.08	13.2	0.07	0.4	0.00	0.3
Eksotika x Kapoho	9.33	-4.33	-0.2	39	1.75	11.0	0.00	0.0	-0.01	-1.1
Eksotika x Subang	2.17	7.50	0.1	138	10.25	7.3	0.07	0.9	0.01	1.1
Eksotika x Sunrise	-5.83	9.67	-0.1	-90	-9.58	-2.0	-0.10	0.3	0.00	0.1
Kapoho x Subang	-14.00	-14.50	0.2	-59	-3.92	-5.2	0.00	-0.6	0.00	0.3
Kapoho x Sunrise	5.50	5.17	0.0	-8	-1.25	-4.5	-0.02	0.0	0.00	0.3
Subang x Sunrise	2.83	-3.50	0.0	-20	2.75	-6.7	0.05	-0.6	0.00	-0.6
sca F	**0.90**	**2.38**	**0.11**	**0.46**	**2.26**	**0.26**	**1.94**	**4.88**	**0.24**	**1.18**
variance component	**0.00**	**585**	**0.00**	**0**	**217.17**	**0.00**	**0.02**	**3.59**	**0.00**	**0.56**

F [p (p-3)/2, m] =Ms/Me'. F 0.05 = 2.84 F0.01 = 4.61

Table 5 - Performance of Female Hybrid Group: Fruit Quality Index

Hybrid	Fruit Value Index	Eating Quality Points	Sugar Level Points	Winter Spot Points	Fruit Shape Points	Fruit Size Points	Flesh Colour Points	Ripening Pattern Points	Teat Shape Points	Stalk End Points	Shelf Life Points
GD 319-2 x Maradol	**3.3**	1.8	4.4	6.0	5.5	2.0	7.0	5.5	8.3	2.5	8.4
GD 319-2 x Mission	**5.3**	3.1	5.1	6.3	5.0	3.7	8.2	8.3	6.3	3.9	9.3
GD 319-2 x NT Red	**5.9**	2.6	5.9	5.2	4.1	5.2	8.1	7.3	9.7	7.7	9.2
GD 319-2 x Paris	**6.2**	1.7	4.3	8.8	6.8	4.8	8.1	7.2	7.4	9.3	9.1
Maradol Roja x	**5.2**	3.6	5.2	5.1	4.6	2.8	9.3	10.0	4.6	0.0	9.9
Maradol Roja x NT	**4.7**	3.8	6.0	3.0	2.4	1.8	10.0	9.1	4.4	0.0	9.4
Maradol Roja x Paris	**5.2**	4.2	5.8	7.1	3.8	1.9	9.4	10.0	0.9	1.0	9.2
Mission Beach x NT	**6.3**	6.0	5.7	7.5	3.1	5.2	7.9	9.9	6.2	2.5	9.7
Mission Beach x Paris	**5.0**	2.8	4.9	5.3	5.9	2.2	9.1	9.8	1.9	1.4	9.6
NT Red x Paris	**6.1**	5.2	6.6	6.8	5.7	3.9	9.8	9.8	1.5	4.7	8.9
Mean	**5.3**	**3.5**	**5.4**	**6.1**	**4.7**	**3.3**	**8.7**	**8.7**	**5.1**	**3.3**	**9.3**
LSD 0.05	**1.7**	**1.4**	**1.5**	**6.0**	**2.7**	**2.3**	**1.9**	**1.9**	**2.7**	**3.4**	**1.6**
LSD 0.01	**2.4**	**2.0**	**2.2**	**8.6**	**3.8**	**3.2**	**2.7**	**2.8**	**3.8**	**4.8**	**2.3**
CV	**14%**	**17%**	**13%**	**44%**	**25%**	**30%**	**10%**	**10%**	**23%**	**45%**	**8%**

Table 6 - Performance of the Bisexual Hybrid Group: Fruit Quality Index

Hybrid	Fruit Value Index	Eating Quality Points	Sugar Level Points	Winter Spot Points	Fruit Shape Points	Fruit Size Points	Flesh Colour Points	Ripening Pattern Points	Teat Shape Points	Stalk End Points	Shelf Life Points
BB5H x Eksotika	**5.3**	4.2	6.6	2.6	6.5	3.8	8.3	5.7	5.5	2.7	7.8
BB5H x Kapoho	**6.4**	4.0	7.5	7.2	6.8	5.3	7.8	5.9	5.6	6.2	9.3
BB5H x Subang	**5.1**	2.5	5.2	3.3	6.9	3.4	8.1	5.5	5.8	4.6	8.9
BB5H x Sunrise	**5.8**	4.4	6.3	2.6	6.1	6.0	7.8	5.7	5.6	7.9	9.4
Eksotika x	**5.5**	6.7	8.5	0.3	5.8	6.2	7.3	5.4	4.9	0.4	7.9
Eksotika x	**5.3**	5.0	6.9	0.9	6.3	2.7	9.8	6.9	5.4	0.7	9.5
Eksotika x	**6.0**	8.5	7.9	0.6	6.3	6.3	9.2	6.0	4.6	0.7	8.8
Kapoho x	**6.2**	4.6	7.8	5.4	6.7	4.4	8.0	7.8	5.7	4.0	8.5
Kapoho x	**5.5**	6.3	8.5	0.8	7.2	4.5	6.1	5.5	4.9	1.9	8.5
Subang x	**5.4**	5.9	6.5	1.1	6.5	3.3	9.4	6.6	4.1	3.5	9.0
Mean	**5.6**	**5.2**	**7.2**	**2.5**	**6.5**	**4.6**	**8.2**	**6.1**	**5.2**	**3.3**	**8.8**
LSD 0.05	**0.9**	**1.3**	**1.6**	**4.3**	**2.0**	**3.7**	**1.1**	**1.9**	**1.7**	**2.8**	**0.9**
LSD 0.01	**1.2**	**1.9**	**2.3**	**6.1**	**2.9**	**5.3**	**1.6**	**2.7**	**2.5**	**4.0**	**1.4**
CV	**7%**	**11%**	**10%**	**76%**	**14%**	**36%**	**6%**	**14%**	**15%**	**38%**	**5%**

Table 7 - General Combining Ability Effects: Fruit Quality Index

Parent	Fruit Value Index	Eating Quality Points	Sugar Level Points	Winter Spot Points	Fruit Shape Points	Fruit Size Points	Flesh Colour Points	Ripening Pattern Points	Teat Shape Points	Stalk End Points	Shelf Life Points
Female Group											
GD 319-2	**-0.17**	-1.57	-0.64	0.63	0.88	0.76	-1.11	-2.17	3.73	3.41	-0.36
Maradol Roja	**-0.97**	-0.16	-0.04	-1.09	-0.82	-1.65	0.31	-0.03	-0.77	-3.21	-0.06
Mission Beach	**0.18**	0.53	-0.21	-0.10	-0.07	0.16	-0.08	1.09	-0.47	-1.81	0.46
NT Red	**0.56**	1.19	0.87	-0.64	-1.17	0.90	0.33	0.44	0.44	0.57	0.03
Paris	**0.41**	0.01	0.02	1.21	1.17	-0.18	0.55	0.67	-2.94	1.04	-0.07
gca F	**4.07**	**17.28**	**4.09**	**0.74**	**4.54**	**6.27**	**3.70**	**13.53**	**25.74**	**18.14**	**1.06**
variance	**1.12**	**3.95**	**0.92**	**0.00**	**3.26**	**3.50**	**1.27**	**6.08**	**22.67**	**25.15**	**0.02**
Bisexual Group											
BB5H	**-0.02**	-1.91	-1.02	1.92	0.09	0.05	-0.26	-0.53	0.56	2.77	0.12
Eksotika	**-0.17**	1.19	0.40	-1.83	-0.36	0.24	0.63	-0.13	-0.16	-2.84	-0.33
Kapoho	**0.34**	0.27	1.20	1.25	0.16	0.67	-1.16	0.07	0.09	-0.19	-0.29
Subang	**-0.21**	-0.96	-0.77	0.27	0.09	-1.53	0.86	0.77	0.06	-0.06	0.27
Sunrise	**0.06**	1.42	0.18	-1.61	0.02	0.57	-0.07	-0.18	-0.56	0.32	0.22
gca F	**2.09**	**35.9**	**9.87**	**4.79**	**0.32**	**1.76**	**14.89**	**2.08**	**1.67**	**15.42**	**2.89**
variance	**0.10**	**7.86**	**2.93**	**8.93**	**0.00**	**1.37**	**2.37**	**0.48**	**0.26**	**14.89**	**0.22**

F [(p-1) m] =Mg/Me'. *F 0.05 = 3.18* *F 0.01 = 5.35*

Table 8 - Specific Combining Ability Effects: Fruit Quality Index

Hybrid	Fruit Value Index	Eating Quality Points	Sugar Level Points	Winter Spot Points	Fruit Shape Points	Fruit Size Points	Flesh Colour Points	Ripening Pattern Points	Teat Shape Points	Stalk End Points	Shelf Life Points
Female Group											
GD 319-2 x Maradol Roja	**-0.86**	0.07	-0.28	0.33	0.73	-0.49	-0.88	-0.97	0.20	-0.97	-0.44
GD 319-2 x Mission	**0.00**	0.65	0.53	-0.33	-0.51	-0.57	0.74	0.68	-2.04	-1.00	-0.06
GD 319-2 x NT Red	**0.21**	-0.53	0.25	-0.87	-0.32	0.16	0.20	0.31	0.38	0.45	0.23
GD 319-2 x Paris	**0.66**	-0.19	-0.50	0.88	0.10	0.90	-0.06	-0.02	1.46	1.53	0.28
Maradol Roja x Mission	**0.69**	-0.23	0.08	0.16	0.78	0.91	0.39	0.26	0.70	1.75	0.19
Maradol Roja x NT Red	**-0.24**	-0.74	-0.25	-1.39	-0.32	-0.78	0.63	0.02	-0.36	-0.63	0.17
Maradol Roja x Paris	**0.41**	0.89	0.45	0.91	-1.20	0.35	-0.14	0.69	-0.53	-0.15	0.07
Mission Beach x NT Red	**0.21**	0.77	-0.33	2.11	-0.37	0.76	-1.08	-0.30	1.13	0.41	-0.09
Mission Beach x Paris	**-0.89**	-1.19	-0.28	-1.94	0.10	-1.10	-0.05	-0.64	0.21	-1.15	-0.04
NT Red x Paris	**-0.17**	0.49	0.33	0.16	1.00	-0.15	0.25	-0.03	-1.15	-0.23	-0.31
sca F	**2.03**	**4.85**	**1.12**	**0.73**	**1.22**	**1.92**	**1.79**	**1.39**	**2.92**	**1.73**	**0.41**
variance component	**1.41**	**3.50**	**0.13**	**0.00**	**0.76**	**2.30**	**1.40**	**0.71**	**6.60**	**4.00**	**0.00**
Bisexual Group											
BB5H x Eksotika	**-0.18**	-0.26	0.07	0.00	0.27	-1.05	-0.23	0.28	-0.13	-0.52	-0.74
BB5H x Kapoho	**0.40**	0.41	0.17	1.52	0.06	0.02	1.01	0.28	-0.23	0.32	0.73
BB5H x Subang	**-0.35**	0.14	-0.22	-1.35	0.17	0.27	-0.71	-0.87	0.00	-1.36	-0.29
BB5H x Sunrise	**0.13**	-0.29	-0.02	-0.17	-0.51	0.77	-0.08	0.32	0.37	1.56	0.31
Eksotika x Kapoho	**-0.30**	0.06	-0.30	-1.58	-0.49	0.68	-0.33	-0.62	-0.27	0.19	-0.22
Eksotika x Subang	**0.00**	-0.46	0.07	0.00	0.08	-0.57	0.11	0.13	0.32	0.36	0.81
Eksotika x Sunrise	**0.48**	0.66	0.17	1.58	0.14	0.93	0.44	0.23	0.08	-0.03	0.16
Kapoho x Subang	**0.43**	0.11	0.22	1.42	-0.09	0.65	0.14	0.82	0.32	1.01	-0.27
Kapoho x Sunrise	**-0.53**	-0.57	-0.08	-1.35	0.52	-1.35	-0.83	-0.47	0.18	-1.53	-0.23
Subang x Sunrise	**-0.08**	0.21	-0.07	-0.07	-0.16	-0.35	0.46	-0.07	-0.63	-0.01	-0.24
sca F	**3.25**	**1.62**	**0.21**	**1.47**	**0.48**	**0.86**	**4.37**	**1.43**	**0.62**	**2.11**	**5.02**
variance component	**0.79**	**0.53**	**0.00**	**4.17**	**0.00**	**0.00**	**2.16**	**0.72**	**0.00**	**4.29**	**1.74**

F [p (p-3)/2,m]=Ms/Me'. *F 0.05 = 2.84* *F 0.01 = 4.61*

Table 9 - Percentage of fruit within each eating quality classification

Hybrid	Very Good	Good	Fair	Poor	Very Poor
Bisexual Group					
BB5H x Eksotika	0	17	58	23	2
BB5H x Kapoho	0	18	51	29	2
BB5H x Subang	0	3	21	61	14
BB5H x Sunrise	2	23	57	14	4
Eksotika x Kapoho	51	30	11	6	2
Eksotika x Subang	0	25	43	32	0
Eksotika x Sunrise	46	35	16	3	0
Kapoho x Subang	0	24	51	24	0
Kapoho x Sunrise	29	33	26	10	2
Sunrise x Subang	0	35	56	8	1
Bisexual Mean	**13**	**24**	**39**	**21**	**3**
Female Group					
Maradol Roja x GD 319-2	0	0	10	55	35
Maradol Roja x Mission Beach	2	4	41	45	8
Maradol Roja x NT Red	0	0	65	30	5
Maradol Roja x Paris	0	13	41	16	31
NT Red x GD 319-2	0	4	26	61	9
NT Red x Mission Beach	0	30	63	7	0
NT Red x Paris	0	24	52	24	0
Paris x Mission Beach	0	0	27	61	12
Paris x GD 319-2	0	0	8	56	36
Female Mean	**0**	**8**	**37**	**39**	**15**
Overall Mean	**7**	**16**	**38**	**30**	**9**

Table 10 - Percentage of fruit with each taste classification

Hybrid	Musk	Sweet	Frangipanni	Bland	Nasturtion
Bisexual Group					
BB5H x Eksotika	5	32	8	12	43
BB5H x Kapoho	0	29	10	12	49
BB5H x Subang	0	1	20	14	64
BB5H x Sunrise	2	44	8	17	29
Eksotika x Kapoho	0	87	2	6	4
Eksotika x Subang	7	43	21	29	0
Eksotika x Sunrise	62	37	0	1	0
Kapoho x Subang	0	38	43	19	0
Kapoho x Sunrise	0	83	3	12	2
Sunrise x Subang	12	64	11	13	0
Bisexual Mean	9	46	13	14	19
Female Group					
Maradol Roja x GD 319-2	0	0	5	5	90
Maradol Roja x Mission Beach	0	12	78	2	8
Maradol Roja x NT Red	0	24	54	5	16
Maradol Roja x Paris	0	47	41	0	13
NT Red x GD 319-2	0	9	4	4	83
NT Red x Mission Beach	7	81	2	9	0
NT Red x Paris	0	71	5	24	0
Paris x Mission Beach	0	14	27	53	7
Paris x GD 319-2	0	0	3	8	90
Female Mean	**1**	**29**	**24**	**12**	**34**
Overall Mean	**5**	**38**	**19**	**13**	**27**

Table 11 - Percentage of fruit with each winter spot classification

Hybrid	No Winter Spot	1-15% Cover	16-30% Cover	31-50% Cover	Over 50% Cover
Bisexual Group					
BB5H x Eksotika	7	2	5	0	87
BB5H x Kapoho	37	16	14	16	16
BB5H x Subang	11	7	23	20	39
BB5H x Sunrise	6	10	12	14	58
Eksotika x Kapoho	0	0	2	2	96
Eksotika x Subang	4	0	7	7	82
Eksotika x Sunrise	0	1	3	1	94
Kapoho x Subang	22	22	19	22	16
Kapoho x Sunrise	0	2	3	14	81
Sunrise x Subang	1	4	8	11	76
Bisexual Mean	**9**	**6**	**10**	**11**	**65**
Female Group					
Maradol Roja x GD 319-2	15	5	30	20	30
Maradol Roja x Mission Beach	25	14	24	14	24
Maradol Roja x NT Red	14	5	11	11	59
Maradol Roja x Paris	50	19	9	9	13
NT Red x GD 319-2	13	9	15	7	56
NT Red x Mission Beach	40	33	14	9	5
NT Red x Paris	38	19	26	10	7
Paris x Mission Beach	14	20	37	22	7
Paris x GD 319-2	69	23	3	5	0
Female Mean	**31**	**16**	**19**	**12**	**22**
Overall Mean	**20**	**11**	**15**	**12**	**44**

Table 12 - Percentage of fruit with each flesh firmness classification

Hybrid	Hard	Firm Throughout	Firm: Soft Centre	Soft Throughout
Bisexual Group				
BB5H x Eksotika	0	23	77	0
BB5H x Kapoho	4	43	51	2
BB5H x Subang	1	50	49	0
BB5H x Sunrise	1	25	74	0
Eksotika x Kapoho	0	4	74	21
Eksotika x Subang	0	32	68	0
Eksotika x Sunrise	0	4	94	1
Kapoho x Subang	0	11	81	8
Kapoho x Sunrise	0	17	69	14
Sunrise x Subang	0	18	78	4
Bisexual Mean	**1**	**23**	**72**	**5**
Female Group				
Maradol Roja x GD 319-2	0	55	45	0
Maradol Roja x Mission Beach	0	51	43	6
Maradol Roja x NT Red	0	24	70	5
Maradol Roja x Paris	0	41	59	0
NT Red x GD 319-2	0	37	61	2
NT Red x Mission Beach	0	40	60	0
NT Red x Paris	0	21	79	0
Paris x Mission Beach	0	58	42	0
Paris x GD 319-2	0	26	74	0
Female Mean	**0**	**39**	**59**	**1**
Overall Mean	**1**	**31**	**66**	**3**

Table 13 - Percentage of fruit with each fruit shape classification

Hybrid	Globular	Round	High Round	Oblong	Oval	Elliptic	Elongate	Pear Shape	Carpelloid
Bisexual Group									
BB5H x Eksotika	0	0	0	0	3	33	32	20	12
BB5H x Kapoho	0	0	0	0	4	29	12	43	12
BB5H x Subang	0	0	1	0	0	17	44	27	10
BB5H x Sunrise	0	0	0	0	0	20	17	41	23
Eksotika x Kapoho	0	0	0	0	4	32	4	38	21
Eksotika x Subang	0	0	0	0	0	14	43	21	21
Eksotika x Sunrise	0	0	0	0	1	21	4	54	19
Kapoho x Subang	0	0	0	0	0	8	43	32	16
Kapoho x Sunrise	0	0	0	0	0	3	0	86	10
Sunrise x Subang	0	0	0	0	0	5	41	34	20
Bisexual Mean	**0**	**0**	**0**	**0**	**1**	**18**	**24**	**40**	**16**
Female Group									
Maradol Roja x GD 319-2	30	0	30	15	25	0	0	0	0
Maradol Roja x Mission Beach	35	12	18	0	31	2	0	2	0
Maradol Roja x NT Red	27	14	5	0	51	3	0	0	0
Maradol Roja x Paris	0	0	0	6	44	41	9	0	0
NT Red x GD 319-2	35	7	19	6	33	0	0	0	0
NT Red x Mission Beach	35	7	2	0	44	12	0	0	0
NT Red x Paris	2	0	0	2	21	74	0	0	0
Paris x Mission Beach	0	0	2	0	25	71	2	0	0
Paris x GD 319-2	0	0	3	0	8	85	5	0	0
Female Mean	**18**	**4**	**9**	**3**	**31**	**32**	**2**	**0**	**0**
Overall Mean	**9**	**2**	**5**	**2**	**16**	**25**	**13**	**20**	**8**

Table 14 Percentage of fruit with each flesh colour classification

Hybrid	Scarlet	Red	Reddish Orange	Bright Yellow	Light Yellow	Other
Bisexual Group						
BB5H x Eksotika	0	2	12	87	0	0
BB5H x Kapoho	0	2	2	94	2	0
BB5H x Subang	0	0	6	94	0	0
BB5H x Sunrise	0	1	7	89	4	0
Eksotika x Kapoho	0	2	2	85	11	0
Eksotika x Subang	11	79	4	7	0	0
Eksotika x Sunrise	0	15	85	0	0	0
Kapoho x Subang	0	0	0	100	0	0
Kapoho x Sunrise	0	0	0	76	24	0
Sunrise x Subang	1	49	48	0	1	0
Bisexual Mean	**1**	**15**	**17**	**63**	**4**	**0**
Female Group						
Maradol Roja x GD 319-2	0	0	0	95	5	0
Maradol Roja x Mission Beach	0	33	65	2	0	0
Maradol Roja x NT Red	14	81	5	0	0	0
Maradol Roja x Paris	3	34	63	0	0	0
NT Red x GD 319-2	0	0	6	94	0	0
NT Red x Mission Beach	2	37	60	0	0	0
NT Red x Paris	2	81	17	0	0	0
Paris x Mission Beach	0	34	61	3	2	0
Paris x GD 319-2	0	0	8	92	0	0
Female Mean	**2**	**33**	**32**	**32**	**1**	**0**
Overall Mean	2	24	25	48	3	0

Table 15 - Percentage of fruit with each ripe fruit rot classification

Hybrid	No Fruit Rots at Full Ripeness	Slight Tanning at Full Ripeness	A Few Spots at Full Ripeness	Many Spots at Full Ripeness	Many Spots at Half Ripeness
Bisexual Group					
BB5H x Eksotika	87	13	0	0	0
BB5H x Kapoho	96	4	0	0	0
BB5H x Subang	87	4	1	6	1
BB5H x Sunrise	88	8	3	0	1
Eksotika x Kapoho	98	0	0	2	0
Eksotika x Subang	93	7	0	0	0
Eksotika x Sunrise	93	7	0	0	0
Kapoho x Subang	95	5	0	0	0
Kapoho x Sunrise	91	5	3	0	0
Sunrise x Subang	95	5	0	0	0
Bisexual Mean	92	6	1	1	0
Female Group					
Maradol Roja x GD 319-2	70	10	10	5	5
Maradol Roja x Mission Beach	82	8	4	6	0
Maradol Roja x NT Red	92	0	3	5	0
Maradol Roja x Paris	84	3	9	3	0
NT Red x GD 319-2	94	2	4	0	0
NT Red x Mission Beach	77	14	5	5	0
NT Red x Paris	95	2	2	0	0
Paris x Mission Beach	90	2	3	2	3
Paris x GD 319-2	87	5	5	3	0
Female Mean	86	5	5	3	1
Overall Mean	89	6	3	2	1

Table 16 - Percentage of fruit with each petal scar rot classification

Hybrid	No Petal Scar Rot	With a Trace of Petal Scar Rot	With Moderate Petal Scar Rot	with Severe Petal Scar Rot
Bisexual Group				
BB5H x Eksotika	90	2	2	7
BB5H x Kapoho	86	0	2	12
BB5H x Subang	90	3	0	7
BB5H x Sunrise	81	7	2	10
Eksotika x Kapoho	94	4	0	2
Eksotika x Subang	93	0	4	4
Eksotika x Sunrise	93	3	1	3
Kapoho x Subang	97	0	0	3
Kapoho x Sunrise	88	2	5	5
Sunrise x Subang	97	1	1	1
Bisexual Mean	**91**	**2**	**2**	**5**
Female Group				
Maradol Roja x GD 319-2	85	5	5	5
Maradol Roja x Mission Beach	96	4	0	0
Maradol Roja x NT Red	100	0	0	0
Maradol Roja x Paris	91	0	3	6
NT Red x GD 319-2	96	4	0	0
NT Red x Mission Beach	91	0	7	2
NT Red x Paris	100	0	0	0
Paris x Mission Beach	98	2	0	0
Paris x GD 319-2	95	0	3	3
Female Mean	**95**	**2**	**2**	**2**
Overall Mean	**93**	**2**	**2**	**4**

Table 17 - Percentage of fruit with each ripening pattern classification

Hybrid	Full Striping	Partial Striping	Even Throughout	Blossom End Only
Bisexual Group				
BB5H x Eksotika	0	12	87	2
BB5H x Kapoho	2	20	78	0
BB5H x Subang	0	11	87	1
BB5H x Sunrise	0	15	82	3
Eksotika x Kapoho	0	11	87	2
Eksotika x Subang	7	36	57	0
Eksotika x Sunrise	3	15	82	0
Kapoho x Subang	8	46	46	0
Kapoho x Sunrise	0	12	86	2
Sunrise x Subang	8	26	66	0
Bisexual Mean	**3**	**19**	**76**	**1**
Female Group				
Maradol Roja x GD 319-2	10	25	60	5
Maradol Roja x Mission Beach	71	29	0	0
Maradol Roja x NT Red	22	57	22	0
Maradol Roja x Paris	41	59	0	0
NT Red x GD 319-2	15	41	43	2
NT Red x Mission Beach	77	21	2	0
NT Red x Paris	26	71	2	0
Paris x Mission Beach	71	25	3	0
Paris x GD 319-2	5	44	51	0
Female Mean	**38**	**41**	**20**	**1**
Overall Mean	**21**	**30**	**48**	**1**

Table 18 - Percentage of fruit with each ridging classification

Hybrid	None	Superficial	Intermediate	Deep
Bisexual Group				
BB5H x Eksotika	**87**	**10**	**3**	**0**
BB5H x Kapoho	**94**	**6**	**0**	**0**
BB5H x Subang	**89**	**11**	**0**	**0**
BB5H x Sunrise	**83**	**16**	**1**	**0**
Eksotika x Kapoho	**79**	**17**	**4**	**0**
Eksotika x Subang	**86**	**14**	**0**	**0**
Eksotika x Sunrise	**74**	**25**	**1**	**0**
Kapoho x Subang	**59**	**35**	**5**	**0**
Kapoho x Sunrise	**93**	**7**	**0**	**0**
Sunrise x Subang	**73**	**27**	**0**	**0**
Bisexual Mean	**82**	**17**	**1**	**0**
Female Group				
Maradol Roja x GD 319-2	**20**	**75**	**5**	**0**
Maradol Roja x Mission Beach	**14**	**86**	**0**	**0**
Maradol Roja x NT Red	**3**	**89**	**8**	**0**
Maradol Roja x Paris	**47**	**53**	**0**	**0**
NT Red x GD 319-2	**6**	**87**	**7**	**0**
NT Red x Mission Beach	**0**	**79**	**19**	**2**
NT Red x Paris	**0**	**88**	**12**	**0**
Paris x Mission Beach	**31**	**69**	**0**	**0**
Paris x GD 319-2	**49**	**46**	**5**	**0**
Female Mean	**19**	**74**	**6**	**0**
Overall Mean	**51**	**46**	**4**	**0**

Table 19 - Percentage of fruit with each stalk end shape classification

Hybrid	Depressed	Flattened	Inflated	Pointed
Bisexual Group				
BB5H x Eksotika	68	27	5	0
BB5H x Kapoho	37	61	2	0
BB5H x Subang	54	41	4	0
BB5H x Sunrise	20	68	9	2
Eksotika x Kapoho	96	4	0	0
Eksotika x Subang	96	4	0	0
Eksotika x Sunrise	93	7	0	0
Kapoho x Subang	59	41	0	0
Kapoho x Sunrise	83	17	0	0
Sunrise x Subang	64	32	4	0
Bisexual Mean	**67**	**30**	**2**	**0**
Female Group				
Maradol Roja x GD 319-2	90	10	0	0
Maradol Roja x Mission Beach	100	0	0	0
Maradol Roja x NT Red	100	0	0	0
Maradol Roja x Paris	91	9	0	0
NT Red x GD 319-2	31	69	0	0
NT Red x Mission Beach	77	23	0	0
NT Red x Paris	62	38	0	0
Paris x Mission Beach	88	12	0	0
Paris x GD 319-2	10	82	8	0
Female Mean	**72**	**27**	**1**	**0**
Overall Mean	**70**	**29**	**2**	**0**

Table 20 - Percentage of fruit with each teat shape classification

Hybrid	Sunken	Flat	Slight	Pronounced
Bisexual Group				
BB5H x Eksotika	60	30	5	5
BB5H x Kapoho	82	14	0	4
BB5H x Subang	61	23	14	1
BB5H x Sunrise	74	17	5	4
Eksotika x Kapoho	70	11	13	6
Eksotika x Subang	46	21	29	4
Eksotika x Sunrise	72	6	9	13
Kapoho x Subang	22	38	24	16
Kapoho x Sunrise	90	2	7	2
Sunrise x Subang	44	10	29	18
Bisexual Mean	**62**	**17**	**14**	**7**
Female Group				
Maradol Roja x GD 319-2	0	90	10	0
Maradol Roja x Mission Beach	39	14	41	6
Maradol Roja x NT Red	3	24	54	19
Maradol Roja x Paris	0	0	28	72
NT Red x GD 319-2	2	96	2	0
NT Red x Mission Beach	19	33	47	2
NT Red x Paris	0	0	50	50
Paris x Mission Beach	0	5	42	53
Paris x GD 319-2	0	69	28	3
Female Mean	**7**	**37**	**34**	**23**
Overall Mean	**35**	**27**	**24**	**15**

Table 21 - Percentage of fruit with each cavity shape classification

Hybrid	Round	Angular	Pentagonal	Slight Star	Star	Floral
Bisexual Group						
BB5H x Eksotika	20	23	0	12	22	23
BB5H x Kapoho	41	6	0	4	0	49
BB5H x Subang	37	16	1	9	0	37
BB5H x Sunrise	38	11	2	2	1	47
Eksotika x Kapoho	13	11	0	17	9	51
Eksotika x Subang	0	57	0	7	14	21
Eksotika x Sunrise	6	15	0	7	37	35
Kapoho x Subang	8	27	0	5	3	57
Kapoho x Sunrise	26	12	0	5	2	55
Sunrise x Subang	11	25	1	7	4	52
Bisexual Mean	**20**	**20**	**0**	**8**	**9**	**43**
Female Group						
Maradol Roja x GD 319-2	0	0	0	45	55	0
Maradol Roja x Mission Beach	0	0	12	78	8	2
Maradol Roja x NT Red	3	0	0	54	43	0
Maradol Roja x Paris	0	0	0	53	44	3
NT Red x GD 319-2	0	0	0	6	91	4
NT Red x Mission Beach	0	0	5	60	33	2
NT Red x Paris	0	0	2	33	64	0
Paris x Mission Beach	0	0	7	47	46	0
Paris x GD 319-2	0	0	0	21	77	3
Female Mean	**0**	**0**	**3**	**44**	**51**	**1**
Overall Mean	**10**	**10**	**1**	**26**	**30**	**22**

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Table 22 - Qualitative Inheritance Data – Descriptions by Trait

Table 22 a

Parent	*Flesh Colour*				
Female Group		**Maradol Roja**	**Mission Beach**	**NT Red**	**Paris**
	Flesh Colour	***Red***	***Reddish Orange***	***Reddish Orange***	***Red***
GD 319-2	***Bright Yellow***	Bright Yellow	Bright Yellow/???	Bright Yellow	Bright Yellow
Maradol Roja	***Red***		Reddish Orange	Red	Reddish Orange
Mission Beach	***Reddish Orange***			Reddish Orange	Reddish Orange
NT Red	***Reddish Orange***				Red
Bisexual Group		**Eksotika**	**Kapoho**	**Subang**	**Sunrise**
	Flesh Colour	***Red***	***Bright Yellow***	***Red***	***Reddish Orange***
BB5H	***Bright Yellow***	Bright Yellow	Bright Yellow	Bright Yellow	Bright Yellow
Eksotika	***Red***		Bright Yellow	Red	Reddish Orange
Kapoho	***Bright Yellow***			Bright Yellow	Bright Yellow
Subang	***Red***				Red/Red Orange

Table 22 b

Parent	*Taste*				
Female Group		**Maradol Roja**	**Mission Beach**	**NT Red**	**Paris**
	Taste	***Frangipanni***	***Bland***	***Musk***	***Bland***
GD 319-2	***Nasturtium***	Nasturtium	?	Nasturtium	Nasturtium
Maradol Roja	***Frangipanni***		Frangipanni	Frangipanni	Sweet/ Frangipanni
Mission Beach	***Bland***			Sweet	Bland
NT Red	***Musk***				Sweet
Bisexual Group		**Eksotika**	**Kapoho**	**Subang**	**Sunrise**
	Taste	***Musk***	***Sweet***	***Bland***	***Musk***
BB5H	***Nasturtium***	Nasturtium	Nasturtium	Nasturtium	Sweet
Eksotika	***Musk***		Sweet	Sweet	Musk
Kapoho	***Sweet***			Sweet	Sweet
Subang	***Bland***				Sweet

Table 22 c

Parent	*Eating Quality*				
Female Group		**Maradol Roja**	**Mission Beach**	**NT Red**	**Paris**
	Eating Quality	***Fair***	***Fair***	***Good***	***Poor***
GD 319-2	***Very Poor***	Poor	?	Poor	Poor
Maradol Roja	***Fair***		Fair/Poor	Fair	Poor
Mission Beach	***Fair***			Fair	Poor
NT Red	***Good***				Fair
Bisexual Group		**Eksotika**	**Kapoho**	**Subang**	**Sunrise**
	Eating Quality	***Good***	***Good***	***Poor***	***Very Good***
BB5H	***Fair/Poor***	Fair	Fair	Poor	Fair
Eksotika	***Good***		Very Good	Fair	Very Good
Kapoho	***Good***			Fair	Good
Subang	***Poor***				Fair

Table 22 d

Parent	*Flesh Firmness*				
Female Group		**Maradol Roja**	**Mission Beach**	**NT Red**	**Paris**
	Flesh Firmness	***Firm/Medium***	***Medium***	***Medium***	***Medium***
GD 319-2	***Firm***	Firm/Medium	?	Medium	Medium
Maradol Roja	***Firm/Medium***		Firm/Medium	Medium	Firm/Medium
Mission Beach	***Medium***			Firm/Medium	Firm/Medium
NT Red	***Medium***				Medium
Bisexual Group		**Eksotika**	**Kapoho**	**Subang**	**Sunrise**
	Flesh Firmness	***Medium/Soft***	***Medium/Soft***	***Medium***	***Medium***
BB5H	***Medium***	Medium	Firm/Medium	Firm/Medium	Medium
Eksotika	***Medium/Soft***		Medium	Medium	Medium
Kapoho	***Medium/Soft***			Medium	Medium
Subang	***Medium***				Medium

Table 22 e

Parent	*Fruit Shape*				
Female Group		**Maradol Roja**	**Mission Beach**	**NT Red**	**Paris**
	Fruit Shape	***Oval***	***Oval***	***Round***	***Elongate***
GD 319-2	***Oval***	Oval	?	Oval	Elliptic
Maradol Roja	***Oval***		Oval	Oval	Oval/Elliptic
Mission Beach	***Oval***			Oval	Elliptic
NT Red	***Round***				Elliptic
Bisexual Group		**Eksotika**	**Kapoho**	**Subang**	**Sunrise**
	Fruit Shape	***Elliptic***	***Pear***	***Elongate***	***Pear***
BB5H	***Pear***	Elliptic	Pear	Elongate	Pear
Eksotika	***Elliptic***		Pear/Elliptic	Elongate	Pear
Kapoho	***Pear***			Elongate/Pear	Pear
Subang	***Elongate***				Elongate/Pear

Table 22 f

Parent	*Cavity Shape*				
Female Group		**Maradol Roja**	**Mission Beach**	**NT Red**	**Paris**
	Cavity Shape	***Pentagon***	***Pentagon***	***Pentagon***	***Pentagon***
GD 319-2	***Star***	Star	?	Star	Star
Maradol Roja	***Pentagon***		Slight Star	Slight Star	Slight Star
Mission Beach	***Pentagon***			Slight Star	Slight Star
NT Red	***Pentagon***				Star
Bisexual Group		**Eksotika**	**Kapoho**	**Subang**	**Sunrise**
	Cavity Shape	***Star***	***Round***	***Round/Angular***	***Round/Angular***
BB5H	***Round/Angular***	Mixed	Round/Floral	Round/Floral	Round/Floral
Eksotika	***Star***		Floral	Angular	Star/Floral
Kapoho	***Round***			Floral	Floral
Subang	***Round/Angular***				Floral

Table 22 g

Parent	*Stalk End Shape*				
Female Group		**Maradol Roja**	**Mission Beach**	**NT Red**	**Paris**
	Stalk End Shape	***Depressed***	***Flat***	***Depressed***	***Depressed***
GD 319-2	***Flat***	Depressed	?	Flat	Flat
Maradol Roja	***Depressed***		Depressed	Depressed	Depressed
Mission Beach	***Flat***			Depressed	Depressed
NT Red	***Depressed***				Depressed
Bisexual Group		**Eksotika**	**Kapoho**	**Subang**	**Sunrise**
	Stalk End Shape	***Depressed***	***Depressed***	***Depressed***	***Depressed***
BB5H	***Flat***	Depressed	Flat	Depressed	Flat
Eksotika	***Depressed***		Depressed	Depressed	Depressed
Kapoho	***Depressed***			Depressed	Depressed
Subang	***Depressed***				Depressed

Table 22 h

Parent	*Teat Shape*				
Female Group		**Maradol Roja**	**Mission Beach**	**NT Red**	**Paris**
	Teat Shape	***Slight***	***Slight***	***Pronounced***	***Pronounced***
GD 319-2	***Flat***	Flat	?	Flat	Flat
Maradol Roja	***Slight***		Slight	Slight	Pronounced
Mission Beach	***Slight***			Slight	Pronounced
NT Red	***Pronounced***				Pronounced
Bisexual Group		**Eksotika**	**Kapoho**	**Subang**	**Sunrise**
	Teat Shape	***Flat/Slight***	***Sunken/Flat***	***Slight Pronounced***	***Sunken***
BB5H	***Sunken/Flat***	Sunken	Sunken	Sunken	Sunken
Eksotika	***Flat/Slight***		Sunken	Flat	Sunken
Kapoho	***Sunken/Flat***			Flat	Sunken
Subang	***Slight Pronounced***				Sunken

Appendix 5

Random Cross One and Two Trials.

Random Cross One Trial

Date Planted: 17-19th January 2001
Location: Southedge Research Station.

Trial Design:	**Single Plant.**	
Total number of Plants:	Planted	4853
	Deaths	349
	Female	2394
	Bisexual	2110
	Total	4504

Random Selected plant for data collection 719 (14.8% of total population planted.)
Actual Plants assessed following further deaths 626. (12.9% of total population planted)
Additional plants assessed because of potential commercial value: 985.
Total plants assessed from RC1 **1611**.

Harvest period for data fruit: 13/09/2001 to 01/02/2002 (152 days)
Total number of fruit assessed: 4614 ie approximately 355 cartons

Random Cross Two Trial

Date Planted: 22nd May 2002
Location: Southedge Research Station.

Trial Design:	**Single Plant.**		
Total number of Plants:	Planted	4564	
	Deaths		117
	Female		2208
	Bisexual	2329	
	Total	4447	

Random Selected plant for data collection 504 (14.8% of total population planted.)
Actual Plants assessed following further deaths 448. (10.07% of total population planted)
Additional plants assessed because of potential commercial value: 662.
Total plants assessed from RC2 **1110**.

Harvest period for data fruit: 17/02/2003 to 28/11/03 (284 days)
Total number of fruit assessed: 7601 ie approximately 585 cartons

Table 1. Selected RC1 Plants: Quantitative Fruit Data

Row-Plant	Sex	Number Fruit	Fruit Weight (g)	Fruit Length (mm)	Fruit L/B Ratio	Fruit/ Cavity Ratio	Cavity Variation (mm)	Shelf Life (days)	TSS %	Fruit/ Carton (Small)
1-005	H	2	795	189	2.0	0.5	8.0	9	11.7	(13)
4-025	H	6	775	175	1.8	0.5	10.3	8	12.0	(13)
5-063	H	5	880	193	2.0	0.6	6.6	8	11.1	(12
7-054	H	2	929	200	1.9	0.5	9.5	8	9.5	15
10-045	H	1	592	148	1.6	0.5	14.0	12	9.8	(13)
10-047	H	2	875	186	1.8	0.4	2.5	9	10.9	(11)
11-057	F	1	728	174	1.8	0.5	9.0	4	11.4	(12)
12-022	H	8	610	171	1.9	0.5	6.5	7	11.0	(13)
12-031	H	7	618	168	1.9	0.5	6.4	8	11.2	(15)
12-070	H	4	772	190	2.0	.05	4.8	6	13.3	(13)
14-033	H	6	719	180	1.9	0.5	10.7	7	10.0	**(13)**
14-085	H	4	726	179	1.9	0.5	8.8	10	10.4	(13)
14-086	H	4	785	184	1.9	0.5	4.8	11	12.1	(12)
14-087	H	5	786	181	1.9	0.5	9.8	7	11.1	(13)
16-093	H	9	730	177	1.8	0.5	9.4	7	12.6	(13)
17-050	H	3	824	191	1.9	0.5	8.0	7	11.6	(12)
17-061	F	2	1,126	168	1.3	0.4	5.0	14	9.7	9
18-011	F	2	930	141	1.2	0.5	17.0	7	11.2	11
19-054	F	2	1,335	192	1.5	0.4	9.0	12	11.7	9
19-055	F	2	1,019	165	1.3	0.4	16.5	8	11.1	9
19-079	H	2	912	199	2.0	0.5	9.0	9	12.2	(11)
21-083	H	5	609	169	1.9	0.5	5.4	8	10.0	(15)
22-095	H	2	834	181	1.8	0.5	8.5	9	12.4	(11)
23-065	F	1	1,110	214	2.0	0.5	14.0	14	9.8	13
25-015	H	3	756	201	2.2	0.5	6.0	5	12.7	(13)
26-039	H	7	770	178	1.9	0.5	8.1	6	12.0	(13)
26-057	H	2	944	200	2.0	0.5	4.5	9	11.5	(11)
26-065	H	8	701	192	2.1	0.4	8.4	8	11.4	(13)
27-051	F	3	1,062	155	1.2	0.5	11.0	11	10.7	9
28-064	H	4	832	188	1.9	0.5	4.8	7	11.9	(12)
29-020	H	5	637	158	1.9	0.6	7.2	7	11.7	(16)
29-064	H	6	973	188	1.8	0.5	8.8	8	12.2	15
29-080	H	2	2,877	168	1.4	0.4	8.0	10	11.9	9
30-052	F	1	1,294	163	1.2	0.4	21.0	6	9.6	8
34-083	H	9	790	184	1.9	0.5	8.7	8	11.8	(13)
35-003	H	4	922	210	2.2	0.6	5.5	6	12.7	(13)
35-004	H	5	845	192	2.0	0.4	8.4	7	11.5	(12)
35-030	H	3	740	170	1.8	0.6	9.3	10	10.2	(13)
36-051	H	3	826	178	1.8	0.5	10.0	11	10.0	(11)
43-001	H	3	564	166	2.0	0.5	8.7	8	13.1	(16)
48-028	F	5	1,040	162	1.3	0.4	8.0	6	12.0	9
48-036	H	2	975	189	1.8	0.5	9.5	6	11.8	15
50-032	**F**	**4**	805	146	1.2	0.4	6.8	10	11.2	11
Female Mean			**1,045**	**168**	**1.4**	**0.5**	**11.7**	**9**	**10.8**	**11**
Bisexual Mean			**846**	**182**	**1.9**	**0.5**	**7.8**	**8**	**11.5**	**(12)**
Mean			**892**	**179**	**1.8**	**0.5**	**8.7**	**8**	**11.3**	**15**

Table 2. Selected RC1 Plants: Fruit Quality (Rating of 0 to 10 for each character)

Row-Plant	Sex	Number Fruit	Eating Quality	Sugar Content	Winter Spot	Fruit Shape	Fruit Size	Flesh Colour	Ripening Pattern	Teat Shape	Stalk Shape	Shelf Life	Value Index
1-005	H	2	8.0	9.0	6.3	10.0	5.9	4.0	3.0	10.0	5.0	8.5	**7.2**
4-025	H	6	8.2	9.5	9.2	9.7	5.5	6.7	7.3	7.5	0.0	8.3	**7.6**
5-063	H	5	5.8	8.6	9.0	9.2	7.6	9.0	7.0	7.0	4.0	8.6	**7.7**
7-054	H	2	4.5	6.3	10.0	7.0	8.2	9.0	7.0	10.0	10.0	10.0	**7.8**
10-045	H	1	5.5	6.7	10.0	9.0	1.8	0.0	3.0	10.0	10.0	10.0	**6.4**
10-047	H	2	5.3	8.3	6.3	10.0	7.5	9.0	7.0	10.0	10.0	9.5	**8.0**
11-057	F	1	6.5	9.1	10.0	6.0	4.6	0.0	7.0	10.0	10.0	5.0	**6.9**
12-022	H	8	7.6	8.5	9.1	7.0	2.3	9.0	3.5	8.8	8.8	7.0	**7.1**
12-031	H	7	7.6	8.7	8.9	6.0	2.4	4.6	3.6	6.4	10.0	8.4	**6.6**
12-070	H	4	7.5	10.0	9.4	6.5	5.4	0.0	6.0	8.8	10.0	5.0	**7.1**
14-033	H	6	5.4	7.0	9.6	7.0	4.4	9.0	7.0	8.3	10.0	7.3	**7.2**
14-085	H	4	5.9	7.6	8.8	7.0	4.5	4.0	4.0	6.3	7.5	10.0	**6.5**
14-086	H	4	7.5	9.8	10.0	8.5	5.7	0.0	7.0	10.0	10.0	10.0	**7.9**
14-087	H	5	6.2	8.6	10.0	6.4	5.4	9.0	3.0	7.0	10.0	7.0	**7.2**
16-093	H	9	7.8	9.9	8.3	6.0	4.4	8.1	6.1	8.9	6.7	7.2	**7.4**
17-050	H	3	6.0	9.4	9.2	10.0	6.5	0.0	7.0	10.0	0.0	7.7	**7.0**
17-061	F	2	5.3	6.6	7.5	9.0	7.5	8.0	3.0	10.0	10.0	10.0	7.4
18-011	F	2	6.5	8.8	6.3	8.0	8.6	4.0	3.0	10.0	10.0	7.5	**7.3**
19-054	F	2	5.3	8.7	8.8	10.0	4.5	4.0	8.5	10.0	5.0	7.5	**7.3**
19-055	F	2	5.3	8.7	8.8	8.0	8.7	9.0	10.0	10.0	10.0	8.5	**8.4**
19-079	H	2	5.3	9.7	10.0	10.0	8.2	0.0	10.0	10.0	5.0	9.5	**8.0**
21-083	H	5	4.9	7.0	8.5	5.2	2.2	6.4	7.6	8.0	8.0	8.0	**6.3**
22-095	H	2	7.0	10.0	8.8	6.0	6.7	9.0	10.0	5.0	0.0	9.5	**7.4**
23-065	F	1	8.0	6.7	7.5	10.0	7.8	8.0	3.0	10.0	10.0	9.0	**7.9**
25-015	H	3	8.8	10.0	7.5	5.3	5.1	9.7	9.0	6.7	10.0	3.7	**7.6**
26-039	H	7	8.1	9.5	6.8	10.0	5.4	1.1	7.4	9.3	10.0	5.7	**7.5**
26-057	H	2	7.0	8.8	6.3	7.0	8.9	8.0	5.0	10.0	10.0	10.0	**7.9**
26-065	H	8	7.4	9.0	6.6	6.8	4.0	3.0	7.8	7.5	2.5	8.6	**6.5**
27-051	F	3	6.8	8.1	7.5	8.0	6.8	8.0	10.0	10.0	0.0	9.7	**7.6**
28-064	H	4	6.8	9.7	8.8	9.0	6.6	4.0	9.3	10.0	10.0	7.5	**8.1**
29-020	H	5	5.5	9.4	9.0	5.2	2.7	4.8	3.0	9.0	10.0	5.8	**6.4**
29-064	H	6	6.8	9.9	9.2	10.0	9.1	8.0	8.5	10.0	8.3	6.2	**8.7**
29-080	H	2	7.0	8.4	7.5	10.0	2.9	8.0	5.0	6.5	10.0	7.5	**7.2**
30-052	F	1	6.5	6.4	7.5	10.0	4.1	8.0	7.0	10.0	0.0	5.0	**6.7**
34-083	H	9	7.1	9.5	8.3	8.7	5.8	4.4	6.0	8.3	2.2	8.6	**7.2**
35-003	H	4	7.3	9.9	7.5	6.0	7.4	4.0	5.0	10.0	10.0	5.5	**7.4**
35-004	H	5	7.3	9.3	9.5	8.8	6.9	3.2	3.8	10.0	0.0	7.2	**7.1**
35-030	H	3	5.7	7.3	8.3	8.0	4.8	8.0	4.3	8.3	0.0	9.0	**6.5**
36-051	H	3	5.7	7.0	8.3	10.0	6.5	0.0	4.3	6.7	6.7	9.0	**6.6**
43-001	H	3	5.0	10.0	10.0	8.7	1.3	0.0	10.0	10.0	10.0	9.3	**7.3**
48-028	F	5	6.7	9.7	10.0	7.6	8.0	9.0	8.2	10.0	4.0	5.8	**8.1**
48-036	H	2	5.8	9.4	10.0	10.0	9.5	8.0	5.0	7.5	5.0	5.5	**7.9**
50-032	F	4	7.6	8.8	8.1	7.5	6.1	4.0	7.8	10.0	5.0	8.3	**7.4**
Female Mean			**6.4**	**8.1**	**8.2**	**8.4**	**6.7**	**6.2**	**6.7**	**10.0**	**6.4**	**7.6**	**7.5**
Bisexual Mean			**6.6**	**8.8**	**8.6**	**8.0**	**5.5**	**5.2**	**6.1**	**8.5**	**7.0**	**7.9**	**Error**
Mean			**6.5**	**8.7**	**8.5**	**8.1**	**5.8**	**5.4**	**6.3**	**8.9**	**6.8**	**7.8**	**7.3**
Female Variance			**0.9**	**1.4**	**1.4**	**1.7**	**3.0**	**9.1**	**7.7**	**0.0**	**17.4**	**3.3**	**0.3**
Bisexual Variance			**1.3**	**1.2**	**1.4**	**2.9**	**4.9**	**12.3**	**4.8**	**2.2**	**14.4**	**2.8**	**0.3**
Variance			**1.2**	**1.3**	**1.4**	**2.6**	**4.6**	**11.5**	**5.4**	**2.1**	**14.7**	**2.9**	**0.3**

Table 3 Selected RC1 Plants: Incidence of Black Spot. **Appendix 5**

RowID	PlantID	Black Spot Incidence	Plant Sex
1	44	Mild	H
3	63	Severe	H
4	61	Severe	H
5	34	Mild	H
6	16	Mild	F
6	31	Severe	F
7	21	Mild	F
8	7	Mild	H
11	20	Mild	F
11	62	Severe	H
12	20	Severe	F
13	6	Severe	H
16	56	Severe	F
16	75	Severe	F
18	45	Severe	F
19	42	Mild	H
20	52	Mild	F
21	36	Mild	F
25	28	Mild	H
25	62	Severe	H
26	38	Mild	F
31	82	Severe	H
33	50	Severe	F
37	73	Severe	F
38	1	Severe	F
39	43	Severe	F
40	81	Severe	F
41	14	Mild	H
42	60	Severe	F
43	60	Mild	H
46	4	Mild	H
46	60	Severe	F
47	23	Mild	H
47	40	Severe	H
48	39	Mild	H
49	37	Mild	F
50	25	Mild	H
50	66	Severe	H
51	24	Mild	F
53	1	Mild	H

Visual Disease Rating

Mild = only in lower part of canopy% leaf
Severe = in upper part of canopy % leaf

Assessed when trees were mature
mid way through harvest

Table 4 Selected RC1 Plants: Fruit Quality Points & Comments. Appendix 5

PLANT ROW	Eating Quality	Sugar Content	Winter Spot	Fruit Shape	Fruit Size	Flesh Colour	Value Index	Plant Sex	COMMENTS
1 - 005	8.0	9.0	6.3	10.0	5.9	4.0	7.2	H	Good taste. Yellow flesh. Fair winter spot tolerance. Very good shape. Fruit tending big.
4 - 025	8.2	9.5	9.2	9.7	5.5	6.7	7.6	H	Good taste. Bright yellow flesh. Good winter spot tolerance. Very good shape. Big fruit.
10 - 047	5.3	8.3	6.3	10.0	7.5	9.0	8.0	H	Borderline taste. Red flesh. Fair winter spot tolerance. Very good shape. Ideal size.
12 - 070	7.5	10.0	9.4	6.5	5.4	0.0	7.1	H	Fair taste. Pale flesh. Very good winter spot tolerance. Fair shape. Big fruit.
14 - 085	5.9	7.6	8.8	7.0	4.5	4.0	6.5	H	Borderline taste. Yellow flesh. Good winter spot tolerance. Good shape. Quite big.
14 - 086	7.5	9.8	10.0	8.5	5.7	0.0	7.9	H	Fair to good taste (high sugar). Very pale flesh. Very good winter spot tolerance. Good shape. Fruit tending big.
14 - 087	6.2	8.6	10.0	6.4	5.4	9.0	7.2	H	Fair taste. Red flesh. Very good winter spot tolerance. Fair shape. Big fruit.
16 - 093	7.8	9.9	8.3	6.0	4.4	8.1	7.4	H	Good taste. Orange flesh. Good winter spot tolerance. Fair shape. Quite big.
19 - 055	5.3	8.7	8.8	8.0	8.7	9.0	8.4	F	Borderline taste. Red flesh. Good winter spot tolerance. Good shape. Ideal size.
28 - 064	6.8	9.7	8.8	9.0	6.6	4.0	8.1	H	Fair taste (high sugar). Yellow flesh. Good winter spot tolerance.. Very good shape. Ideal size.
29 - 020	5.5	9.4	9.0	5.2	2.7	4.8	6.4	H	Borderline taste (high sugar). Yellow flesh. Very good winter spot tolerance. Poor shape. Very big.
35 - 004	7.3	9.3	9.5	8.8	6.9	3.2	7.1	H	Good taste. Yellow flesh. Very good winter spot tolerance. Good shape. Fruit tending big.
43 - 001	5.0	10.0	10.0	8.7	1.3	0.0	7.3	H	Borderline taste (high sugar). Pale flesh. Very good winter spot tolerance. Good shape. Very big.
48 - 036	5.8	9.4	10.0	10.0	9.5	8.0	7.9	H	Borderline taste (high sugar). Orange flesh. Very good winter spot tolerance. Very good shape. Ideal size.

Table 5 Selected RC2 Plants: Quantitative Fruit Data Appendix 5

Row-Plant	Sex	Number Fruit	Fruit Weight (g)	Fruit Length (mm)	Fruit L/B Ratio	Fruit Flesh Ratio	Fruit Flesh Variation	Days Harvest to Ripe	TSS %	Fruit/ Carton (Small)
1-007	H	12	513	164	2.1	0.6	11.1	5	11.6	(18)
1-010	H	15	788	204	2.2	0.5	10.7	5	11.6	(13)
1-012	H	19	772	174	1.9	0.5	11.2	7	11.6	(13)
1-075	H	25	1,050	161	1.4	0.5	13.4	13	10.4	12
2-015	F	17	790	142	1.3	0.5	8.5	10	11.4	13
3-033	H	13	1,071	200	1.9	0.6	11.3	5	11.7	13
5-098	H	16	791	191	2.1	0.6	14.7	9	11.3	(13)
6-108	H	12	751	203	2.4	0.5	9.9	7	11.4	(16)
7-051	H	21	496	149	1.8	0.6	10.3	6	10.8	(16)
7-082	H	18	870	172	1.7	0.5	13.2	7	11.4	(12)
8-093	H	13	1,024	186	1.7	0.5	12.2	8	10.9	13
10-058	F	16	1,392	168	1.3	0.4	12.5	10	10.1	9
11-037	H	11	1,155	204	1.9	0.5	7.7	8	10.7	13
12-002	H	11	1,095	186	1.7	0.6	8.3	8	10.0	13
12-054	H	10	1,084	216	2.2	0.5	6.0	7	11.7	(11)
12-093	H	12	1,083	202	1.9	0.6	15.8	8	9.7	13
12-115	H	9	894	201	2.2	0.5	8.8	8	11.6	(13)
14-115	H	10	1,082	216	2.1	0.5	12.4	7	11.1	15
15-123	H	11	936	208	2.0	0.5	11.1	10	11.7	15
15-131	F	17	1,271	167	1.4	0.5	16.2	10	10.2	9
18-045	H	29	1,042	199	1.9	0.5	5.7	8	11.9	13
18-084	H	12	903	179	1.8	0.6	10.5	9	11.3	15
19-036	H	21	1,040	220	2.2	0.5	11.6	8	10.5	15
19-106	H	13	647	169	1.9	0.6	8.2	10	10.9	(15)
20-065	H	23	803	168	1.8	0.6	12.6	7	10.9	(12)
23-100	H	11	880	171	1.6	0.5	13.2	7	9.6	12
24-029	H	17	720	186	2.0	0.6	14.9	9	11.3	(13)
24-087	H	15	1,141	197	1.8	0.5	15.3	9	10.4	13
25-005	H	13	860	170	1.7	0.5	7.1	7	12.2	15
25-040	H	18	894	199	2.0	0.5	14.2	7	11.9	(12)
28-011	H	22	1,378	219	1.9	0.5	11.1	10	10.5	12
28-038	H	15	1,392	218	1.9	0.5	14.4	9	10.9	12
28-039	H	24	861	161	1.5	0.5	11.7	7	10.3	13
28-071	H	21	894	189	1.9	0.5	8.7	6	11.2	(12)
29-082	H	30	624	151	1.6	0.5	11.4	6	9.5	(13)
32-006	H	7	1,070	183	1.7	0.5	6.7	8	10.9	13
32-105	F	19	1,172	150	1.2	0.4	9.1	7	12.0	9
33-039	F	21	1,019	158	1.4	0.5	8.6	10	10.7	12
33-066	H	20	901	169	1.7	0.5	10.1	8	12.8	(11)
Female Mean			**1,203**	**174**	**1.4**	**0.4**	**10.8**	**8**	**10.5**	**9**
Bisexual Mean			**1,052**	**197**	**1.9**	**0.5**	**11.1**	**8**	**10.6**	**13**
Mean			**953**	**184**	**1.8**	**0.5**	**11.0**	**8**	**11.0**	**13**

Table 6 **Appendix 5**

Selected RC2 Plants: Fruit Quality (Rating of 0 to 10 for Each Character)

Row-Plant	Sex	Number Fruit	Eating Quality Points	Sugar Content Points	Winter Spot Points	Fruit Shape Points	Fruit Size Points	Flesh Colour Points	Ripening Points	Teat Shape Points	Stalk Shape Points	Shelf Life Points	Fruit Value Index
1-007	H	12	7.1	8.9	9.8	4.3	1.1	7.3	3.6	8.3	10.0	4.0	**6.5**
1-010	H	15	6.4	9.1	6.7	3.7	5.4	9.4	4.5	8.5	9.3	4.3	**6.7**
1-012	H	19	6.4	9.1	8.3	5.9	4.6	7.6	6.2	8.3	8.9	6.2	**7.1**
1-075	H	25	4.9	7.6	6.8	9.5	5.9	8.3	7.6	9.2	5.6	7.8	**7.2**
2-015	F	17	7.7	8.6	4.4	9.8	5.8	9.6	3.0	5.1	8.8	7.8	**7.1**
3-033	H	13	8.5	9.4	8.5	8.1	6.6	9.8	5.0	8.2	9.2	3.7	**7.9**
5-098	H	16	6.7	8.9	6.7	4.7	4.6	7.5	6.4	8.3	3.8	8.6	**6.6**
6-108	H	12	6.9	8.8	7.1	4.6	5.0	7.3	3.3	5.3	9.2	6.8	**6.4**
7-051	H	21	7.6	8.2	8.9	6.0	0.8	2.7	3.0	8.3	9.0	4.5	**6.0**
7-082	H	18	7.7	8.9	5.0	7.1	7.0	7.6	5.3	9.2	8.3	6.2	**7.3**
8-093	H	13	6.7	8.4	5.2	7.7	6.2	9.1	7.2	8.8	9.2	6.6	**7.4**
10-058	F	16	6.5	7.1	5.8	8.0	3.1	8.0	6.0	5.6	2.5	7.9	**6.1**
11-037	H	11	6.7	8.0	5.5	6.4	6.0	9.6	6.2	8.2	3.6	5.0	**6.6**
12-002	H	11	6.4	7.0	7.5	7.5	6.4	8.7	4.5	5.9	2.7	6.3	**6.5**
12-054	H	10	5.9	9.1	9.0	6.8	6.2	8.0	7.1	9.5	8.0	6.7	**7.6**
12-093	H	12	7.0	6.5	9.0	7.8	4.8	7.3	5.0	9.2	8.3	7.3	**7.1**
12-115	H	9	6.4	9.3	8.6	7.8	5.5	8.0	4.3	5.2	7.8	8.3	**7.2**
14-115	H	10	8.9	8.3	5.3	6.4	7.3	9.8	3.4	9.3	5.0	6.8	**7.2**
15-123	H	11	7.6	9.5	8.4	1.1	6.8	10.0	8.0	4.2	4.5	7.1	**6.8**
15-131	F	17	7.6	7.1	7.4	8.0	2.1	3.3	7.6	7.1	8.8	7.2	**6.6**
18-045	H	29	6.3	9.3	6.1	6.6	6.2	10.0	9.2	7.4	4.1	6.0	**7.2**
18-084	H	12	6.5	8.6	6.7	5.2	5.7	8.2	3.7	8.8	7.5	6.3	**6.7**
19-036	H	21	7.8	7.8	7.1	4.0	4.7	2.7	4.3	7.4	6.2	6.7	**6.0**
19-106	H	13	5.8	8.3	9.2	9.2	2.8	4.3	8.8	7.5	3.1	7.4	**6.8**
20-065	H	23	7.1	8.3	4.7	7.5	4.9	7.7	4.0	7.2	8.7	5.7	**6.6**
23-100	H	11	6.0	6.5	6.8	9.5	7.2	5.1	3.7	9.4	8.2	6.2	**6.9**
24-029	H	17	8.1	8.9	6.3	4.9	4.4	0.0	8.2	7.9	6.5	7.4	**7.2**
24-087	H	15	7.4	7.5	4.7	7.7	5.5	8.0	3.3	8.2	9.3	6.7	**6.8**
25-005	H	13	9.2	9.5	8.3	4.5	6.2	9.7	3.0	7.3	6.9	6.7	**7.3**
25-040	H	18	7.2	9.6	9.6	6.2	7.3	7.6	7.5	9.6	3.9	4.8	**7.6**
28-011	H	22	6.2	7.6	3.2	5.8	3.3	7.3	7.3	6.3	8.2	8.0	**6.0**
28-038	H	15	6.0	8.0	5.2	4.3	3.2	7.5	5.1	7.2	2.0	6.4	**5.6**
28-039	H	24	7.9	7.4	4.3	7.8	6.3	1.0	3.8	9.2	1.7	7.0	**6.0**
28-071	H	21	8.2	8.7	8.6	5.8	5.1	10.0	4.8	8.8	9.5	6.0	**7.5**
29-082	H	30	6.2	6.3	8.8	7.1	3.0	6.3	3.4	8.7	8.0	4.7	**6.3**
32-006	H	7	7.1	8.2	10.0	8.3	2.9	8.0	5.0	8.0	10.0	7.1	**7.4**
32-105	F	19	9.1	9.3	6.3	7.1	5.4	7.2	5.1	10.0	1.1	5.2	**7.0**
33-039	F	21	8.2	8.0	4.9	9.7	4.7	9.6	4.4	7.0	0.5	8.0	**6.8**
33-066	H	20	9.0	9.8	3.1	9.2	6.2	7.6	3.0	9.0	7.5	7.0	**7.3**
Female Mean			**7.8**	**8.0**	**5.7**	**8.5**	**4.2**	**7.5**	**5.2**	**7.0**	**4.3**	**7.2**	**6.7**
Bisexual Mean			**7.0**	**8.4**	**7.0**	**6.4**	**5.1**	**7.6**	**5.3**	**8.0**	**6.9**	**6.4**	**6.9**
Mean			**7.1**	**8.3**	**6.9**	**6.7**	**5.0**	**7.6**	**5.3**	**7.9**	**6.6**	**6.5**	**6.8**
Female Variance			**0.9**	**0.9**	**1.4**	**1.4**	**2.5**	**6.7**	**3.0**	**3.7**	**7.3**	**1.4**	**0.2**
Bisexual Variance			**1.0**	**0.9**	**3.7**	**3.6**	**2.8**	**4.9**	**3.4**	**1.7**	**6.3**	**1.4**	**0.3**
Variance			**1.0**	**0.9**	**3.5**	**3.8**	**2.8**	**4.9**	**3.3**	**2.0**	**8.1**	**1.5**	**0.3**

Table 7 . Appendix 5

RC1 and RC2 Populations: Fruit and Plant Data Set (a)

	Group	Mean		Maximum		Minimum		Standard Deviation	
		RC1	RC2	RC1	RC2	RC1	RC2	RC1	RC2
Minimum Fruiting Height	Female	81	61	137	104	49	37	13	12
	Bisexual	84	64	137	101	47	37	16	12
	All	**82**	**62**	**137**	**104**	**47**	**37**	**14**	**12**
Fruit Weight	Female	1,476	1,329	2,947	2,476	463	432	443	361
	Bisexual	1,069	1,100	2,877	2,391	425	286	316	353
	All	**1,276**	**1,225**	**2,947**	**2,476**	**425**	**286**	**436**	**375**
Fruit Circum	Female	444	410	626	531	305	272	50	44
	Bisexual	331	328	448	450	230	216	34	40
	All	**388**	**372**	**626**	**531**	**230**	**216**	**71**	**59**
Fruit Length	Female	185	179	274	257	114	127	30	25
	Bisexual	210	205	330	296	139	136	31	27
	All	**197**	**191**	**330**	**296**	**114**	**127**	**33**	**29**
Fruit Flesh Variation	Female	12	10	28	22	1	3	5	4
	Bisexual	11	10	26	18	2	5	4	3
	All	**11**	**10**	**28**	**22**	**1**	**3**	**4**	**3**
Fruit Flesh Ratio	Female	0.40	0.41	0.54	0.59	0.30	0.32	0.05	0.04
	Bisexual	0.51	0.51	0.78	0.61	0.30	0.40	0.05	0.04
	All	**0.46**	**0.46**	**0.78**	**0.61**	**0.30**	**0.32**	**0.07**	**0.06**
% Brix	Female	9.4	10.7	14.2	13.4	5.1	8.0	1.5	1.0
	Bisexual	9.6	10.6	14.3	13.1	4.0	8.0	1.7	1.0
	All	**9.5**	**10.7**	**14.3**	**13.4**	**4.0**	**8.0**	**1.6**	**1.0**
Fruit Length/ Breadth	Female	1.32	1.39	2.02	2.00	0.85	0.95	0.19	0.19
	Bisexual	2.01	1.99	6.62	2.74	1.13	1.18	0.37	0.24
	All	**1.66**	**1.66**	**6.62**	**2.74**	**0.85**	**0.95**	**0.45**	**0.37**
Days to Ripen	Female	12	8	21	13	4	3	3	2
	Bisexual	10	8	21	12	4	5	3	1
	All	**11**	**8**	**21**	**13**	**4**	**3**	**3**	**2**
Teat Size Rating	Female	4.2	4.6	7.0	7.0	1.0	1.0	1.4	1.2
	Bisexual	2.2	3.4	7.0	6.6	1.0	1.2	1.4	1.0
	All	**3.2**	**4.0**	**7.0**	**7.0**	**1.0**	**1.0**	**1.7**	**1.3**
Fruit Ridging Rating	Female	2.5	2.2	7.0	6.2	1.0	1.0	1.3	0.9
	Bisexual	1.3	1.5	5.0	4.3	1.0	1.0	0.7	0.6
	All	**1.9**	**1.9**	**7.0**	**6.2**	**1.0**	**1.0**	**1.2**	**0.9**
Winter Spot Rating	Female	2.1	2.1	4.0	4.0	0.0	0.0	1.4	1.1
	Bisexual	2.4	1.9	4.0	4.0	0.0	0.0	1.4	1.1
	All	**2.2**	**2.0**	**4.0**	**4.0**	**0.0**	**0.0**	**1.4**	**1.1**
Fruit Rot Rating	Female	0.6	0.3	4.0	1.6	0.0	0.0	0.9	0.4
	Bisexual	0.2	0.2	4.0	1.5	0.0	0.0	0.5	0.2
	All	**0.4**	**0.2**	**4.0**	**1.6**	**0.0**	**0.0**	**0.8**	**0.3**
Scar Rot Rating	Female	0.4	0.5	3.0	3.0	0.0	0.0	0.9	0.5
	Bisexual	0.3	0.6	3.0	3.0	0.0	0.0	0.7	0.5
	All	**0.4**	**0.5**	**3.0**	**3.0**	**0.0**	**0.0**	**0.8**	**0.5**
Flesh Firmness Rating	Female	2.8	2.8	4.0	3.7	1.0	1.5	0.4	1.5
	Bisexual	2.8	2.9	4.0	3.4	1.0	1.5	0.5	1.5
	All	**2.8**	**2.9**	**4.0**	**3.7**	**1.0**	**1.5**	**0.4**	**1.5**

Table 8. **Appendix 5**

RC1 and RC2 Populations: Fruit and Plant Data Set (b)

	Group	Mean		Maximum		Minimum		Standard Deviation	
		RC1	RC2	RC1	RC2	RC1	RC2	RC1	RC2
Flesh Colour Rating	Female	1.6	1.7	3.3	3.4	0.0	0.0	1.0	1.0
	Bisexual	1.4	1.6	4.0	3.8	0.0	0.0	0.9	1.0
	All	**1.5**	**1.7**	**4.0**	**3.8**	**0.0**	**0.0**	**1.0**	**1.0**
Eating Quality Rating	Female	3.2	2.7	5.0	4.8	1.0	1.1	0.8	0.6
	Bisexual	3.3	2.8	5.0	4.3	1.3	1.0	0.7	0.7
	All	**3.2**	**2.7**	**5.0**	**4.8**	**1.0**	**1.0**	**0.8**	**0.7**
Value Index Points	Female	5.6	6.2	8.2	7.9	2.8	3.9	0.9	0.9
	Bisexual	5.5	5.9	8.3	7.4	2.7	4.1	1.1	0.7
	All	**5.6**	**6.0**	**8.3**	**7.9**	**2.7**	**3.9**	**1.0**	**0.8**
Eating Quality Points	Female	4.8	6.0	9.3	8.8	1.0	1.3	2.1	1.6
	Bisexual	4.7	5.6	9.0	9.2	1.0	1.8	1.9	1.7
	All	**4.7**	**5.8**	**9.3**	**9.2**	**1.0**	**1.3**	**2.0**	**1.7**
Sugar Level Points	Female	6.0	8.0	10.0	10.0	0.0	4.0	2.1	1.3
	Bisexual	6.3	7.8	10.0	10.0	0.0	4.1	2.4	1.3
	All	**6.2**	**7.9**	**10.0**	**10.0**	**0.0**	**4.0**	**2.3**	**1.3**
Winter Spot Points	Female	4.8	4.8	10.0	10.0	0.0	0.0	3.6	2.6
	Bisexual	4.0	5.3	10.0	10.0	0.0	0.0	3.5	2.8
	All	**4.4**	**5.0**	**10.0**	**10.0**	**0.0**	**0.0**	**3.5**	**2.7**
Fruit Shape Points	Female	6.3	7.5	10.0	10.0	0.0	2.3	2.3	1.6
	Bisexual	6.5	5.3	10.0	10.0	0.0	0.0	2.9	2.3
	All	**6.4**	**6.5**	**10.0**	**10.0**	**0.0**	**0.0**	**2.7**	**2.2**
Fruit Size Points	Female	3.1	3.9	10.0	8.8	0.0	0.0	3.4	2.4
	Bisexual	3.8	3.6	10.0	10.0	0.0	0.0	3.3	2.4
	All	**3.5**	**3.8**	**10.0**	**10.0**	**0.0**	**0.0**	**3.4**	**2.4**
Flesh Colour Points	Female	7.5	7.8	10.0	10.0	0.0	0.0	3.0	2.3
	Bisexual	7.1	7.8	10.0	10.0	0.0	0.0	3.0	2.2
	All	**7.3**	**7.8**	**10.0**	**10.0**	**0.0**	**0.0**	**3.0**	**2.2**
Ripening Pattern Points	Female	6.9	7.1	10.0	10.0	0.0	3.0	2.7	2.1
	Bisexual	4.9	5.2	10.0	9.6	0.0	2.7	2.2	1.8
	All	**5.9**	**6.3**	**10.0**	**10.0**	**0.0**	**2.7**	**2.6**	**2.2**
Teat Shape Points	Female	6.0	4.0	10.0	10.0	0.0	0.0	3.8	3.0
	Bisexual	6.2	6.6	10.0	10.0	0.0	0.6	2.3	2.2
	All	**6.1**	**5.1**	**10.0**	**10.0**	**0.0**	**0.0**	**3.2**	**3.0**
Stalk End Points	Female	4.5	5.1	10.0	10.0	0.0	0.0	4.6	3.5
	Bisexual	4.3	6.5	10.0	10.0	0.0	0.0	4.0	3.0
	All	**4.4**	**5.7**	**10.0**	**10.0**	**0.0**	**0.0**	**4.3**	**3.4**
Shelf Life Points	Female	8.6	6.5	10.0	10.0	0.0	3.0	1.9	1.5
	Bisexual	8.6	6.2	10.0	9.7	0.3	1.0	1.6	1.5
	All	**8.6**	**6.3**	**10.0**	**10.0**	**0.0**	**1.0**	**1.8**	**1.5**
% Fruit Set	Female	102		33		233		27	
	Bisexual	96		28		200		33	
	All	**99**		**31**		**233**		**27**	
% Carpelloid Fruit	Female	0		2		29		0	
	Bisexual	12		17		93		0	
	All	**6**		**13**		**93**		**0**	

Table 9. RC1 Population: Correlation Bisexual Data

Appendix 5

	Fruit Weight	Fruit Circum	Fruit Length	Flesh Variance	Fruit Flesh Ratio	TSS %	Length/Breadth	Days to Ripe	Teat Size Rating	Fruit Ridging Pattern	Winter Spot	Fruit Rot	Scar Rot	Flesh Firmness	Flesh Colour	Eating Quality	Fruit Value Index	Eating Quality Points	Sugar Level Points	Winter Spot Points	Fruit Shape Points	Fruit Size Points	Flesh Colour Points	Ripening Points	Teat Shape Points	Stalk Insertion Points	Shelf Life Points	Fruit Set	Carpelloid
Fruit Height	-0.04	-0.06	0.01	-0.14	-0.03	0.41	-0.03	-0.40	0.07	0.04	-0.17	-0.21	-0.22	0.03	-0.18	-0.18	0.26	0.21	0.43	0.17	-0.07	-0.03	-0.18	0.22	0.17	0.11	-0.17	-0.26	-0.06
Fruit Weight		0.84	0.74	0.17	-0.28	-0.11	0.23	-0.10	0.20	0.19	-0.11	0.06	0.02	0.07	0.26	0.20	-0.40	-0.24	-0.11	0.11	-0.22	-0.75	0.25	0.19	-0.21	-0.18	-0.04	-0.16	0.04
Fruit Circum			0.46	0.26	-0.52	-0.16	-0.22	-0.01	0.06	0.29	0.02	-0.00	0.03	0.04	0.24	0.22	-0.43	-0.23	-0.16	-0.02	-0.14	-0.69	0.24	0.23	-0.27	-0.26	0.03	-0.16	0.10
Fruit Length				0.03	-0.06	-0.06	0.60	-0.18	0.40	0.15	-0.18	0.04	-0.09	0.09	0.29	0.17	-0.41	-0.22	-0.05	0.18	-0.47	-0.71	0.19	0.22	-0.19	-0.11	-0.09	-0.18	-0.01
Flesh Variance					0.11	-0.31	-0.16	0.28	-0.20	-0.09	0.31	0.05	0.06	-0.05	0.17	0.10	-0.24	-0.06	-0.31	-0.31	0.15	-0.13	0.18	-0.19	-0.14	-0.07	0.17	0.07	-0.01
Fruit Flesh Ratio						-0.07	0.42	0.16	-0.28	-0.38	-0.03	0.05	0.02	-0.12	-0.10	0.03	0.09	-0.05	-0.06	0.03	0.17	0.22	-0.07	-0.33	0.15	0.05	0.09	0.13	-0.23
TSS %							0.02	-0.62	0.31	0.18	-0.30	-0.30	-0.35	0.15	-0.19	-0.59	0.62	0.55	0.99	0.30	-0.11	0.05	-0.21	0.42	0.23	0.19	-0.29	-0.25	-0.07
Length/breadth								-0.10	0.27	-0.05	-0.17	0.08	-0.07	0.03	0.08	0.02	-0.09	-0.07	0.03	0.17	-0.29	-0.16	0.03	0.03	-0.02	0.03	-0.09	-0.07	-0.09
Days to Ripe									-0.38	-0.18	0.33	0.28	0.43	-0.12	0.06	0.27	-0.35	-0.25	-0.64	-0.33	0.19	0.13	0.13	-0.36	-0.24	-0.18	0.55	0.22	-0.00
Teat Size Rating										0.43	-0.20	-0.06	-0.19	0.09	0.06	-0.15	0.09	0.12	0.31	0.20	-0.28	-0.21	-0.03	0.28	-0.10	0.20	-0.16	-0.12	0.13
Ridge pattern											-0.09	-0.04	-0.12	-0.02	0.07	-0.02	-0.16	-0.02	0.18	0.09	-0.43	-0.22	0.06	0.27	-0.32	-0.10	-0.01	-0.19	0.20
Winter Spot												-0.03	0.18	0.09	0.19	-0.06	-0.43	0.04	-0.32	-1.00	0.20	0.06	0.22	-0.29	-0.23	-0.07	0.17	0.17	0.13
Fruit Rot													0.22	-0.05	0.01	0.15	-0.16	-0.14	-0.31	0.03	0.01	-0.00	0.05	-0.14	-0.06	-0.01	-0.16	0.13	0.13
Scar Rot														0.02	0.02	0.11	-0.28	-0.14	-0.36	-0.18	0.07	0.00	0.07	-0.15	-0.13	-0.18	-0.14	0.13	0.12
Flesh Firmness															0.16	-0.27	0.05	0.15	0.15	-0.09	0.02	-0.11	0.18	0.05	-0.04	0.09	-0.35	0.14	0.12
Flesh Colour																0.12	-0.17	-0.09	-0.18	-0.19	-0.09	-0.24	0.85	0.02	-0.24	-0.21	0.02	-0.01	0.02
Eating Quality																	-0.50	-0.87	-0.57	0.06	-0.08	-0.16	0.10	-0.19	-0.14	-0.13	0.20	0.08	-0.02
Fruit Value Index																		0.55	0.63	0.43	0.36	0.52	-0.12	0.27	0.49	0.44	-0.14	-0.04	-0.06
Eating Quality Pts																			0.54	-0.04	0.10	0.21	-0.12	0.20	0.11	0.10	-0.14	-0.04	0.02
Sugar Level Pts																				0.32	-0.11	0.04	-0.20	0.42	0.23	0.18	-0.29	-0.26	-0.08
Winter Spot Pts																					-0.20	-0.06	-0.22	0.29	0.23	0.07	-0.17	-0.17	-0.13
Fruit Shape Pts																						0.30	-0.03	-0.27	0.17	0.10	0.09	0.19	0.11
Fruit Size Pts																							-0.19	-0.23	0.21	0.21	0.05	0.17	0.01
Flesh Colour Pts																								-0.02	-0.23	-0.20	0.02	-0.01	0.01
Ripening Pattern Pts																									-0.01	0.04	-0.21	-0.20	-0.01
Teat Shape Pts																										0.29	-0.13	0.03	-0.12
Stalk Insertion Pts																											-0.15	0.11	0.03
Shelf Life Pts																												0.00	-0.12
Fruit Set																													0.12

Table 10. RC1 Population: Correlation Female Data

Appendix 5

	Fruit Weight	Fruit Circum	Fruit Length	Flesh Variance	Fruit Flesh Ratio	TSS %	Length/Breadth	Days to Ripe	Teat Size Rating	Fruit Ridging Pattern	Winter Spot	Fruit Rot	Scar Rot	Flesh Firmness	Flesh Colour	Eating Quality	Fruit Value Index	Eating Quality Points	Sugar Level Points	Winter Spot Points	Fruit Shape Points	Fruit Size Points	Flesh Colour Points	Ripening Points	Teat Shape Points	Stalk Insertion Points	Shelf Life Points	Fruit Set	Carpelloid
Fruit Height	-0.10	-0.04	-0.10	-0.06	-0.10	0.20	-0.08	-0.02	-0.02	0.19	0.23	-0.13	-0.20	0.15	-0.19	-0.16	-0.01	0.16	0.22	-0.23	-0.19	0.11	-0.09	-0.07	0.01	-0.00	0.11	-0.23	-0.06
Fruit Weight		0.91	0.78	0.01	-0.35	-0.16	0.14	0.14	0.35	0.05	-0.11	0.01	0.11	0.07	0.22	0.11	-0.39	-0.12	-0.16	0.11	-0.02	-0.76	0.20	0.19	-0.31	0.03	0.05	0.01	-0.02
Fruit Circum			0.55	-0.05	-0.54	-0.16	-0.20	0.23	0.32	0.15	-0.06	0.06	0.12	0.08	0.21	0.07	-0.41	-0.07	-0.15	0.06	-0.20	-0.71	0.21	0.26	-0.24	-0.06	0.07	-0.02	-0.05
Fruit Length				-0.01	-0.21	-0.10	0.69	-0.02	0.57	0.07	-0.09	-0.10	0.04	0.08	0.23	0.06	-0.31	-0.08	-0.11	0.09	0.15	-0.60	0.16	0.15	-0.56	0.15	0.01	0.01	0.06
Flesh Variance					0.50	-0.26	0.02	0.05	-0.08	-0.03	-0.03	-0.11	0.02	0.03	-0.08	0.16	-0.06	-0.11	-0.26	0.03	0.09	-0.04	-0.06	-0.22	0.12	0.19	0.05	0.08	-0.08
Fruit Flesh Ratio						-0.04	0.24	-0.18	-0.38	-0.28	-0.07	-0.08	-0.02	-0.06	-0.20	0.07	0.21	-0.07	-0.04	0.07	0.26	0.28	-0.17	-0.34	0.32	0.08	-0.09	0.09	-0.03
TSS %							0.01	-0.39	0.07	0.14	0.19	-0.25	-0.21	0.08	-0.06	-0.71	0.40	0.62	0.99	-0.19	-0.17	0.17	-0.04	0.04	-0.09	-0.13	-0.09	-0.05	0.13
Length/breadth								-0.22	0.37	-0.06	-0.03	-0.16	-0.04	0.02	0.10	0.02	-0.04	-0.04	-0.00	0.03	0.33	-0.11	0.01	-0.04	-0.43	0.21	-0.05	0.02	0.12
Days to Ripe									-0.00	0.07	0.19	0.19	0.12	-0.05	0.08	0.25	-0.26	-0.23	-0.39	-0.19	-0.07	-0.13	0.14	0.16	0.02	-0.09	0.50	-0.04	-0.07
Teat Size Rating										0.33	0.09	-0.07	-0.06	0.04	0.30	-0.12	-0.33	0.12	0.06	-0.09	-0.06	-0.24	0.17	0.19	-0.90	-0.01	0.07	-0.06	0.03
Ridge pattern											0.23	-0.06	-0.17	0.15	0.17	-0.21	-0.29	0.22	0.14	-0.23	-0.60	-0.05	0.11	0.18	-0.33	-0.18	0.09	-0.18	0.10
Winter Spot												-0.10	-0.13	0.24	0.09	-0.28	-0.28	0.33	0.20	-1.00	-0.19	0.13	0.09	-0.05	-0.11	0.09	0.17	0.01	0.02
Fruit Rot													0.31	-0.14	0.12	0.24	-0.14	-0.20	-0.25	0.10	0.09	-0.07	0.09	0.02	0.02	-0.09	-0.28	-0.01	-0.03
Scar Rot														-0.03	0.06	0.23	-0.15	-0.23	-0.22	0.13	0.09	-0.11	0.05	0.12	0.04	-0.15	-0.39	0.05	-0.04
Flesh Firmness															0.05	-0.20	-0.04	0.15	0.09	-0.24	-0.08	-0.02	0.10	-0.03	0.01	0.02	-0.04	-0.03	0.05
Flesh Colour																0.00	-0.07	-0.03	-0.06	-0.09	-0.07	-0.23	0.82	0.14	-0.29	-0.08	0.00	0.10	0.03
Eating Quality																	-0.41	-0.87	-0.73	0.28	0.15	-0.17	-0.05	-0.04	0.09	0.05	-0.06	0.03	-0.06
Fruit Value Index																		0.38	0.41	0.28	0.33	0.51	0.04	0.12	0.41	0.23	0.10	0.09	-0.02
Eating Quality Pts																			0.65	-0.33	-0.16	0.17	0.00	0.02	-0.10	-0.07	0.07	-0.04	0.03
Sugar Level Pts																				-0.20	-0.18	0.18	-0.03	0.03	-0.08	-0.11	-0.08	-0.05	0.13
Winter Spot Pts																					0.19	-0.13	-0.09	0.05	0.11	-0.09	-0.17	-0.01	-0.02
Fruit Shape Pts																						0.02	-0.09	-0.16	0.07	0.20	-0.02	0.18	-0.16
Fruit Size Pts																							-0.23	-0.07	0.25	-0.06	-0.00	0.03	-0.01
Flesh Colour Pts																								0.10	-0.17	-0.05	0.08	0.06	0.04
Ripening Pattern Pts																									-0.15	-0.20	0.10	-0.12	-0.06
Teat Shape Pts																										0.09	-0.05	0.10	-0.04
Stalk Insertion Pts																											0.11	0.10	0.03
Shelf Life Pts																												0.00	0.01
Fruit Set																													-0.04

Table 11. RC1 Population: Correlation All Data (Female and Bisexual)

Appendix 5

	Fruit Weight	Fruit Circum	Fruit Length	Flesh Variance	Fruit Flesh Ratio	TSS %	Length/Breadth	Days to Ripe	Teat Size Rating	Fruit Ridging Pattern	Winter Spot	Fruit Rot	Scar Rot	Flesh Firmness	Flesh Colour	Eating Quality	Fruit Value Index	Eating Quality Points	Sugar Level Points	Winter Spot Points	Fruit Shape Points	Fruit Size Points	Flesh Colour Points	Ripening Points	Teat Shape Points	Stalk Insertion Points	Shelf Life Points	Fruit Set	Carpelloid
Fruit Height	-0.11	-0.11	0.00	-0.11	0.04	0.33	0.05	-0.23	-0.03	0.06	0.02	-0.17	-0.20	0.07	-0.19	-0.16	0.14	0.19	0.34	-0.02	-0.12	0.05	-0.14	0.03	0.07	0.05	-0.03	-0.25	0.00
Fruit Weight		0.85	0.44	0.15	-0.54	-0.15	-0.26	0.15	0.48	0.29	-0.15	0.14	0.09	0.08	0.25	0.10	-0.30	-0.14	-0.15	0.15	-0.11	-0.71	0.23	0.33	-0.27	-0.03	0.02	-0.00	-0.19
Fruit Circum			-0.01	0.19	-0.81	-0.14	-0.68	0.27	0.56	0.48	-0.11	0.23	0.10	0.06	0.20	0.03	-0.18	-0.07	-0.13	0.11	-0.13	-0.51	0.19	0.44	-0.18	-0.07	0.04	0.03	-0.32
Fruit Length				-0.07	0.21	-0.05	0.65	-0.18	0.16	-0.11	-0.07	-0.14	-0.04	0.06	0.21	0.12	-0.36	-0.14	-0.05	0.07	-0.17	-0.56	0.13	0.01	-0.36	0.02	-0.03	-0.10	0.16
Flesh Variance					0.05	-0.28	-0.20	0.19	0.01	0.06	0.09	-0.01	0.05	-0.00	0.04	0.12	-0.13	-0.09	-0.28	-0.09	0.11	-0.10	0.06	-0.11	0.03	0.09	0.10	0.09	-0.10
Fruit Flesh Ratio						0.01	0.73	-0.20	-0.61	-0.54	0.06	-0.22	-0.04	-0.09	-0.16	0.08	0.03	-0.05	0.01	-0.06	0.16	0.25	-0.14	-0.49	0.19	0.03	-0.01	-0.00	0.24
TSS %							0.06	-0.50	0.13	0.10	-0.06	-0.25	-0.27	0.12	-0.13	-0.64	0.52	0.58	0.99	0.06	-0.13	0.11	-0.13	0.18	0.04	0.03	-0.19	-0.15	-0.01
Length/breadth								-0.27	-0.29	-0.39	0.02	-0.22	-0.08	-0.01	-0.01	0.05	-0.11	-0.05	0.05	-0.02	-0.04	-0.00	-0.05	-0.29	-0.08	0.04	-0.05	-0.09	0.29
Days to Ripe									-0.00	0.11	0.22	0.26	0.24	-0.07	0.09	0.24	-0.27	-0.23	-0.50	-0.22	0.05	-0.04	0.15	0.04	-0.08	-0.12	0.51	0.09	-0.11
Teat Size Rating										0.52	-0.11	0.10	-0.06	0.08	0.20	-0.14	-0.04	0.11	0.13	0.11	-0.16	-0.25	0.10	0.39	-0.52	0.08	-0.02	-0.02	-0.18
Ridge pattern											0.05	0.08	-0.11	0.09	0.15	-0.15	-0.15	0.13	0.10	-0.05	-0.45	-0.14	0.12	0.35	-0.30	-0.13	0.06	-0.11	-0.13
Winter Spot												-0.11	-0.01	0.16	0.13	-0.17	-0.36	0.19	-0.06	-1.00	0.02	0.11	0.14	-0.19	-0.14	0.02	0.17	0.07	0.13
Fruit Rot													0.29	-0.09	0.10	0.18	-0.11	-0.16	-0.26	0.11	0.04	-0.07	0.09	0.08	-0.01	-0.06	-0.23	0.05	-0.07
Scar Rot														-0.00	0.05	0.18	-0.20	-0.19	-0.28	0.01	0.07	-0.07	0.06	0.04	-0.01	-0.16	-0.30	0.09	0.03
Flesh Firmness															0.11	-0.23	0.01	0.15	0.12	-0.16	-0.02	-0.07	0.14	0.02	-0.01	0.06	-0.18	0.05	0.07
Flesh Colour																0.05	-0.11	-0.05	-0.13	-0.13	-0.09	-0.24	0.83	0.11	-0.27	-0.14	0.01	0.06	-0.02
Eating Quality																	-0.46	-0.87	-0.64	0.17	0.03	-0.16	0.02	-0.11	0.01	-0.03	0.05	0.05	0.01
Fruit Value Index																		0.46	0.53	0.36	0.34	0.50	-0.04	0.21	0.41	0.33	-0.02	0.03	-0.07
Eating Quality Pts																			0.59	-0.19	-0.03	0.19	-0.05	0.10	-0.03	0.00	-0.02	-0.03	0.01
Sugar Level Pts																				0.06	-0.14	0.11	-0.12	0.17	0.04	0.03	-0.18	-0.16	-0.02
Winter Spot Pts																					-0.02	-0.11	-0.14	0.19	0.14	-0.02	-0.17	-0.07	-0.13
Fruit Shape Pts																						0.18	-0.06	-0.21	0.11	0.15	0.04	0.18	0.08
Fruit Size Pts																							-0.21	-0.17	0.23	0.06	0.02	0.08	0.05
Flesh Colour Pts																								0.07	-0.19	-0.12	0.05	0.04	-0.03
Ripening Pattern Pts																									-0.11	-0.08	-0.02	-0.11	-0.18
Teat Shape Pts																										0.15	-0.08	0.07	-0.04
Stalk Insertion Pts																											0.00	0.11	0.01
Shelf Life Pts																												0.00	-0.07
Fruit Set																													0.03

Table 12 RC2 Population: Correlation Female Data

Appendix 5

	Fruit Height	Fruit Weight	Fruit Circum	Fruit Length	Fruit Flesh Variance	Fruit Flesh Ratio	TSS %	Length/Breadth	Days to Ripe	Teat Size Rating	Fruit Ridging Pattern	Winter Spot	Fruit Rot	Scar Rot	Flesh Firmness	Flesh Colour	Eating Quality	Fruit Value Index	Eating Quality Points	Sugar Level Points	Winter Spot Points	Fruit Shape Points	Fruit Size Points	Flesh Colour Points	Ripening Points	Teat Shape Points	Stalk Insertion Points	Shelf Life Points
Plant Side Shoots	0.11	-0.08	-0.07	-0.10	-0.05	0.04	-0.10	-0.06	-0.05	-0.06	-0.01	-0.05	-0.08	0.02	-0.11	0.06	0.14	-0.04	-0.14	-0.09	0.05	0.02	0.08	0.03	-0.15	0.03	-0.07	-0.04
Fruit Height		-0.11	-0.14	-0.02	0.04	0.03	0.10	0.10	-0.02	-0.03	0.06	-0.05	0.09	-0.04	0.04	0.06	-0.14	0.17	0.09	0.12	0.05	0.03	0.07	0.09	-0.03	0.08	0.18	-0.08
Fruit Weight			0.92	0.64	0.26	-0.20	-0.23	-0.08	-0.01	0.18	0.20	0.28	0.13	-0.26	0.04	0.03	0.07	-0.57	-0.18	-0.22	-0.28	-0.19	-0.74	0.09	0.01	-0.19	-0.19	0.05
Fruit Circum				0.40	0.25	-0.36	-0.22	-0.39	0.06	0.07	0.34	0.33	0.12	-0.26	0.03	-0.02	-0.01	-0.57	-0.10	-0.20	-0.33	-0.42	-0.65	0.06	0.02	-0.09	-0.27	0.14
Fruit Length					0.00	-0.23	-0.09	0.68	-0.15	0.61	-0.03	0.11	-0.00	-0.16	0.10	0.25	0.12	-0.26	-0.16	-0.10	-0.11	0.28	-0.42	0.17	0.23	-0.58	0.07	-0.12
Flesh Variance		F				0.38	-0.23	-0.19	0.19	-0.03	0.16	0.19	0.25	0.07	0.02	-0.14	0.01	-0.21	-0.03	-0.22	-0.19	-0.18	-0.21	0.01	-0.24	0.04	0.21	0.12
Fruit Flesh Ratio							-0.10	0.08	0.06	-0.18	-0.28	-0.07	0.10	0.07	-0.12	-0.13	0.06	0.07	-0.09	-0.11	0.07	0.24	0.09	-0.04	-0.33	0.21	0.07	0.04
TSS %								0.08	-0.21	0.08	0.09	-0.13	-0.12	0.06	0.20	0.10	-0.60	0.51	0.59	0.98	0.13	0.00	0.20	0.10	0.32	-0.07	-0.05	-0.23
Length/breadth									-0.20	0.55	-0.28	-0.14	-0.09	0.05	0.08	0.25	0.12	0.17	-0.07	0.06	0.14	0.58	0.08	0.11	0.20	-0.50	0.28	-0.24
Days to Ripe										-0.04	0.06	-0.01	0.40	0.45	-0.08	-0.10	0.02	-0.01	-0.01	-0.22	0.01	-0.08	-0.06	-0.05	0.05	0.07	-0.11	0.79
Teat Size Rating											0.17	0.17	-0.04	-0.04	0.07	0.25	-0.02	-0.25	0.00	0.06	-0.17	0.13	-0.16	0.17	0.21	-0.91	0.03	-0.01
Ridge pattern												0.37	0.04	-0.10	0.18	-0.09	-0.28	-0.36	0.24	0.08	-0.37	-0.75	-0.18	-0.08	-0.00	-0.18	-0.04	0.04
Winter Spot													0.02	-0.14	0.02	0.06	-0.13	-0.60	0.09	-0.11	-1.00	-0.26	-0.22	0.07	-0.26	-0.20	-0.00	0.03
Fruit Rot														0.36	-0.06	-0.03	0.05	-0.07	-0.07	-0.14	-0.02	-0.02	-0.13	0.00	0.01	0.12	-0.04	0.07
Scar Rot															-0.03	-0.08	0.05	0.14	0.06	0.06	0.14	0.14	0.09	-0.09	0.12	0.07	-0.10	0.04
Flesh Firmness																0.19	-0.28	0.13	0.27	0.20	-0.02	-0.12	0.05	0.16	0.12	-0.06	0.06	-0.22
Flesh Colour																	0.02	0.15	0.01	0.09	-0.06	0.11	-0.01	0.86	0.15	-0.22	-0.05	-0.09
Eating Quality																		-0.32	-0.89	-0.62	0.13	0.22	-0.12	0.02	-0.16	0.01	-0.01	0.07
Fruit Value Index																			0.41	0.50	0.60	0.34	0.63	0.16	0.39	0.31	0.30	-0.04
Eating Quality Pts																				0.61	-0.09	-0.16	0.18	-0.02	0.17	-0.01	0.05	-0.08
Sugar Level Pts																					0.11	0.00	0.19	0.09	0.31	-0.06	-0.06	-0.23
Winter Spot Pts																						0.26	0.22	-0.07	0.26	0.20	0.00	-0.03
Fruit Shape Pts																							0.13	0.03	0.05	-0.12	0.13	-0.11
Fruit Size Pts																								-0.03	0.07	0.17	0.17	-0.08
Flesh Colour Pts																									0.06	-0.15	-0.05	-0.02
Ripening Pattern Pts																										-0.17	-0.09	0.03
Teat Shape Pts																											0.00	0.04
Stalk Insertion Pts																												-0.11

Table 13. RC2 Population: Correlation Bisexual Data

Appendix 5

	Fruit Height	Fruit Weight	Fruit Circum	Fruit Length	Fruit Flesh Variance	Fruit Flesh Ratio	TSS %	Length/Breadth	Days to Ripe	Teat Size Rating	Fruit Ridging Pattern	Winter Spot	Fruit Rot	Scar Rot	Flesh Firmness	Flesh Colour	Eating Quality	Fruit Value Index	Eating Quality Points	Sugar Level Points	Winter Spot Points	Fruit Shape Points	Fruit Size Points	Flesh Colour Points	Ripening Points	Teat Shape Points	Stalk Insertion Points	Shelf Life Points
Plant Side Shoots	0.05	-0.12	-0.12	-0.08	-0.15	-0.03	-0.02	0.03	0.05	-0.12	0.08	-0.28	0.04	0.14	0.05	0.01	0.11	0.13	-0.07	-0.02	0.28	-0.07	0.12	0.01	0.09	0.02	-0.05	-0.05
Fruit Height		0.01	0.05	-0.08	-0.05	-0.01	0.07	-0.13	0.11	-0.08	0.01	0.13	-0.11	0.03	0.03	-0.13	-0.08	-0.01	0.04	0.07	-0.13	0.03	0.01	-0.09	-0.01	0.09	-0.02	0.13
Fruit Weight			0.93	0.76	0.21	-0.37	-0.11	-0.10	0.06	0.18	0.08	0.41	0.10	-0.11	-0.11	0.14	-0.03	-0.54	-0.00	-0.12	-0.41	0.10	-0.85	0.17	0.23	-0.23	-0.16	0.10
Fruit Circum				0.55	0.21	-0.49	-0.10	-0.41	0.14	0.04	0.09	0.43	0.11	-0.06	-0.09	0.15	-0.08	-0.49	0.03	-0.10	-0.43	0.10	-0.78	0.19	0.22	-0.14	-0.27	0.15
Fruit Length					0.13	-0.26	-0.14	0.54	-0.06	0.47	0.19	0.22	0.01	-0.09	-0.06	0.21	0.08	-0.55	-0.08	-0.13	-0.22	-0.24	-0.67	0.16	0.27	-0.46	0.02	-0.03
Flesh Variance						0.09	0.18	-0.06	-0.05	0.00	0.02	0.13	-0.07	-0.02	0.11	-0.05	-0.15	-0.03	0.11	0.17	-0.13	0.03	-0.16	-0.01	0.07	0.09	-0.12	0.01
Fruit Flesh Ratio							0.12	0.22	0.01	-0.30	-0.40	-0.23	-0.11	0.02	-0.14	-0.30	0.06	0.39	0.01	0.12	0.23	0.28	0.28	-0.20	-0.31	0.34	0.18	0.07
TSS %								-0.05	-0.17	-0.04	0.11	0.04	-0.11	0.00	0.19	0.04	-0.62	0.44	0.58	0.99	-0.04	0.06	0.12	0.13	0.05	-0.13	-0.20	-0.18
Length/breadth									-0.21	0.47	0.13	-0.19	-0.09	-0.05	0.03	0.06	0.16	-0.12	-0.12	-0.04	0.19	-0.38	0.04	-0.03	0.07	-0.36	0.30	-0.18
Days to Ripe										-0.26	-0.08	0.07	0.21	0.48	-0.21	-0.10	0.03	0.00	-0.04	-0.18	-0.07	0.04	-0.09	-0.15	0.21	0.18	-0.11	0.80
Teat Size Rating											0.36	0.14	-0.07	-0.25	-0.00	0.20	0.01	-0.36	0.02	-0.02	-0.14	-0.33	-0.13	0.10	0.12	-0.67	0.13	-0.17
Ridge pattern												-0.04	0.07	0.03	0.10	0.09	-0.04	-0.29	0.04	0.12	0.04	-0.57	-0.07	0.04	0.34	-0.53	-0.18	-0.09
Winter Spot													0.03	-0.12	0.07	0.22	-0.31	-0.47	0.27	0.02	-1.00	0.14	-0.34	0.17	-0.04	-0.13	-0.08	0.11
Fruit Rot														0.11	-0.08	0.07	0.04	-0.04	-0.08	-0.11	-0.03	-0.00	-0.03	0.08	0.05	0.05	-0.03	-0.00
Scar Rot															0.04	-0.05	0.02	0.09	-0.05	-0.01	0.12	-0.05	0.13	-0.05	0.25	0.12	-0.21	0.00
Flesh Firmness																0.17	-0.35	0.18	0.30	0.20	-0.07	0.01	0.14	0.11	0.03	-0.01	0.05	-0.35
Flesh Colour																	-0.02	-0.03	0.03	0.04	-0.22	-0.16	-0.08	0.84	0.11	-0.25	-0.01	-0.15
Eating Quality																		-0.31	-0.93	-0.62	0.31	-0.15	0.03	-0.01	0.00	0.03	0.20	0.05
Fruit Value Index																			0.36	0.45	0.47	0.37	0.60	0.09	-0.08	0.42	0.19	-0.06
Eating Quality Pts																				0.59	-0.27	0.13	0.01	0.01	-0.02	-0.05	-0.17	-0.03
Sugar Level Pts																					-0.02	0.05	0.12	0.13	0.06	-0.14	-0.20	-0.18
Winter Spot Pts																						-0.14	0.34	-0.17	0.04	0.13	0.08	-0.11
Fruit Shape Pts																							-0.04	-0.07	-0.26	0.35	-0.02	0.02
Fruit Size Pts																								-0.05	-0.23	0.21	0.17	-0.18
Flesh Colour Pts																									0.03	-0.17	-0.01	-0.21
Ripening Pattern Pts																										-0.28	-0.32	0.14
Teat Shape Pts																											0.08	0.13
Stalk Insertion Pts																												-0.05

Table 14. RC2 Population: Correlation All Data (Female and Bisexual) Appendix 5

	Fruit Height	Fruit Weight	Fruit Circum	Fruit Length	Fruit Flesh Variance	Fruit Flesh Ratio	TSS %	Length/Breadth	Days to Ripe	Teat Size Rating	Fruit Ridging Pattern	Winter Spot	Fruit Rot	Scar Rot	Flesh Firmness	Flesh Colour	Eating Quality	Fruit Value Index	Eating Quality Points	Sugar Level Points	Winter Spot Points	Fruit Shape Points	Fruit Size Points	Flesh Colour Points	Ripening Points	Teat Shape Points	Stalk Insertion Points	Shelf Life Points
Plant Side Shoots	0.09	-0.10	-0.08	-0.07	-0.08	0.03	-0.07	0.01	-0.01	-0.09	0.01	-0.16	-0.05	0.07	-0.04	0.03	0.13	0.02	-0.11	-0.06	0.16	-0.04	0.09	0.02	-0.06	0.03	-0.05	-0.04
Fruit Height		-0.09	-0.13	0.02	0.01	0.10	0.07	0.09	0.03	-0.10	-0.01	0.02	-0.01	0.00	0.03	-0.03	-0.10	0.08	0.05	0.09	-0.02	-0.04	0.03	0.01	-0.07	0.13	0.12	0.01
Fruit Weight			0.84	0.45	0.20	-0.40	-0.15	-0.30	0.04	0.30	0.25	0.36	0.17	-0.21	-0.03	0.09	-0.02	-0.49	-0.06	-0.15	-0.36	0.12	-0.74	0.12	0.22	-0.31	-0.23	0.09
Fruit Circum				-0.02	0.10	-0.73	-0.08	-0.73	0.11	0.40	0.44	0.35	0.23	-0.19	-0.02	0.06	-0.11	-0.31	0.05	-0.08	-0.35	0.25	-0.46	0.09	0.37	-0.37	-0.33	0.17
Fruit Length					0.09	0.22	-0.13	0.68	-0.13	0.19	-0.14	0.10	-0.09	-0.07	0.02	0.19	0.14	-0.39	-0.16	-0.13	-0.10	-0.23	-0.51	0.14	0.00	-0.22	0.13	-0.11
Flesh Variance						0.24	-0.08	0.01	0.10	-0.07	0.07	0.15	0.13	0.04	0.06	-0.11	-0.04	-0.16	0.02	-0.07	-0.15	-0.12	-0.19	-0.00	-0.16	0.09	0.11	0.07
Fruit Flesh Ratio							-0.04	0.69	-0.02	-0.53	-0.48	-0.18	-0.15	0.11	-0.07	-0.15	0.13	0.04	-0.11	-0.04	0.18	-0.24	0.06	-0.07	-0.52	0.49	0.23	-0.04
TSS %								-0.04	-0.19	0.06	0.11	-0.05	-0.10	0.03	0.19	0.07	-0.61	0.48	0.58	0.98	0.05	0.05	0.17	0.11	0.21	-0.10	-0.12	-0.20
Length/breadth									-0.17	-0.17	-0.38	-0.19	-0.22	0.08	0.04	0.06	0.18	-0.07	-0.15	-0.04	0.19	-0.39	-0.02	0.02	-0.28	0.14	0.33	-0.20
Days to Ripe										-0.07	0.04	0.03	0.34	0.45	-0.14	-0.10	0.02	0.00	-0.01	-0.20	-0.03	0.01	-0.07	-0.09	0.13	0.07	-0.12	0.79
Teat Size Rating											0.38	0.19	0.06	-0.16	0.03	0.21	-0.07	-0.19	0.07	0.05	-0.19	0.18	-0.09	0.13	0.36	-0.86	-0.05	-0.02
Ridge pattern												0.24	0.12	-0.09	0.13	-0.01	-0.22	-0.27	0.19	0.10	-0.24	-0.31	-0.10	-0.03	0.25	-0.40	-0.15	0.03
Winter Spot													0.05	-0.14	0.04	0.14	-0.23	-0.52	0.19	-0.04	-1.00	0.02	-0.26	0.12	-0.10	-0.20	-0.06	0.08
Fruit Rot														0.24	-0.07	0.01	0.02	-0.04	-0.05	-0.11	-0.05	0.09	-0.07	0.03	0.11	-0.00	-0.07	0.06
Scar Rot															-0.00	-0.07	0.05	0.11	-0.00	0.03	0.14	-0.02	0.10	-0.08	0.11	0.13	-0.12	0.01
Flesh Firmness																0.18	-0.31	0.15	0.28	0.20	-0.04	-0.05	0.09	0.14	0.07	-0.03	0.06	-0.28
Flesh Colour																	-0.00	0.08	0.02	0.07	-0.14	-0.02	-0.04	0.85	0.13	-0.22	-0.04	-0.11
Eating Quality																		-0.32	-0.91	-0.62	0.23	-0.05	-0.05	0.00	-0.13	0.07	0.11	0.05
Fruit Value Index																			0.39	0.48	0.52	0.35	0.62	0.13	0.23	0.27	0.23	-0.04
Eating Quality Pts																				0.60	-0.19	0.06	0.11	-0.00	0.13	-0.07	-0.07	-0.04
Sugar Level Pts																					0.04	0.05	0.16	0.11	0.20	-0.10	-0.13	-0.20
Winter Spot Pts																						-0.02	0.26	-0.12	0.10	0.20	0.06	-0.08
Fruit Shape Pts																							0.06	-0.02	0.13	-0.14	-0.05	0.01
Fruit Size Pts																								-0.04	-0.02	0.14	0.15	-0.12
Flesh Colour Pts																									0.05	-0.14	-0.04	-0.10
Ripening Pattern Pts																										-0.36	-0.24	0.11
Teat Shape Pts																											0.12	0.03
Stalk Insertion Pts																												-0.10

Appendix 6

Plants with Commercial Potential Selected from the RC2 Population

Variety 2-15

Data Item	Mean Value	Data Item	Mean Points (0-10)
Sex	Female	Eating Quality	7.7
Flesh Colour	Red	Sugar Content	8.6
Total Soluble Solids (%)	11.4	Winter Spot	4.4
Fruit Weight (g)	790	Fruit Shape	9.8
Fruit Length (mm)	142	Fruit Size	5.8
Fruit Length/Breadth	1.3	Flesh Colour	9.6
Days Harvest to Ripe	10	Ripening Pattern	3.0
Flesh/Cavity Ratio	0.5	Teat Shape	5.1
Cavity Variation (mm)	8.5	Stalk End Shape	8.8
Fruit per Large Carton	13	Shelf Life	7.8
Fruit per Small Carton	-	Fruit Value Index	7.1
Comment: Very good taste. Low winter spot tolerance.			

Variety 3-33

Data Item	Mean Value	Data Item	Mean Points (0-10)
Sex	Bisexual	Eating Quality	8.5
Flesh Colour	Red	Sugar Content	9.4
Total Soluble Solids (%)	11.7	Winter Spot	8.5
Fruit Weight (g)	1,071	Fruit Shape	8.1
Fruit Length (mm)	200	Fruit Size	6.6
Fruit Length/Breadth	1.9	Flesh Colour	9.8
Days Harvest to Ripe	5	Ripening Pattern	5.0
Flesh/Cavity Ratio	0.6	Teat Shape	8.2
Cavity Variation (mm)	11.3	Stalk End Shape	9.2
Fruit per Large Carton	13	Shelf Life	3.7
Fruit per Small Carton	-	Fruit Value Index	7.9
Comment: Good taste and winter spot tolerance.			

Variety 7-82

Data Item	Mean Value	Data Item	Mean Points (0-10)
Sex	Bisexual	Eating Quality	7.7
Flesh Colour	Yellow	Sugar Content	8.8
Total Soluble Solids (%)	11.3	Winter Spot	5.0
Fruit Weight (g)	878	Fruit Shape	7.2
Fruit Length (mm)	172	Fruit Size	7.1
Fruit Length/Breadth	1.7	Flesh Colour	7.6
Days Harvest to Ripe	8	Ripening Pattern	5.2
Flesh/Cavity Ratio	0.5	Teat Shape	9.2
Cavity Variation (mm)	12.9	Stalk End Shape	7.9
Fruit per Large Carton	-	Shelf Life	6.4
Fruit per Small Carton	12	Fruit Value Index	7.2
Comment: Very good taste			

Variety 8-93

Data Item	Mean Value	Data Item	Mean Points (0-10)
Sex	Bisexual	Eating Quality	6.7
Flesh Colour	Orange Red	Sugar Content	8.4
Total Soluble Solids (%)	10.9	Winter Spot	5.2
Fruit Weight (g)	1,024	Fruit Shape	7.7
Fruit Length (mm)	186	Fruit Size	6.2
Fruit Length/Breadth	1.7	Flesh Colour	9.1
Days Harvest to Ripe	8	Ripening Pattern	7.2
Flesh/Cavity Ratio	0.5	Teat Shape	8.8
Cavity Variation (mm)	12.2	Stalk End Shape	9.2
Fruit per Large Carton	13	Shelf Life	6.6
Fruit per Small Carton	-	Fruit Value Index	7.4
Comment: Borderline taste and poor winter spot tolerance.			

Variety 11-37

Data Item	Mean Value	Data Item	Mean Points (0-10)
Sex	Bisexual	Eating Quality	6.7
Flesh Colour	Orange Red	Sugar Content	8.0
Total Soluble Solids (%)	10.7	Winter Spot	5.5
Fruit Weight (g)	1,155	Fruit Shape	6.4
Fruit Length (mm)	204	Fruit Size	6.0
Fruit Length/Breadth	1.9	Flesh Colour	9.6
Days Harvest to Ripe	8	Ripening Pattern	6.2
Flesh/Cavity Ratio	0.5	Teat Shape	8.2
Cavity Variation (mm)	7.7	Stalk End Shape	3.6
Fruit per Large Carton	13	Shelf Life	5.0
Fruit per Small Carton	-	Fruit Value Index	6.6
Comment: Good taste and poor winter spot tolerance.			

Variety 15-123

Data Item	Mean Value	Data Item	Mean Points (0-10)
Sex	Bisexual	Eating Quality	7.6
Flesh Colour	Red	Sugar Content	9.5
Total Soluble Solids (%)	11.7	Winter Spot	8.4
Fruit Weight (g)	936	Fruit Shape	1.1
Fruit Length (mm)	208	Fruit Size	6.8
Fruit Length/Breadth	2.0	Flesh Colour	10.0
Days Harvest to Ripe	10	Ripening Pattern	8.0
Flesh/Cavity Ratio	0.5	Teat Shape	4.2
Cavity Variation (mm)	11.1	Stalk End Shape	4.5
Fruit per Large Carton	15	Shelf Life	7.1
Fruit per Small Carton	-	Fruit Value Index	6.8
Comment: Good taste and winter spot tolerance.			

Variety 18-45

Data Item	Mean Value	Data Item	Mean Points (0-10)
Sex	Bisexual	Eating Quality	6.3
Flesh Colour	Red	Sugar Content	9.3
Total Soluble Solids (%)	11.9	Winter Spot	6.1
Fruit Weight (g)	1,042	Fruit Shape	6.6
Fruit Length (mm)	199	Fruit Size	6.2
Fruit Length/Breadth	1.9	Flesh Colour	10.0
Days Harvest to Ripe	8	Ripening Pattern	9.2
Flesh/Cavity Ratio	0.5	Teat Shape	7.4
Cavity Variation (mm)	5.7	Stalk End Shape	4.1
Fruit per Large Carton	13	Shelf Life	6.0
Fruit per Small Carton	-	Fruit Value Index	7.2
Comment: Picked as good by limited grower taste panel.			

Variety 19-36

Data Item	Mean Value	Data Item	Mean Points (0-10)
Sex	Bisexual	Eating Quality	7.8
Flesh Colour	Pale Yellow	Sugar Content	7.8
Total Soluble Solids (%)	10.5	Winter Spot	7.1
Fruit Weight (g)	1,040	Fruit Shape	4.0
Fruit Length (mm)	220	Fruit Size	4.7
Fruit Length/Breadth	2.2	Flesh Colour	2.7
Days Harvest to Ripe	8	Ripening Pattern	4.3
Flesh/Cavity Ratio	0.5	Teat Shape	7.4
Cavity Variation (mm)	11.6	Stalk End Shape	6.2
Fruit per Large Carton	15	Shelf Life	6.7
Fruit per Small Carton	-	Fruit Value Index	6.0
Comment: Good taste. Fair winter spot tolerance.			

Variety 23-100

Data Item	Mean Value	Data Item	Mean Points (0-10)
Sex	Bisexual	Eating Quality	6.0
Flesh Colour	Pale Yellow	Sugar Content	6.5
Total Soluble Solids (%)	9.6	Winter Spot	6.8
Fruit Weight (g)	880	Fruit Shape	9.5
Fruit Length (mm)	171	Fruit Size	7.2
Fruit Length/Breadth	1.6	Flesh Colour	5.1
Days Harvest to Ripe	7	Ripening Pattern	3.7
Flesh/Cavity Ratio	0.5	Teat Shape	9.4
Cavity Variation (mm)	13.2	Stalk End Shape	8.2
Fruit per Large Carton	12	Shelf Life	6.2
Fruit per Small Carton	-	Fruit Value Index	6.9
Comment:			

Variety 24-29

Data Item	Mean Value	Data Item	Mean Points (0-10)
Sex	Bisexual	Eating Quality	8.1
Flesh Colour	Red	Sugar Content	8.9
Total Soluble Solids (%)	11.3	Winter Spot	6.3
Fruit Weight (g)	720	Fruit Shape	4.9
Fruit Length (mm)	186	Fruit Size	4.4
Fruit Length/Breadth	2.0	Flesh Colour	10.0
Days Harvest to Ripe	9	Ripening Pattern	8.2
Flesh/Cavity Ratio	0.6	Teat Shape	7.9
Cavity Variation (mm)	14.9	Stalk End Shape	6.5
Fruit per Large Carton	-	Shelf Life	7.4
Fruit per Small Carton	13	Fruit Value Index	7.2
Comment: Good taste. Fair winter spot tolerance.			

Variety 24-87

Data Item	Mean Value	Data Item	Mean Points (0-10)
Sex	Bisexual	Eating Quality	7.4
Flesh Colour	Yellow	Sugar Content	7.5
Total Soluble Solids (%)	10.4	Winter Spot	4.7
Fruit Weight (g)	1,141	Fruit Shape	7.7
Fruit Length (mm)	197	Fruit Size	5.5
Fruit Length/Breadth	1.8	Flesh Colour	8.0
Days Harvest to Ripe	9	Ripening Pattern	3.3
Flesh/Cavity Ratio	0.5	Teat Shape	8.2
Cavity Variation (mm)	15.3	Stalk End Shape	9.3
Fruit per Large Carton	13	Shelf Life	6.7
Fruit per Small Carton	-	Fruit Value Index	6.8
Comment: Good taste and winter spot tolerance.			

Variety 25-5

Data Item	Mean Value	Data Item	Mean Points (0-10)
Sex	Bisexual	Eating Quality	9.2
Flesh Colour	Orange Red	Sugar Content	9.5
Total Soluble Solids (%)	12.2	Winter Spot	8.3
Fruit Weight (g)	860	Fruit Shape	4.5
Fruit Length (mm)	170	Fruit Size	6.2
Fruit Length/Breadth	1.7	Flesh Colour	9.7
Days Harvest to Ripe	7	Ripening Pattern	3.0
Flesh/Cavity Ratio	0.5	Teat Shape	7.3
Cavity Variation (mm)	7.1	Stalk End Shape	6.9
Fruit per Large Carton	15	Shelf Life	6.7
Fruit per Small Carton	-	Fruit Value Index	7.3
Comment: very good taste. Good winter spot tolerance.			

Variety 28-39

Data Item	Mean Value	Data Item	Mean Points (0-10)
Sex	Bisexual	Eating Quality	7.9
Flesh Colour	Pale Yellow	Sugar Content	7.4
Total Soluble Solids (%)	10.3	Winter Spot	4.3
Fruit Weight (g)	861	Fruit Shape	7.8
Fruit Length (mm)	161	Fruit Size	6.3
Fruit Length/Breadth	1.5	Flesh Colour	1.0
Days Harvest to Ripe	7	Ripening Pattern	3.8
Flesh/Cavity Ratio	0.5	Teat Shape	9.2
Cavity Variation (mm)	11.7	Stalk End Shape	1.7
Fruit per Large Carton	13	Shelf Life	7.0
Fruit per Small Carton	-	Fruit Value Index	6.0
Comment: Fair taste. Good winter spot tolerance.			

Variety 32-105

Data Item	Mean Value	Data Item	Mean Points (0-10)
Sex	Female	Eating Quality	9.1
Flesh Colour	Yellow	Sugar Content	9.3
Total Soluble Solids (%)	12.0	Winter Spot	6.3
Fruit Weight (g)	1,172	Fruit Shape	7.1
Fruit Length (mm)	150	Fruit Size	5.4
Fruit Length/Breadth	1.2	Flesh Colour	7.2
Days Harvest to Ripe	7	Ripening Pattern	5.1
Flesh/Cavity Ratio	0.4	Teat Shape	10.0
Cavity Variation (mm)	9.1	Stalk End Shape	1.1
Fruit per Large Carton	9	Shelf Life	5.2
Fruit per Small Carton	-	Fruit Value Index	7.0
Comment:			

Variety 33-39

Data Item	Mean Value	Data Item	Mean Points (0-10)
Sex	Female	Eating Quality	8.2
Flesh Colour	Orange Red	Sugar Content	8.0
Total Soluble Solids (%)	10.7	Winter Spot	4.9
Fruit Weight (g)	1,019	Fruit Shape	9.7
Fruit Length (mm)	158	Fruit Size	4.7
Fruit Length/Breadth	1.4	Flesh Colour	9.6
Days Harvest to Ripe	10	Ripening Pattern	4.4
Flesh/Cavity Ratio	0.5	Teat Shape	7.0
Cavity Variation (mm)	8.6	Stalk End Shape	0.5
Fruit per Large Carton	12	Shelf Life	8.0
Fruit per Small Carton	-	Fruit Value Index	6.8
Comment: Good taste and winter spot tolerance.			

Variety 33-66

Data Item	Mean Value	Data Item	Mean Points (0-10)
Sex	Bisexual	Eating Quality	9.0
Flesh Colour	Yellow	Sugar Content	9.8
Total Soluble Solids (%)	12.8	Winter Spot	3.1
Fruit Weight (g)	901	Fruit Shape	9.2
Fruit Length (mm)	169	Fruit Size	6.2
Fruit Length/Breadth	1.7	Flesh Colour	7.6
Days Harvest to Ripe	8	Ripening Pattern	3.0
Flesh/Cavity Ratio	0.5	Teat Shape	9.0
Cavity Variation (mm)	10.1	Stalk End Shape	7.5
Fruit per Large Carton	-	Shelf Life	7.0
Fruit per Small Carton	11	Fruit Value Index	7.3
Comment: Very good taste. Borderline winter spot tolerance.			