# Horticulture Innovation Australia

**Final Report** 

## Creating wealth for the Australian apple industry with consumer-preferred scab resistant apple selections - Stage 2

Dr Simon Middleton The Department of Agriculture and Fisheries (DAF)

Project Number: AP08041

#### AP08041

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## FINAL REPORT

## PROJECT AP08041 (June 2013)

## CREATING WEALTH FOR THE AUSTRALIAN APPLE INDUSTRY WITH CONSUMER-PREFERRED SCAB RESISTANT APPLE SELECTIONS – STAGE 2

Simon Middleton et al.

## Department of Agriculture, Fisheries and Forestry, Queensland

## **CONFIDENTIAL REPORT**



## AP08041

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The primary objectives of this project were to evaluate superior apple selections developed in the scab-resistance apple breeding program based at Applethorpe, Qld, identify those selections with commercial potential, and undertake consumer evaluations on a selection of these. This document is the final report for the project, and as such contains the details and results of work carried out in this project.

This report was prepared for submission on 7 June 2013.

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Garry Langford, Manager, Coregeo® Australia, kindly provided the summary Coregeo® commercialisation plan for 'Kalei' (Chapter 10).

## Abbreviations

APAL	Apple and Pear Australia Limited
APFIP	Australian Pome Fruit Improvement Program
ARS	Applethorpe Research Station, Stanthorpe, Queensland
BSA	Bulk Segregant Analysis
CA	Controlled Atmosphere
DAFF Qld	Department of Agriculture, Fisheries and Forestry, Queensland
DNA	Deoxyribonucleic acid
EOI	Expression of Interest
HAL	Horticulture Australia Limited
IP	Intellectual Property
LSD	Least Significant Difference
PBR	Plant Breeder's Rights
PCR	Polymerase Chain Reaction
PRI	Purdue-Rutgers-Illinois
RAPD	Random Amplified Polymorphic DNA
QAAFI	Queensland Alliance for Agriculture and Food Innovation
SCAR	Sequence Characterised Amplified Region
SPI	Starch Pattern Index
TCSA	Trunk Cross-Sectional Area
mm	millimetre
g	gram
kg	kilogram
t	tonne
ha	hectare
apple scab	apple black spot caused by Venturia inaequalis

## Media Summary

Apple scab (colloquially known as black spot), is a major fungal disease of apples worldwide, and costs the Australian industry upwards of \$10 million annually in chemical control and fruit losses. New apple varieties resistant to scab have been bred by the Department of Agriculture, Fisheries and Forestry, Queensland (DAFF Qld).

'Kalei' is the first scab-resistant apple to be released from this program, and was publically launched in May 2012 by the Hon. John McVeigh, Minister for Agriculture, Fisheries and Forestry, Queensland.

Coregeo® Australia has signed a licence agreement with DAFF Qld to commercialise 'Kalei', and was instrumental in developing the 'Kalei' name for the apple previously known and tested as 'RS103-130'. The first 'Kalei' trees for commercial planting will be available from Coregeo® in winter 2013.

'Kalei' is attracting worldwide interest for its high quality, sweetness and resistance to the apple scab disease. It is an attractive, crisp, juicy, red apple that matures just before 'Pink Lady'<sup>TM</sup>. 'Kalei' apples retain firmness and crispness whether sold fresh or out of long-term storage, and have exceptional crispness even when left at room temperature for three weeks.

'Kalei' can be grown either conventionally or organically. The scab resistance of 'Kalei' has proven durable in the orchard, and no sprays for apple scab (apart from an annual green tip copper) have been used in eleven seasons of producing 'Kalei' apples at Applethorpe Research Station, Qld.

A second scab-resistant selection, which matures immediately after 'Royal Gala', will likely be the next apple released from the breeding program. It is a crisp, juicy, red apple, with balanced, sweet flavour and fine melting texture.

The acceptability of apples to consumers in Brisbane is a key part of the process to determine which scab-resistant apples have the potential to become commercial varieties.

Another 34 scab-resistant apple selections have been identified that may have commercial potential. These include apples that are sweet, tart or a blend of both; apples that are red, yellow or green; and apples that mature between January and May. Further work with consumers will help determine which of these may be new Australian apple varieties for the future.

## **Technical Summary**

Apple scab caused by the fungus *Venturia inaequalis*, is a major disease of apples (*Malus domestica* Borkh.) in Australia and throughout the world. Apple varieties resistant to scab have been bred and developed in the Department of Agriculture, Fisheries and Forestry, Queensland (DAFF Qld) apple breeding program, and several show promise as high quality apples with commercial potential.

One of these, 'RS103-130', was released in May 2012 as 'Kalei'. Coregeo® Australia has signed a licence agreement with DAFF Qld to commercialise this variety, and the first 'Kalei' trees for commercial planting will be available from Coregeo® in winter 2013.

'Kalei' matures one to two weeks before 'Pink Lady'<sup>TM</sup>, and is an attractive, sweet, crisp, red apple that has exceptional shelf-life and quality, whether marketed fresh or out of long-term storage. In addition to resistance to apple scab, 'Kalei' is tolerant to *Alternaria* and western flower thrip (*Frankliniella occidentalis*).

The scab resistance of 'Kalei' has proven robust in the field. No sprays for apple scab control (apart from an annual green tip copper spray) have been applied in eleven seasons of 'Kalei' production at Applethorpe Research Station (ARS), Qld, and no apple scab has been found on 'Kalei' leaves or fruit, despite some very wet, humid seasons.

A second scab-resistant selection, 'RS103-110', will likely be the next apple released from the DAFF Qld breeding program. 'RS103-110' matures immediately after 'Royal Gala', and is a crisp, juicy, red apple, with balanced, sweet flavour and fine melting texture. A Part 1 Australian Plant Breeder's Rights application for 'RS103-110' has been submitted.

A further 34 scab-resistant selections have been identified that are considered to have, to varying degrees, potential for commercialisation. In addition, there are eleven selections that require evaluation for another season before a decision can be made about their future commercial potential; three selections that are very large, juicy apples suitable only for processing; and ten selections that, whilst not deemed to be commercial varieties in their own right, have desirable characteristics that make them candidates as potential parents in any future breeding program.

Consumer acceptability studies and postharvest sensory evaluations (shelf life and flesh browning) were key components of the process to identify the scab-resistant apple selections with commercial potential. This work could not be undertaken for all selections, as there were only a few trees of some; insufficient to produce the apple quantities required for consumer and postharvest studies.

The early season red apple 'RS102-50' is a very strong candidate for potential commercialisation, and rated highly in consumer and postharvest sensory evaluations. 'FB12-23' is another selection with considerable promise, and is a distinctively attractive pale yellow apple with light red-pink blush and exceptional texture. A further twelve scab-resistant selections are also high priority candidates for consumer testing and shelf life studies, as this will determine their potential commercial status.

With the exception of 'Kalei' and 'RS103-110', the field and laboratory evaluations of the scabresistant selections have been confined to Queensland. Further work must include testing of these selections at interstate APFIP evaluation sites. To commence this process, budwood of 'RS109-15', 'FB12-23', 'RS108-96' and 'SP7-226' has been provided to APFIP, for evaluation of these selections at sites in NSW, Vic, Tas and WA.

*Vf, Vh2, Vr1 and Vm* scab resistance genes have been identified in the molecular marker screening of a cross-section of 18 of the DAFF Qld scab-resistant selections. It is therefore possible that the resistance of other ARS selections is not confined to *Vf*, but may be due to other genes, or be polygenic. This potentially adds significant value to the apple germplasm held at ARS.

## 1. Introduction

The DAFF Qld apple breeding program based at Applethorpe Research Station (ARS) commenced in 1985, with the objective of developing scab-resistant apple varieties that are adapted to Australian growing conditions, and that satisfy the fruit quality requirements of consumers (Zeppa *et al.*, 2002).

Apple scab (colloquially known in Australia as apple black spot), is caused by the fungus *Venturia inaequalis* (Ascomycetes) (Tenzer and Gessler, 1997), and is one of the most widespread diseases of apple trees in Australia and throughout the world. Apple scab costs the Australian industry upwards of \$10million annually in fruit losses and chemical control.

The apple scab resistance gene Vf, derived from *Malus floribunda*, has been the most widely used source of scab-resistance in breeding programs around the world (Janick *et al.*, 1996). This was also the primary source of resistance used in the DAFF Qld breeding program (Zeppa and Middleton, 2008). While there are European reports of cases of the Vf resistance being overcome by races 6 and 7 of the apple scab fungus (Sansavini *et al.*, 2002), Heaton *et al.* (1991) reported that only the more common race of the scab fungus (race 1) was present in Australia. There has been no breakdown of Vf scab resistance in North America in over 50 years of growing scab-resistant varieties.

Vf still confers resistance to Race 1, and in his review of the ARS breeding program, Brennan (2006) considered "the resistance gene Vf likely to remain effective for an extended period and will provide economic benefits to the Australian apple industry." Indeed, the robustness of this resistance in ARS scab-resistant apple selections has been demonstrated by Middleton *et al.* (2012). Despite the absence of sprays for apple scab control (apart from green tip copper), no apple scab occurred on the leaves or fruit of trees of six scab-resistant selections grown in high density planting systems over a ten year period. In contrast to this, 'Pink Lady'<sup>TM</sup> and 'Granny Smith' trees within this planting showed high levels of scab infection of fruit and leaves during this time (Middleton *et al.*, 2012).

The PRI (Purdue-Rutgers-Illinois) apple breeding program based in the USA has been the source of many varieties used worldwide as parents with V*f* resistance in apple breeding programs (Janick, 2002). Scab-resistant varieties developed from the PRI program were initially identified as a numbered series of selections, and later given names such as 'Prima', 'Jonafree', 'Sir Prize', 'William's Pride' and 'GoldRush'<sup>TM</sup> (Crosby, *et al*, 1992).

These varieties, with their poor fruit quality relative to mainstream commercial varieties, are only grown to a small extent in North Amercia. They have not adapted well to Australian conditions, and their characteristic acid flavour is not popular with Australian consumers. Similarly, scab-resistant apples developed in Europe to date have not been appropriate for growing conditions and/or consumer palates in Australia.

Scab-resistant parents used in the DAFF Qld breeding program included the varieties Prima, Liberty, GoldRush<sup>TM</sup>, Jonafree and Enterprise, all of which possess the V*f* gene. 'Prima' also possesses the V*r* gene for apple-scab resistance (Kruger, 1991).

The scab-resistant apples developed in the DAFF Qld breeding program were selected as resistant to apple scab by glasshouse inoculation of the seedlings, and the culling of those with scab infection (Zeppa and Middleton, 2008). It is possible that, in particular, selections with 'Prima' as a parent may possess multiple sources of genetic resistance to apple scab (polygenic resistance).

Molecular markers are published for many of the major scab resistance genes in apple (Gygax *et al.*, 2004; Patocchi *et al.*, 2005; Erdin *et al.*, 2006). It is therefore possible to screen some of the more advanced DAFF Qld apple selections for genetic sources of resistance, using DNA marker technology. Preliminary screening was undertaken in project AP08041 of 18 scab-resistant selections, using SCAR (sequence characterised amplified region) markers for four scab-resistance genes, including V*f*.

At the conclusion of previous project AP05008 there were 350 advanced scab-resistant apple selections requiring further evaluation (Zeppa and Middleton, 2008). These had been progressively selected from the breeding progeny blocks over the previous ten years, and planted in a medium density orchard at ARS.

One of these, 'RS103-130', is a scab-resistant apple of excellent eating quality, and was granted provisional Australian Plant Breeder's Rights (PBR) protection in December 2005. 'RS103-130' has rated highly in consumer evaluations to date (Zeppa and Middleton, 2008), is a highly productive variety consistently yielding upwards of 70 t/ha annually (Middleton *et al.*, 2012), and is also suitable for organic production (Middleton *et al.*, 2007).

Project AP08041 was specifically designed to build on the outputs of the DAFF Qld apple breeding program, and implement the key recommendations of the Brennan Review conducted in April 2006 (Brennan, 2006). The primary objectives of project AP08041 were to:

- Evaluate the remaining 350 advanced scab-resistant apple selections from the DAFF Qld breeding program, and, based on field and laboratory measurements of agronomic and fruit quality parameters, identify those with commercial potential for the Australian apple industry.
- Complete a series of consumer evaluations to compare the acceptability of several advanced scab-resistant selections (including 'RS103-130') with current commercial varieties. Consumer feedback is an essential component of the evaluation process.
- Undertake postharvest sensory evaluations of a range of advanced scab-resistant apple selections. These were identified as among the most promising selections, and produced sufficient quantities of apples for replicated studies of shelf life, firmness and flesh browning.
- Conduct preliminary genotyping across a range of scab-resistant apples to identify the genetic sources of resistance in this material.
- Commercialise and release 'RS103-130' scab-resistant apple, including the completion of Australian PBR and USA plant patent applications for intellectual property (IP) protection of this new variety.

The productivity and performance of six potential new scab-resistant varieties from the DAFF Qld breeding program, including 'RS103-130, were evaluated in a semi-commercial high density orchard planting at ARS (Middleton *et al.*, 2012) in project AP08008. This work was an important complement to project AP08041, for, regardless of consumer feedback, apple growers will not plant a new apple variety unless it is highly productive, and economically viable to do so. Project AP08008 also provided a site for growers to observe the field performance of 'RS103-130' and other advanced apple selections, and taste apples of these selections. It was also used as a source of apples for some of the consumer evaluations and postharvest sensory experiments in AP08041.

Additional functions of project AP08041 included the maintenance of a specifically designed PBR block of trees to provide the comparative varietal data necessary to prepare PBR applications, and a budwood multiplication block of trees to enable the supply of virus indexed budwood of 'RS103-130' to a commercial partner.

It should be noted that for the purposes of Plant Breeder's Rights, until the selections are secured by PBR, the 'intellectual property' of these potential varietal releases is at risk. Consequently, with the exception of 'RS103-130' ('Kalei'), the selections in this report cannot be named or fully described in publications that will ultimately reach the public domain.

## 2. Materials and Methods

### 2.1 Orchard plantings

#### (a) Advanced scab-resistant selections

Trees of the 350 advanced scab-resistant apple selections remaining from the DAFF Qld breeding program were grown in medium to high density plantings at ARS. The majority of these were planted on M.26 rootstock at a density of 2500 trees/ha, with all trees trained to a central leader system supported by a four or five wire vertical trellis. The trellis enhanced tree support, helped maintain apical dominance of the leader, and enabled tying down of branches to encourage early cropping. The planting was protected by a permanent hail netting structure covering five hectares at ARS.

In 2009 most of the trees were in at least their 5<sup>th</sup> leaf. The final planting, of approximately 20 advanced selections, was made in 2009, with these trees fruiting for the first time in 2011-2012. There were generally three or four trees per selection for most of the 350 lines, however numbers varied. For a few selections there was only one tree, while at the other extreme there were up to 80 trees on a range of rootstocks for 'SP7-226', a selection considered to have potential as a late-maturing, solid block red (Jonathan type) scab-resistant apple.

Since planting, no sprays for apple scab (caused by *Venturia inaequalis*) control were applied, with the exception of a copper spray at green tip (mid-late September) each year. Hence the trees were exposed to the natural field pressure of apple scab infection, confirming the durability of their scab resistance under field conditions. In some years the apple scab infection pressure was very high, with interplanted 'Pink Lady'<sup>TM</sup> and 'Granny Smith' trees losing up to 75% of their apples through severe apple scab damage.

Powdery mildew (caused by *Podosphaera leucotricha*) was minimal in most seasons, and kept under control either with targeted Nimrod® sprays (which has no effect on apple scab), or removal of infected shoots. A standard spray program was used to control the major pests: codling moth (*Cydia pomonella*), light brown apple moth (LBAM) (*Epiphyas posvittana*), native budworms (*Heliocoverpa punctigera*) and Queensland fruit fly (*Bactrocera tryoni*). No sprays were applied for control of apple dimpling bug (*Campylomma liebknechti*), plague thrip (*Thrips imaginis*), two-spotted mite (*Tetranychus urticae*) or western flower thrip (*Frankliniella occidentalis*). The spray program for codling moth and LBAM control was suspended in December each year, as apples were progressively harvested from January onwards as different selections successively matured.

The absence of fungicide sprays since planting, and the wet humid conditions of spring/summer 2009 saw bitter rot (*Glomerella cingulata*) infection on some fruit at harvest in 2010. Three Delan® sprays in each of spring 2010 and spring 2011 were subsequently applied to control bitter rot in the wet 2010/11 and 2011/12 seasons.

Calcium nitrate (30 kg/ha) was applied to trees via the trickle irrigation system at fortnightly intervals between September and November each year. Sulphate of potash (40 kg/ha) was also applied through the trickle irrigation system, but at fortnightly intervals between late December and early March each season, to enhance fruit colour development and storage potential. Supplementary PitStop® calcium sprays were applied up to ten times per season, between early November and late March. A 5% w/v urea spray was used at leaf fall in late May each year to assist in apple scab control.

Four hives of honeybees (*Apis mellifera*) were annually introduced into the block during the flowering period, to ensure adequate pollination of flowers. Hand thinning of trees was done in November and December each year.

#### (b) Plant Breeders Rights (PBR) block

The PBR block consists of two plantings, the first established in October 2003 and the second in September 2006. The purpose of this block of trees is to provide the information required in the preparation and submission of PBR applications, and hence the protection of IP, for scab-resistant selections deemed suitable for potential commercialisation. The two plantings contain a range of scab-resistant selections from the DAFF Qld breeding program, (that at the time of planting were considered potential candidates for commercialisation), and several commercial apple varieties as comparators.

The 2003 planting consists of the three scab-resistant selections 'RS103-130', 'RS103-56' and 'FB22-47', and the three commercial varieties 'Galaxy', 'Fuji' (Nagafu 2) and 'Sundowner'<sup>TM</sup>. Each of the six apple varieties is replicated ten times as single tree plots in a randomised complete block design. All trees are on M.26 rootstock at a spacing of 3.8 m x 1.5 m (1750 trees/ha).

The 2006 planting consists of the five scab-resistant selections 'RS103-110', 'RS103-130' ('Kalei'), 'RS109-15', 'RS104-1' and 'SP7-226' and the five commercial varieties 'Red Jonathan', 'Royal Gala', 'Red Delicious' (Hi Early), 'Fuji' (Nagafu 2) and 'Red Braeburn'. Each of the ten apple varieties is replicated ten times as single tree plots in a randomised complete block design. Again, all trees are on M.26 rootstock at a spacing of 3.8 m x 1.5 m (1750 trees/ha).

#### (c) Budwood multiplication block

The budwood multiplication block was planted in 2003 and consists of 43 trees of six scab-resistant apple selections grafted onto virus-free Seedling rootstock, or virus-tested MM.106 rootstock sourced from the Australian Pome Fruit Improvement Program (APFIP). The trees are planted as an alternating zig-zag pattern in a double-row system. The two rows in the double-row are one metre apart, with 1.5m between the trees within each row of the double-row. The number of trees per scab-resistant selection/rootstock combination varies from three to eight. For 'RS103-130' ('Kalei'), there are seven trees on APFIP sourced MM.106, and five trees on Seedling rootstock.

The purpose of the budwood multiplication block is to serve as a repository of virus-indexed trees available to provide "clean", virus-tested propagation material of new scab-resistant apple selections if/when they are commercialised. The six selections currently in this block were deemed to have commercial potential at the time this block of trees was planted, however it is likely that only two of these will be commercialised. As future decisions are made regarding the commercial potential of other scab-resistant selections from the DAFF Qld breeding program, these will need to be virus-indexed and added to the existing collection.

The trees and individual branches and shoots on the trees are cut back severely every winter to encourage maximum production of shoots the following season for the supply of propagation wood. Virus indexing of the 'RS103-130' trees in this planting showed they were free of Apple Mosaic Virus, Apple Chlorotic Leaf Spot Virus, Apple Stem Grooving Virus and Apple Stem Pitting Virus (Zeppa and Middleton, 2008).

### **2.2 Evaluation of advanced scab-resistant selections**

The evaluation protocols used to assess the 350 remaining advanced scab-resistant apple selections and identify those with commercial potential, were based on the procedure outlined in previous project AP05008 (Zeppa and Middleton, 2008) and recommendations of the Brennan review (Brennan, 2006). The evaluation process is summarised below.

#### (a) Field measurements

The vigour and habit of trees was assessed annually in winter, prior to dormant pruning. Tree height and trunk circumference (15cm above the graft union) were measured as indicators of tree vigour, and trunk circumference used to calculate trunk cross-sectional area (TCSA). A subjective assessment of fruit bud development and tree habit (spreading, weeping, upright) was also made, in addition to recording the levels of powdery mildew infestation, before the removal of infected shoots during pruning.

Budbreak and flowering were recorded annually in spring as a progression of dates, commencing with the date of green tip, followed by first blossom, 10% bloom, full bloom and calyx (petal fall). Blossom density (light, moderate, heavy) was also recorded, as was any evidence of protracted flowering, or the occurrence of secondary blossom after the peak flowering period had concluded.

Hand thinning of trees commenced onwards of four weeks after calyx, by which time fruit set was evident. At the time of hand thinning, other measurements and observations were made, including fruiting habit (spurs, terminals, axillaries), fruit set (light, moderate, heavy), mean number of fruit per cluster and thinning requirement. Trees were hand thinned to standardised crop loads of five apples per cm<sup>2</sup> trunk cross-sectional area (TCSA). If the fruit set was below this crop load level, trees were just minimally thinned to remove multiple fruit in clusters.

As each of the 350 advanced scab-resistant selections approached maturity, apples were sampled weekly for maturity testing. This occurred over a continuous five month period from January to May each season. The timing of harvest of each selection was based on starch:iodine measurements (1.5% aqueous iodine solution). Apple selections were harvested when the starch pattern index (SPI) of cut apples (five apple sample) correlated to SPI 3.5-4 as per the Cornell Cooperative Extension Starch-Iodine Index Chart (Blanpied and Silsby, 1997).

This allowed a further 7-10 days for the apples to reach "eating ripe" stage. Apples from individual trees were harvested, labelled and placed in storage at ARS (2°C- 5°C) until time was available to conduct laboratory assessments of fruit appearance and eating quality. This generally occurred within two to three weeks of harvest. Most scab-resistant selections required multiple (two or three) harvests.

#### (b) Laboratory assessments at ARS

On removal of scab-resistant apples from storage, boxes of fruit were allowed to warm to room temperature, and a 10 fruit sample was then taken and assessed for fruit quality. Assessment was made using a criteria sheet developed as part of the protocols recommended in the Brennan review (Brennan, 2006). The criteria were scored on a scale of 1-10, with a score of  $\geq$  7 considered to be commercially acceptable. Each criterion also had an importance rating, which is multiplied by the selection's score for that criterion. These were then summed to determine a total score (criterion x importance rating). An example assessment sheet is included as Appendix 1.

Eight fruit appearance criteria were subjectively assessed. ie. skin (ground) colour, blush/over-colour, skin smoothness, shape, size, stalk length, lenticels and sinus. A final subjective assessment was made of apple appearance by classifying the overall attractiveness as either poor, satisfactory, good or excellent (refer Appendix 1).

Six fruit quality criteria were subjectively assessed. ie. flesh firmness, flesh texture, juiciness, acidity, acid/sugar balance and flavour. A final subjective assessment was made of the fruit quality criteria by classifying the overall eating quality as either poor, satisfactory, good or excellent (refer Appendix 1).

To focus the assessment of each criterion, an attempt was made to standardise the scale ratings to the subjective assessments for overall attractiveness and overall eating quality. ie. a score of 1 to 3 was considered poor, 4 to 6 satisfactory, 7 and 8 good, 9 and 10 excellent (refer Appendix 1).

A total value of 550 was the maximum a selection could achieve when the individual fruit appearance and quality criteria were multiplied by their importance ratings and summated. A criterion rating of  $\geq$  7 was considered to be commercially acceptable, therefore, on a theoretical basis, a selection that scored 385 or 70% overall was deemed to be of commercial quality.

In addition to the qualitative assessments described above, measurements of the following parameters were also made in the laboratory (five apples of each scab-resistant selection for each parameter):

- Fruit firmness (pressure): kg force (kgF) using 11mm penetrometer head. One reading taken on the sun side and one reading taken on the shade side.
- Fruit colour: Foreground colour was measured using Royal Horticultural Society (RHS) colour charts (Flower Council of Holland, Leiden, undated). RHS Colour Codes (e.g. 46A) used in variety descriptions Chapters 4, 5 and 6.
- Sugar content (%brix): measured of juice from each of five apples using an Atago PR-101 digital refractometer.
- Starch Pattern Index (SPI): 1-6 scale as per the Cornell Cooperative Extension Starch-Iodine Index Chart (Blanpied and Silsby, 1997), using 1.5% aqueous iodine solution.
- Flesh browning: at time zero (T0) and again after 15 minutes (T15) using Royal Horticultural Society (RHS) colour charts (Flower Council of Holland, Leiden, undated). In 2012 and 2013 assessed at T0, and again after 30 minutes (T30) and 60 minutes (T60). The degree of browning also rated as nil, slight, moderate or severe at each time point.
- Fruit weight (g): Average individual fruit weight of 10 apples.

Subjective assessment was also made of insect and disease damage, russet, mouldy core, bitter pit and water core. The presence/absence of any symptoms was rated as nil, slight, moderate or severe.

In 2012 and 2013 the detailed assessments outlined above were supplemented with tasting sessions involving seven ARS staff. The sessions were held at regular intervals throughout the season, and approximately ten selections were evaluated at each tasting. This was particularly useful in sourcing additional qualitative feedback about selections with similar attributes and harvest dates.

As part of the final subjective assessment of the potential of each scab-resistant selection, a decision was made on whether the selection had a particular "Critical Failure" that would preclude it from ever becoming a commercial variety.

For all selections, a final assessment decision was based on observations and measurements over a minimum of two years. The four options at this decision point were to (a) discard the selection, (b) see the selection again for a further season of assessment, (c) consider the selection as a potential parent or (d) progress the selection to further testing and consideration for commercialisation.

#### (c) Consumer evaluations and postharvest sensory quality

During each year of the project, and following the laboratory assessments and staff tastings held at ARS, decisions were made on which of the scab-resistant selections warranted consumer acceptability studies and detailed postharvest sensory evaluations by DAFF Qld sensory scientists and postharvest specialists based in Brisbane. Unfortunately, for many promising selections there was insufficient fruit for them to be included in this phase of the evaluation process. In addition, the high costs of this work meant that it was necessarily restricted to only some of the superior scab-resistant selections deemed to have commercial potential.

A total of eight consumer acceptability studies and eight postharvest evaluations were conducted between 2009 and 2013 by DAFF Qld staff based at the Health and Food Sciences Precinct, Brisbane. The postharvest sensory experiments over this period focused on the shelf life, texture and flesh browning of fourteen scab-resistant apples (some on multiple occasions), in comparison with a wide range of current commercial apple varieties. Similarly, the consumer evaluations included eight scab-resistant selections (some on multiple occasions) between 2009 and 2013, in comparison with all of the major apple varieties currently grown in Australia.

The detail of the procedures used in the consumer acceptability studies and postharvest sensory evaluations are provided in Sections 7.2 and 8.2 respectively.

## 3. Status of advanced selections from the breeding program

As of June 2013 there were 36 scab-resistant selections considered to have, to varying degrees, at least some potential for commercialisation. The procedure outlined in Section 2.2 was used to identify these 36 selections from the population of 350 advanced selections at the commencement of this project.

In addition to this, there are eleven selections that still require further evaluation before a definitive decision can be made about their future. For example, many of these have only been seen in one season, or have only produced two or three apples to date.

A further ten selections, whilst deemed unsuitable as potential commercial varieties in their own right, have, in addition to scab-resistance, certain particularly desirable characteristics that make them possibilities as potential parents in any future breeding program.

The three selections 'FB18-95', 'FB19-139' and 'FB16-79' are very large, juicy apples that may have potential as processing apples, particularly for the organic juice market, but are unsuitable candidates as dessert apples.

The scab-resistant selections that (a) require further evaluation or (b) are possible potential parents, are listed below.

#### (a) Require further evaluation

SP14-292	- Attractive midseason red apple. Only assessed once.
FB26-1	- Early to midseason sweet apple. Attractive pink blush.
FB22-58	- Large late season 'Pink Lady' type.
FB6-63	- Only two apples for first assessment in 2013.
FB19-116	- Mid to late season green apple with pink blush. Only assessed once.
SP9-317	- Mid to late season red block apple. Balanced flavour and excellent texture.
FB6-94	- Late season very attractive red apple. Balanced flavour and fine texture.
SP1-175	- Mid season attractive bright cherry red apple. Balanced flavour.
FB6-74	- Mid to late season green apple with pink blush. Only assessed once.
SP17-72	- Early season sweet red apple. Juicy with excellent texture.
SP11-65	- Mid season 'Golden Delicious' type. Large, good texture and shape.

#### (b) Potential Parent

FB19-144	- Late season 'Pink Lady' type in appearance. Fine melting texture.
SP10-410	- Early season very attractive bicolour apple. Sweet and crunchy.
FB1-156	- Early season attractive red apple. Good size and shape. Ok texture.
SP12-358	- Large early season attractive red apple. Distinctive flavour.
SP12-126	- Early season large deep red apple. Very sweet.
SP1-218	- Early season apple. Potential parent for size, appearance, skin smoothness.
FB13-61	- Very attractive mid season bicolour apple. Tart, very white flesh.
FB16-64	- Late season apple. Outstanding texture but poor appearance.
SP16-79	- Very early season red apple of good size. Poor flavour.
FB18-59	- Attractive mid season bock red apple. Juicy with refreshing, citrus flavour.

Scab-resistant apples considered to have commercial potential are illustrated and described in detail in Chapter 6.

## 4. 'Kalei' ('RS103-130') scab-resistant apple

'Kalei' is the first scab-resistant apple to be released from the DAFF Qld apple breeding program, and was publically launched at the Brisbane Markets on 3 May 2012 by the Minister for Agriculture, Fisheries and Forestry, Queensland, the Hon. John McVeigh.

Apple and Pear Australia Ltd (APAL) signed a licence agreement with DAFF Qld in 2012 to commercialise 'Kalei'. Coregeo® Australia, a division of APAL, was instrumental in developing the 'Kalei' name for the apple selection previously known and tested as 'RS103-130'. Further details of the commercialisation process and plan for 'Kalei' are provided in Chapter 10.

'Kalei' matures mid to late season (one to three weeks before 'Pink Lady'<sup>TM</sup>), and has a broken red stripe to almost full block red overcolour on a yellow-green to yellow background (refer photo overleaf). Fruit is round-conic in shape with a medium stalk length. Flesh is off-white, medium textured, crisp and breaking. 'Kalei' is juicy with a sweet, low-acid and mild flavour.

Fruit colour up very late on the tree, often within one to two weeks of harvest, which helps ensure the apples are picked close to optimum maturity for eating and storage quality. 'Kalei' trees are semi-spur and of medium vigour. Two to three harvests are required over a four to six week picking season for this variety.

'Kalei' is by nature a large apple, and the trees can support heavy crops. A more detailed description of the tree and fruit characteristics of 'Kalei' is provided on the following page.

Intensive plantings of 'Kalei' on M.9, M.26 and MM.106 rootstocks have very high yield and packout potential, and yields of at least 60-70 t/ha/annum can be expected from well-managed, fully mature trees (Middleton *et al.*, 2012). The semi-spur growth habit of 'Kalei' trees is easy to manage and manipulate, and trees respond well to shoot and limb bending.

No apple scab has been observed on leaves or fruit of 'Kalei' trees in eleven years of high density production at ARS. This is despite the absence of sprays for apple scab control (apart from an annual green tip copper spray), and the presence of apple scab inoculum in the orchard. 'Pink Lady'<sup>TM</sup> and 'Granny Smith' trees planted as pollenisers beside 'Kalei' trees in this planting have shown moderate to severe symptoms of apple scab, with up to 75% crop losses due to apple scab in some years.

In addition to resistance to apple scab, 'Kalei' is tolerant of *Alternaria* and western flower thrip (*Frankliniella occidentalis*). With such attributes, 'Kalei' is a high quality apple eminently suited to organic production (Middleton *et al.*, 2007).

'Kalei' has also been evaluated at interstate sites in NSW (Batlow), Victoria (Goulburn Valley), SA (Adelaide Hills) and Tasmania (Huon Valley). The latter three sites were all part of the national APFIP evaluation network. Over several years of observations at each site, 'Kalei' showed no incidence of apple scab infection and, as in Qld, the trees were described as 'semi-spur' and of spreading growth habit. The apples were consistently described as 80% red over-colour with eating quality of rich/sweet flavour (rare for a scab-resistant apple), very crisp, very juicy and fine/melting to medium texture.

'Kalei' has rated highly in consumer evaluations in Brisbane when compared with a wide range of commercial apple varieties currently grown in Australia (Chapter 7). The apple has excellent eating quality, whether straight off the tree or out of long-term storage. Of particular note is the crisp, firm texture of 'Kalei' apples, which is still retained after three weeks at room temperature. Further detail of postharvest sensory evaluations of 'Kalei' is included in Chapter 8.

## KALEI (RS103-130)



**Full Bloom (2011) :** 26 Sept (overlap with Braeburn, Sundowner)

**Full Bloom (2012) :** 24 Sept (overlap with Braeburn, Granny Smith)

Harvest (2012): 3 Apr - 5 May (similar to Pink Lady)

Harvest (2013) : 27 Mar - 13 May (similar to Granny Smith, Pink Lady)

#### Description

'Kalei' has a broken red stripe to almost full block red foreground colour over a yellow-green to yellow background colour. It is a sweet, juicy, medium textured apple with off-white, crisp, breaking flesh. 'Kalei' matures one to three weeks before 'Pink Lady'<sup>TM</sup>.

#### **Fruit Characteristics**

Foreground Colour:	Red (46A - 53A)	TSS:	13.6 %
Blush Coverage:	>80%	Fruit Firmness:	Firm 8.5 kgF
Shape:	Round Conical	Flesh Browning:	-
Average Fruit Wt:	200 g	5 minutes -	Slight
Texture:	Medium, Crisp,	30 minutes -	Slight
Shelflife: (14 days)	Breaking 7.5 kgF; Eating quality retained	60 minutes -	Moderate

#### **Tree Characteristics**

Habit:	Spreading	
Fruiting Habit:	Spurs, Terminals	
Vigour:	Medium	

#### **Disease Susceptibility**

Powdery Mildew: Nil

Alternaria Leaf Spot: Nil

#### Status

Released to the Australian apple industry as 'Kalei' in May 2012, with Coregeo® Australia as the commercial partner.

## 5. 'RS103-110' scab-resistant apple

'RS103-110' will likely be the second scab-resistant apple to be released from the DAFF Qld apple breeding program. An Australian Plant Breeder's Rights Part 1 application has been prepared and submitted to secure provisional Australian PBR protection for this selection.

'RS103-110' matures immediately after 'Royal Gala'. The timing of the first harvest of 'RS103-110' generally coincides with the final harvest of 'Gala' and its strains. 'RS103-110' apples mature over a three week period, during which two to three harvests are required.

The apple has a balanced, sweet flavour, fine melting texture and is crisp and juicy. 'RS103-110' tends to be a small to medium sized apple, and the fruit shape is flat-round to round-conical. 'RS103-110' apples borne on spurs tend to be smaller and flatter than those fruit borne on terminal buds. Trees of 'RS103-110' are of medium vigour and spreading growth habit. A more detailed description of the tree and fruit characteristics of 'RS103-110' is provided on the following page.

The medium vigour of 'RS103-110' trees makes this selection well-adapted to high density planting systems. Trees respond well to shoot and limb bending, and can produce exceptionally high packouts (> 90%) of first grade fruit, even when large parts of the canopy are relatively shaded (Middleton *et al.*, 2012).

One deficiency of 'RS103-110' is that it can be a small apple, especially when trees are over-cropped or thinned in late spring or early summer (Middleton *et al.*, 2012). Interestingly however, many consumers see small fruit size as a desirable trait (refer Chapter 7), and 'RS103-110' as a small, sweet apple well suited to children's lunchboxes.

Nevertheless, 'RS103-110' has the capacity to be a larger apple if trees are appropriately managed (Middleton *et al.*, 2012), and the use of Artificial Spur Extinction (Tustin *et al.*, 2011) may be an effective strategy to increase fruit size, if so desired, of this selection.

No apple scab has been observed on leaves or fruit of 'RS103-110' trees in eight years of high density production at ARS. This is despite the absence of sprays for apple scab control (apart from an annual green tip copper spray), and the presence of apple scab inoculum in the orchard.

'RS103-110' has particular potential as an organic scab-resistant 'Gala' style of apple. In addition to resistance to apple scab, 'RS103-110' is tolerant of *Alternaria*. 'RS103-110' has shown no symptoms of this disease of leaves and fruit, despite trees being planted immediately adjacent to a row of a highly *Alternaria* susceptible cultivar that loses 50% of its leaves to the disease by February each year.

'RS103-110' has also been evaluated at interstate APFIP sites in Victoria (Goulburn Valley), SA (Adelaide Hills) and Tasmania (Huon Valley). Over several years of observations at the three sites, 'RS103-110' showed no incidence of apple scab infection. As in Qld, the apples were consistently described as 80-90% red over-colour with rich/sweet flavour and crisp, fine/melting texture.

'RS103-110' rated very highly in consumer evaluations in Brisbane when compared with a wide range of current commercial apples varieties (Chapter 7). In addition, 'RS103-110' apples have retained excellent postharvest texture when held at room temperature for three to four weeks (Chapter 8). Postharvest quality is consistently superior to 'Gala', 'Red Delicious' and 'Fuji', and, to a more variable extent, broadly comparable to or better than 'Pink Lady'<sup>TM</sup> and 'Sundowner'<sup>TM</sup>. Details of these experiments are provided in Chapter 8.

Positive feedback from consumers in Brisbane, observers at APFIP evaluation sites, and apple growers who have seen cropping trees of 'RS103-110' and tasted the fruit, has helped confirm the decision to submit the Part 1 Australian PBR application and progress commercialisation of 'RS103-110'.

## **RS103-110**



**Full Bloom (2011) :** 28 Sep (overlap with Granny Smith, Pink Lady)

**Full Bloom (2012) :** 26 Sep (overlap with Granny Smith, Pink Lady)

Harvest (2012) : 29 Feb - 15 Mar (similar to Red Delicious)

Harvest (2013) : 27 Feb - 14 Mar (similar to Red Delicious)

#### Description

'RS103-110' has a dark red foreground stripe over a yellow-green background. It is a small-medium sized apple, with a balanced, sweet flavour and crisp, firm, fine melting texture.

#### **Fruit Characteristics**

Foreground Colour:	Red (46A - 53A)	TSS:	13.0 %
Blush Coverage:	>60%	Fruit Firmness:	Firm 8.7 kgF
Shape:	Flat Round - Round Conical	Flesh Browning:	-
Average Fruit Weight:	130-145 g	5 minutes -	Nil
Texture:	Crisp, Medium	30 minutes -	Slight
Shelflife:	8.8 kgF; Firm, over-ripe	60 minutes -	Slight
(14 days)			-

#### **Tree Characteristics**

Habit:	Spreading	
Fruiting Habit:	Spurs, Terminals	
Vigour:	Medium	

#### **Disease Susceptibility**

Powdery Mildew: Nil

Alternaria Leaf Spot: Nil

#### Status

Likely to be the second scab-resistant apple released from the DAFF Qld breeding program. Part 1 Australian PBR application submitted.

## 6. Scab-resistant apples with commercial potential

In addition to 'Kalei' ('RS103-130') and 'RS103-110', there are a further 34 scab-resistant selections considered to have, to varying degrees, at least some potential for commercialisation.

Each of these is illustrated and described in detail in the following pages. The descriptions are based on the observations and measurements outlined in Section 2.2. The current status of each apple selection is also provided, and in some cases includes suggested future evaluation needs and possible commercialisation niches.

The 34 scab-resistant apple selections detailed in this chapter can be broadly divided as early, mid or late season selections, as below. They are listed in chronological order of maturity.

Early season (Jan/Feb)	Mid season (March)	Late season (Apr/May)
SP17-239	FB1-155	SP5-348
SP17-270	FB7-119	RS103-95
FB13-40	FB22-47	FB14-61
FB13-36	RS108-96	SP18-61
FB1-97	FB1-128	RS103-56
RS102-50	FB12-23	SP6-317
SP16-51	FB12-31	FB24-108
RS104-1	RS109-70	SP7-226
FB1-39	SP7-338	
FB15-61	FB11-123	
SP16-97	FB17-5	
	FB7-159	
	SP13-12	
	SP7-82	
	RS109-15	

It is possible that only one or two of these may make it through to full commercialisation in the medium to long term. Some of these scab-resistant selections have one or two deficiencies that, whilst not considered points of "Critical Failure", make them less likely than others to be commercialised.

This, however, is no different to the situation with current commercial apple varieties grown in Australia. For example, 'Red Delicious' can be a soft, mealy apple, and 'Gala' apples do not maintain their quality after long term storage as well as other varieties.

The identification of multiple scab resistance genes across some of these selections (Chapter 9) adds significant weight to their value and future potential, either as varieties in their own right, or as potential parents in future breeding programs.

The procedure described in Section 2.2 was used to provide the data and information presented in the following 34 selection description pages. These are a compilation of the observations and measurements made over the two seasons 2012 and 2013.

### SP17-239



**Full Bloom (2011) :** 5 Oct (overlap with Red Delicious, Fuji) **Full Bloom (2012) :** 2 Oct (overlap with Red Delicious) Harvest (2012) : 20 Jan - 17 Feb (before/similar to Gala) Harvest (2013) : 17 Feb - 20 Feb (similar to Gala)

#### Description

'SP17-239' has a block red-purple colour with a light stripe, over a yellow background. It is juicy with medium texture and neutral to mild flavour. Excellent size and shape for an early variety.

#### **Fruit Characteristics**

Foreground Colour:	Red (46A)	TSS:	12.0 %
Blush Coverage:	>90%	Fruit Firmness:	Medium 6.3 kgF
Shape:	Conical - Square Oblong	Flesh Browning:	-
Average Fruit Wt:	168 g	5 minutes -	Slight
Texture:	Medium - Soft	30 minutes -	Slight
Shelflife:	6.6 kgF; Soft	60 minutes -	Slight
(14 days)	-		-

#### **Tree Characteristics**

Habit:	Spreading	
Fruiting Habit:	Spurs	
Vigour:	Medium - High	

#### **Disease Susceptibility**

Powdery Mildew: Nil

Alternaria Leaf Spot: Nil

#### Status

The primary advantage of 'SP17-239' is its early maturity, coupled with good fruit size. Texture can be soft. There are currently only two trees of 'SP17-239' at ARS. A further ten trees were grafted onto M.26 rootstock in 2012-13.

## **SP17-270**



**Full Bloom (2011) :** 5 Oct (overlap with Red Delicious, Fuji) **Full Bloom (2012) :** 29 Sep (overlap with Granny Smith, Fuji) Harvest (2012) : 30 Jan - 10 Feb (similar to Gala) Harvest (2013) : 15 Feb - 22 Feb (similar to Gala)

#### Description

'SP17-270' is an attractive red block medium-sized apple with a light stripe. 'SP17-270' has a crisp, breaking texture and a balanced, sweet flavour. Fruit shape and size can be variable.

#### **Fruit Characteristics**

Foreground Colour:	Red (46A)	TSS:	13.5 %
Blush Coverage:	>70%	Fruit Firmness:	Crisp 7.5 kgF
Shape:	Round Conical	Flesh Browning:	
Average Fruit Wt:	150 g	5 minutes -	Nil
Texture:	Crisp, Breaking	30 minutes -	Slight
Shelflife:	6.4 kgF; Soft, Bland	60 minutes -	Slight
(14 days)	-		-

#### **Tree Characteristics**

Habit:	Spreading	
Fruiting Habit:	Spurs	
Vigour:	Medium	

#### **Disease Susceptibility**

**Powdery Mildew:** Nil

Alternaria Leaf Spot: Nil

#### Status

The early maturity, attractiveness and good eating quality of 'SP17-270' are desirable attributes. There are currently only two trees of 'SP17-239' at ARS. A further 30 trees were grafted onto M.26 rootstock in 2012-13, for potential further testing of this selection.

## FB13-40



Full Bloom (2011): 7 Oct (overlap with Red Delicious) Full Bloom (2012): 5 Oct (overlap with Red Delicious) Harvest (2012) : 14 - 24 Feb (similar to Gala) Harvest (2013) : 4 - 15 Feb (similar to Gala)

#### Description

'FB13-40' is a small, attractive block red apple with a yellow-green background. It has a strong white flesh colour and is juicy, with good texture and a somewhat tart flavour.

#### **Fruit Characteristics**

Foreground Colour:	Red (46A)	TSS:	13.0 %
Blush Coverage:	>70%	Fruit Firmness:	Firm 7.5 kgF
Shape:	Flat Round	Flesh Browning:	-
Average Fruit Wt:	110 g	5 minutes -	Slight
Texture:	Crisp, Medium	30 minutes -	Slight
Shelflife:	7.4 kgF; Firm, over-ripe	60 minutes -	Slight
(14 days)			

#### **Tree Characteristics**

Habit:	Spreading Spurs	
Fruiting Habit:		
Vigour:	Low	

#### **Disease Susceptibility**

Powdery Mildew: Nil

Alternaria Leaf Spot: Nil

#### Status

The small fruit size of 'FB13-40' may be an issue. There are currently only two trees of 'FB13-40' at ARS. Additional trees should be propagated for further testing, especially in relation to fruit size.

## FB13-36



Full Bloom (2011) : 8 Oct (overlap with Red Delicious) Full Bloom (2012) : 5 Oct (overlap with Red Delicious) Harvest (2012) : 13 - 24 Feb (similar to Gala) Harvest (2013) : 6 - 15 Feb (similar to Gala)

#### Description

'FB13-36' is an attractive, block red apple with a light stripe. Similar to, but larger than 'FB13-40', with strong white flesh colour, good texture and tart flavour. Not as juicy as 'FB13-40'.

#### **Fruit Characteristics**

Foreground Colour:	Red (46A)	TSS:	12.4 %
Blush Coverage:	>60%	Fruit Firmness:	Firm 7.6 kgF
Shape:	Flat Round	Flesh Browning:	
Average Fruit Wt:	120 g	5 minutes -	Slight
Texture:	Crisp, Moderate	30 minutes -	Slight
Shelflife:	7.2 kgF; Firm, over-ripe	60 minutes -	Moderate
(14 days)			

#### **Tree Characteristics**

Habit:	Spreading Spurs	
Fruiting Habit:		
Vigour:	Low	

#### **Disease Susceptibility**

**Powdery Mildew:** Nil

Alternaria Leaf Spot: Nil

#### Status

The overall appearance and eating quality of 'FB13-36' is good. There are currently only two trees of 'FB13-36' at ARS. Additional trees should be propagated for further testing. Has potential as a 'European' style tart apple.

### FB1-97



**Full Bloom (2011) :** 5 Oct (overlap with Red Delicious, Fuji) **Full Bloom (2012) :** 27 Sep (overlap with Granny Smith, Fuji) Harvest (2012) : 6 -17 Feb (similar to Gala) Harvest (2013) : 6 - 15 Feb (similar to Gala)

#### Description

'FB1-97' is a small to medium-sized apple with a red stripe over a yellow background. It has an attractive, distinctive appearance, a very sweet, honey flavour and is of crisp medium texture.

#### **Fruit Characteristics**

Foreground Colour:	Red (46A)	TSS:	15.9 %
Blush Coverage:	>60%	Fruit Firmness:	Medium 7.5 kgF
Shape:	Round Conical	Flesh Browning:	
Average Fruit Wt:	130-150 g	5 minutes -	Slight
Texture:	Medium	30 minutes -	Slight
Shelflife:	6.9 kgF;	60 minutes -	Moderate
(14 days)	-		

#### **Tree Characteristics**

Habit:	Spreading	
Fruiting Habit:	Spurs	
Vigour:	Low	

#### **Disease Susceptibility**

Powdery Mildew: Nil

Alternaria Leaf Spot: Nil

#### Status

The overall eating quality and shelf life of 'FB1-97' is good. 'FB1-97' is considered to have potential as an early season, sweet scab-resistant apple. There are currently only three trees of 'FB1-97' at ARS. Additional trees need to be propagated, for further testing of this selection.

### **RS102-50**



Full Bloom (2011): 2 Oct (overlap with Sundowner) Full Bloom (2012): 29 Sep (overlap with Gala, Fuji) Harvest (2012) : 6 - 20 Feb (similar to Gala) Harvest (2013) : 5 - 21 Feb (similar to Gala)

#### Description

'RS102-50' is an attractive, medium-large apple with mixed red block/stripe over a yellow-green background. Eating quality is excellent, and apples retain firm, crisp texture at room temperature. 'RS102-50' can be picked over a long period without premature fruit drop.

#### **Fruit Characteristics**

Foreground Colour:	Red (46A)	TSS:	13.9 %
Blush Coverage:	>80%	Fruit Firmness:	Firm 8.5 kgF
Shape:	Round Conical - Conical	Flesh Browning:	-
Average Fruit Wt:	150-170 g	5 minutes -	Slight
Texture:	Medium	30 minutes -	Moderate
Shelflife:	8.9 kgF; Retains appearance	60 minutes -	Moderate
(14 days)	and eating quality		

#### **Tree Characteristics**

Habit:	Spreading	
Fruiting Habit:	Spurs	
Vigour:	Low	

#### **Disease Susceptibility**

Powdery Mildew: Nil

Alternaria Leaf Spot: Nil

#### Status

'RS102-50' is a strong candidate for potential commercialisation, as a large, early-season apple of high quality. 'RS102-50' rated highly in consumer and postharvest sensory evaluations (Chapters 7 and 8). There are currently 14 trees of 'RS102-50' at ARS. Additional trees need to be propagated.

## SP16-51



Full Bloom (2011) :1 Oct(overlap with Gala, Fuji)Full Bloom (2012) :28 Sep(overlap with Granny Smith, Fuji)

Harvest (2012): 7 - 22 Feb (similar to Gala) Harvest (2013): 11 - 22 Feb (similar to Gala)

#### Description

'SP16-51' is an attractive red block medium size apple. It is very juicy and moderately tart, with a crisp, breaking texture. Trees consistently produce good annual yields.

#### **Fruit Characteristics**

Foreground Colour:	Red (42A - 46A)	TSS:	14.2 %
Blush Coverage:	>80%	Fruit Firmness:	Medium 7.4 kgF
Shape:	Round Conical	Flesh Browning:	
Average Fruit Wt:	135-160 g	5 minutes -	Slight
Texture:	Crisp, Breaking	30 minutes -	Slight
Shelflife:	5.9 kgF; Good appearance	60 minutes -	Slight
(14 days)	and flavour		

#### **Tree Characteristics**

Habit:	Spreading	
Fruiting Habit:	Spurs	
Vigour:	High	

#### **Disease Susceptibility**

Powdery Mildew: Nil

Alternaria Leaf Spot: Nil

#### Status

The moderately tart flavour of the attractive 'SP16-51' apple is distinctive and appealing. There are currently five trees of 'SP16-51' at ARS. Additional trees need to be propagated for further testing of this selection.

## **RS104-1**



Full Bloom (2011) :5 Oct(overlap with Red Delicious, Fuji)Full Bloom (2012) :1 Oct(overlap with Red Delicious, Gala)

Harvest (2012) : 13 - 24 Feb (similar to Gala, Red Delicious) Harvest (2013) : 10 - 20 Feb (similar to Gala)

#### Description

'RS104-1' is a medium size red apple with a very attractive blush and underlying stripe. The flavour is balanced and sweet, and apples are juicy with strong white flesh. Texture can be soft.

#### **Fruit Characteristics**

Foreground Colour:	Red (46A-59A)	TSS:	13.2 %
Blush Coverage:	>75%	Fruit Firmness:	Medium 7.6 kgF
Shape:	Flat Round - Round Conical	Flesh Browning:	
Average Fruit Wt:	150 g	5 minutes –	Slight
Texture:	Initial crunch but soft	30 minutes -	Slight
Shelflife:	4.4 kgF; Soft with off	60 minutes -	Moderate
(14 days)	flavours		

#### **Tree Characteristics**

Habit:	Spreading	
Fruiting Habit:	Spurs	
Vigour:	Medium	

#### **Disease Susceptibility**

**Powdery Mildew:** Slight

Alternaria Leaf Spot: Nil

#### Status

'RS104-1' is a highly attractive apple with beautiful colour and good flavour. Loss of firmness in shelf life tests may be an issue, however 'RS104-1' performed well in consumer evaluations (Chapter 7). There are currently four trees of 'RS104-1' at ARS. Additional trees need to be propagated to allow further testing of 'RS104-1' to conclusively determine its commercialisation potential.

**FB1-39** 



Full Bloom (2011) : 29 Sep (overlap with Pink Lady, Granny Smith) Full Bloom (2012) : 27 Sep (overlap with Red Delicious, Gala)

Harvest (2012) : 13 Feb - 2 Mar (similar to Gala, Red Delicious) Harvest (2013): 11 Feb - 15 Feb (similar to Gala)

#### Description

'FB1-39' is a medium sized, block red apple with an underlying stripe, over a light yellow background. It is somewhat tart, which is balanced with slight sweetness that becomes more pronounced if fruit are left on the tree. 'FB1-39' firmness declines at room temperature.

#### **Fruit Characteristics**

Foreground Colour:	Red (46A - 53A)	TSS:	13.0 %
Blush Coverage:	>80%	Fruit Firmness:	Medium 7.5 kgF
Shape:	Round Conical	Flesh Browning:	
Average Fruit Wt:	140-160 g	5 minutes -	Nil
Texture:	Crisp, Breaking	30 minutes -	Slight
Shelflife:	5.8 kgF; Softening,	60 minutes -	Moderate
(14 days)	over-ripe		
Tree Characteristics			
Habit:	Spreading		
Fruiting Habit:	Spurs		
Vigour:	Medium		
Disease Susceptibility			

**Powdery Mildew:** Moderate

Alternaria Leaf Spot: Nil

#### Status

'FB1-39' has potential as a tart apple that may be particularly suited to European or North American palates. There are currently only three trees of 'FB1-39' at ARS. Additional trees should be propagated for further testing.

## FB15-61



**Full Bloom (2011) :** 5 Oct (overlap with Fuji, Red Delicious) **Full Bloom (2012) :** 1 Oct (overlap with Gala, Fuji, Red Delicious) Harvest (2012) : 20 Feb - 2 Mar (similar to Gala) Harvest (2013) : 11 Feb - 25 Feb (similar to Gala)

#### Description

'FB15-61' is an attractive, block red apple with yellow-green background and prominent lenticels. It has a sprightly, balanced flavour and excellent crisp, fine texture which rapidly declines postharvest.

#### **Fruit Characteristics**

Foreground Colour:	Red (46A-53A)	TSS:	12.6 %
Blush Coverage:	>70%	Fruit Firmness:	Firm 7.1 kgF
Shape:	Flat Round - Round	Flesh Browning:	-
Average Fruit Wt:	140-160 g	5 minutes -	Slight
Texture:	Fine, Crunchy	30 minutes -	Moderate
Shelflife: (14 days)	4.7 kgF; Poor eating quality	60 minutes -	Moderate
Tree Characteristics			

Spreading

Spurs High

Habit: Fruiting Habit: Vigour:

Disease Susceptibility

Powdery Mildew: Nil

Alternaria Leaf Spot: Nil

#### Status

Fresh 'FB15-61' apples are very good eating, but poor shelf life in tests to date indicate it is likely to only have potential for the fresh market. There are currently four trees of 'FB15-61' at ARS.

### **SP16-97**



Full Bloom (2011): 4 Oct (overlap with Fuji, Red Delicious) Full Bloom (2012): 6 Oct (overlap with Red Delicious) Harvest (2012) : 20 Feb - 2 Mar (similar to Gala, Red Delicious) Harvest (2013) : 18 Feb - 28 Feb (similar to Gala, Red Delicious)

#### Description

'SP16-97' is a large, block red apple with a light stripe and yellow background. It is crisp, juicy and moderately sweet. Firmness declines significantly over 14 days at room temperature.

#### **Fruit Characteristics**

Foreground Colour:	Red (46A)	TSS:	13.4 %
Blush Coverage:	>50%	Fruit Firmness:	Medium 7.4 kgF
Shape:	Round - Round Conical	Flesh Browning:	
Average Fruit Wt:	170-190 g	5 minutes -	Slight
Texture:	Medium	30 minutes -	Slight
Shelflife:	3.6 kgF; Soft, Poor	60 minutes -	Slight
(14 days)	Quality		

#### **Tree Characteristics**

Habit:	Weeping	
Fruiting Habit:	Spurs	
Vigour:	Low	

#### **Disease Susceptibility**

**Powdery Mildew:** Nil

Alternaria Leaf Spot: Nil

#### Status

'SP16-97' is a very attractive, large apple, however the poor shelf life is a drawback. 'SP16-97' may therefore only have potential as a fresh market apple, or, alternatively, as an easy to grow scab-resistant apple appropriate to third world regions, where agronomic skills are limited and the apples are used to feed local communities. There are currently three trees of 'SP16-97' at ARS.

## FB1-155



Full Bloom (2011) : 8 Oct (overlap with Red Delicious, Fuji) Full Bloom (2012) : 5 Oct (overlap with Red Delicious, Fuji) Harvest (2012) : 27 Feb - 9 Mar (similar to Red Delicious, Fuji) Harvest (2013) : 15 Feb - 1 Mar (similar to Gala, Red Delicious)

#### Description

'FB1-155' is a pink-red, medium to large apple with a light stripe and prominent lenticels. 'FB1-155' has a subtle, sweet flavour and low acidity. Trees consistently yield well. Questionable shelf life.

#### **Fruit Characteristics**

Foreground Colour:	Red (46A)	TSS:	13.5 %
Blush Coverage:	>70%	Fruit Firmness:	Firm 8.0 kgF
Shape:	Round - Round Conical	Flesh Browning:	-
Average Fruit Wt:	190 g	5 minutes -	Slight
Texture:	Fine Melting	30 minutes -	Slight
Shelflife:	6.6 kgF; Eating quality	60 minutes -	Slight
(14 days)	deteriorated		-
Tree Characteristics			
Habit:	Spreading		
Fruiting Habit:	Spurs		
Vigour:	Medium		

#### **Disease Susceptibility**

Powdery Mildew: Slight

Alternaria Leaf Spot: Nil

#### Status

'FB1-155' is of excellent appearance and eating quality. There are currently only three trees of 'FB1-155' at ARS. Consumer and postharvest sensory evaluations would have been undertaken if there were more trees to produce the required fruit numbers. Additional trees need to be propagated.

## FB7-119



Full Bloom (2011): 30 Sep (overlap with Pink Lady, Granny Smith)
Full Bloom (2012): 29 Sep (overlap with Red Delicious, Fuji) Harvest (2012): 5 - 16 Mar (similar to Red Delicious, Fuji) Harvest (2013): 15 - 27 Feb (similar to Gala)

#### Description

'FB7-119' is a large bi-colour apple with a block red blush on a yellow- green background. 'FB7-119' is a sweet, low acid apple with a fine texture. It is juicy, with a delicate flavour and hint of aniseed. The trees consistently produce heavy crops.

#### **Fruit Characteristics**

Foreground Colour:	Red (46A)	TSS:	14.0 %
Blush Coverage:	>70%	Fruit Firmness:	Soft 6.6 kgF
Shape:	Round Conical	Flesh Browning:	-
Average Fruit Wt:	170-190 g	5 minutes -	Nil
Texture:	Moderate to Soft	30 minutes -	Slight
Shelflife:	5.7 kgF; Softening	60 minutes -	Slight
(14 days)	and over-ripe		
Tree Characteristics			
Habit:	Spreading		
Fruiting Habit:	Spurs		
Vigour:	Medium		
Disease Susceptibility			
Powdery Mildew: Nil		<i>Alternaria Leaf Spot:</i> N	il

#### Status

'FB7-119' is an attractive apple but the texture may be too soft for wide appeal, or restrict it to the fresh market. There are currently fifteen trees of 'FB7-119' at ARS. Consumer and postharvest evaluations are required to determine the future potential of this selection.

### **FB22-47**



Full Bloom (2011):6 Oct(overlap with Gala, Fuji)Full Bloom (2012):29 Sep(overlap with Gala, Fuji)

Harvest (2012) : 22 Feb - 2 Mar (similar to Gala, Red Delicious) Harvest (2013) : 21 Feb - 9 Mar (similar to Gala, Red Delicious)

#### Description

'FB22-47' is a block red to purple apple, with a pale yellow background. The fruit is brightly coloured, and it takes several weeks for the balanced, sweet flavour to develop in apples on the tree. In the interim there can be significant preharvest drop.

#### **Fruit Characteristics**

Foreground Colour:	Red (46A) - Purple (59A)	TSS:	12.0 %
Blush Coverage:	>70%	Fruit Firmness:	Medium 7.1 kgF
Shape:	Flat Round - Round	Flesh Browning:	-
Average Fruit Wt:	175-225 g	5 minutes -	Slight
Texture:	Crisp, Medium	30 minutes -	Moderate
Shelflife:	7.0 kgF; Moderate texture	60 minutes -	Moderate
(14 days)	but over-ripe		
Tree Characteristics			
Habit:	Spreading		
Fruiting Habit:	Spurs		
Vigour:	High		
Disease Susceptibility			

#### Powdery Mildew: High

Alternaria Leaf Spot: Very High

#### Status

'FB22-47' is very highly susceptible to *Alternaria*, and 50% defoliation can occur on trees prior to harvest. This makes it unsuited to organic production. 'FB22-47' cannot be commercialised unless more effective controls for *Alternaria* are found. There are 180 'FB22-47' trees at ARS.
# **RS108-96**



Full Bloom (2011): 13 Oct (overlap with Red Jonathan)
Full Bloom (2012): 28 Feb (overlap with Granny Smith, Jonathan) Harvest (2012) : 12 Mar - 23 Mar (similar to Red Delicious) Harvest (2013) : 21 Feb - 12 Mar (similar to Gala, Red Delicious)

# Description

'RS108-96' is a medium to large sized apple, with a red stripe over yellow green background. Apples are very attractive and russet free. 'RS108-96' has a subtle, sweet flavour and excellent texuture.

#### **Fruit Characteristics**

Foreground Colour: Blush Coverage: Shape:	Red (46A – 45B) 60 - 80% Round - Round Conical	TSS: Fruit Firmness: Flesh Browning:	12.0 % Firm 9.9 kgF
Average Fruit Wt: Texture: Shelflife: (14 days)	175 g Medium 8.8 kgF; Good texture, bland flavour	5 minutes – 30 minutes – 60 minutes –	Nil Slight Moderate

# **Tree Characteristics**

Habit:	Spreading	
Fruiting Habit:	Spurs	
Vigour:	Low	

# **Disease Susceptibility**

Powdery Mildew: Nil

Alternaria Leaf Spot: Nil

#### Status

The attractive appearance and excellent eating qualities of 'RS108-96' make it a strong candidate for potential commercialisation. Unfortunately, there are only three 'RS108-96' at ARS. Further trees must be propagated as a priority to allow more detailed evaluation of this selection.

# FB1-128



Full Bloom (2011):5 Oct(overlap with Gala, Fuji)Full Bloom (2012):26 Sep(overlap with Gala, Fuji)

Harvest (2012) : 27 Feb - 12 Mar (similar to Red Delicious) Harvest (2013) : 25 Feb - 8 Mar (similar to Red Delicious)

# Description

'FB1-128' is a medium sized, block red apple with prominent lenticels. It is very juicy, with a balanced, sweet flavour and delicate texture. Firmness declines significantly at room temperature.

### **Fruit Characteristics**

Foreground Colour:	Red (53A)	TSS:	13.6 %
Blush Coverage:	>/0%	Fruit Firmness:	Soft 7.0 kgF
Shape:	Round - Round Conical	Flesh Browning:	
Average Fruit Wt:	165 g	5 minutes -	Slight
Texture:	Soft	30 minutes -	Slight
Shelflife:	5.4 kgF; Mealy,	60 minutes -	Slight
(14 days)	unpalatable		

#### **Tree Characteristics**

Habit:	Spreading	
Fruiting Habit:	Spurs	
Vigour:	Low	

#### **Disease Susceptibility**

**Powdery Mildew:** Nil

Alternaria Leaf Spot: Nil

#### Status

The distinctive appearance and delicate texture of 'FB1-128' are seen as positive attributes by some, but the poor shelf life is a concern. There are currently four trees of 'FB1-128' at ARS. 'FB1-128' requires further testing of postharvest quality and shelf life. It is unlikely to be commercialised.

# FB12-23



Full Bloom (2011) : 11 Oct (overlap with Red Delicious) Full Bloom (2012) : 1 Oct (overlap with Red Delicious) Harvest (2012): 19 Mar - 29 Mar (similar to Red Delicious, Fuji) Harvest (2013): 25 Feb - 8 Mar (similar to Red Delicious, Fuji)

### Description

'FB12-23' is a highly attractive pale yellow apple with a distinctive light red-pink blush. 'FB12-23' is crisp and juicy, with breaking texture and an interesting sweet, yet slightly tart flavour balance.

#### **Fruit Characteristics**

Foreground Colour:	Red (43A - 44B)	TSS:	14.8 %
Blush Coverage:	10 - 40%	Fruit Firmness:	Firm 9.0 kgF
Shape:	Round Conical	Flesh Browning:	-
Average Fruit Wt:	150-170 g	5 minutes -	Slight
Texture:	Medium	30 minutes -	Slight
Shelflife:	7.3 kgF; Coarse, Chewy	60 minutes -	Slight
(14 days)	-		-

#### **Tree Characteristics**

Habit:	Spreading
Fruiting Habit:	Spurs
Vigour:	Low - Medium

#### **Disease Susceptibility**

**Powdery Mildew:** Nil

Alternaria Leaf Spot: Nil

#### Status

The attractive, unique appearance, flavour and texture of 'FB12-23' make this an appealing apple with possible strong commercial potential. 'FB12-23' has only been observed in 2012 and 2013. There are currently four trees of 'FB12-23' at ARS. Additional trees need to be propagated as a priority, to allow further detailed evaluation of this very interesting selection.

# FB12-31



Full Bloom (2011) : 8 Oct (overlap with Red Delicious) Full Bloom (2012) : 4 Oct (overlap with Red Delicious) Harvest (2012) : 26 Mar - 30 Mar (similar to Red Delicious) Harvest (2013) : 25 Feb - 14 Mar (similar to Red Delicious, Fuji)

#### Description

'FB12-31' is a predominately block red apple, with an underlying light stripe. The apples have prominent lenticels, and are moderately juicy, with rich, sweet flavour and excellent texture.

#### **Fruit Characteristics**

Foreground Colour:	Red (46A - 59A)	TSS:	14.8 %
Blush Coverage:	>50%	Fruit Firmness:	Firm 8.7 kgF
Shape:	Flat Round - Round Conical	Flesh Browning:	-
Average Fruit Wt:	140-150 g	5 minutes -	Slight
Texture:	Firm, Crisp, slightly Chewy	30 minutes -	Slight
Shelflife:	9.0 kgF; Good eating quality	60 minutes -	Moderate
(14 days)			

#### **Tree Characteristics**

Habit:	Spreading	
Fruiting Habit:	Spurs	
Vigour:	Low - Medium	

#### **Disease Susceptibility**

Powdery Mildew: Nil

Alternaria Leaf Spot: Slight - Moderate

#### Status

The flavour, excellent texture and distinctive appearance of 'FB12-31' make this an apple with potential consumer appeal. There are currently only two trees of 'FB12-31' at ARS. Additonal trees need to be propagated for further testing of this selection. *Alternaria* leaf spot may be an issue.

# **RS109-70**



Full Bloom (2011) : 28 Sep(overlap with Fuji)Full Bloom (2012) : 3 Oct(overlap with Red Delicious)

Harvest (2012): 5 Mar - 16 Mar (similar to Red Delicious, Fuji) Harvest (2013): 25 Feb - 15 Mar (similar to Red Delicious, Fuji)

# Description

'RS109-70' is a large, russet-free, very attractive, red striped apple. 'RS109-70' has a coarse, crunchy texture and tart, low sugar flavour that is distinctively effervescent and tastes of lemonade.

### **Fruit Characteristics**

Foreground Colour:	Red (46A)	TSS:	11.4 %
Blush Coverage:	60 - 80%	Fruit Firmness:	Firm 7.3 kgF
Shape:	Round Conical	Flesh Browning:	
Average Fruit Wt:	170-190 g	5 minutes -	Slight
Texture:	Firm, Coarse	30 minutes -	Moderate
Shelflife: (14 days)	8.2 kgF; Firm, fair texture and flavour	60 minutes -	Moderate

### **Tree Characteristics**

Habit:	Spreading
Fruiting Habit:	Spurs
Vigour:	Medium - High

#### **Disease Susceptibility**

Powdery Mildew: High

Alternaria Leaf Spot: Nil

#### Status

'RS109-70' is an attractive apple distinctive for its "lemonade" flavour. There are currently only three trees of 'RS109-70' at ARS. Consumer evaluations would have been undertaken if there were more trees to produce the required fruit numbers. Additional trees must be propagated for future evaluation.

# **SP7-338**



Full Bloom (2011):2 Oct(overlap with Fuji, Gala)Full Bloom (2012):27 Sep(overlap with Fuji, Gala)

Harvest (2012) : 27 Feb - 9 Mar (similar to Red Delicious, Fuji) Harvest (2013) : 25 Feb - 8 Mar (similar to Red Delicious, Fuji)

### Description

'SP7-338' is an attractive, bicoloured red blush apple with a yellow-green background. 'SP7-338' has a fresh "biflavour" mix of acid and sugar, and fine melting, soft flesh. The shelf life of 'SP7-338' is poor.

### **Fruit Characteristics**

Foreground Colour:	Red (46A)	TSS:	14.4 %
Blush Coverage:	>50%	Fruit Firmness:	Medium 7.3 kgF
Shape:	Round - Round Conical	Flesh Browning:	
Average Fruit Wt:	140-170 g	5 minutes -	Slight
Texture:	Fine Melting	30 minutes -	Slight
Shelflife:	4.1 kgF; Soft, inedible	60 minutes -	Slight
(14 days)	-		-

#### **Tree Characteristics**

Habit: Fruiting Habit: Vigour: Spreading Predominately Spurs Low

#### **Disease Susceptibility**

**Powdery Mildew:** Nil

Alternaria Leaf Spot: Low - Moderate

#### Status

The unique flavour and attractive appearance of 'SP7-338' are its main appeal, however potentially poor shelf life may be a concern. There are four trees of 'SP7-338' at ARS. Additional trees would need to be propagated to further evaluate this selection, primarily for postharvest sensory quality.

# FB11-123



Full Bloom (2011): 9 Oct (overlap with Red Delicious) Full Bloom (2012): 6 Oct (overlap with Red Delicious) Harvest (2012) : 12 - 23 Mar (similar to Red Delicious, Fuji) Harvest (2013) : 4 - 14 Mar (similar to Red Delicious, Fuji)

### Description

'FB11-123' is a pale yellow apple which can have a slight brownish red blush. 'FB11-123' has excellent eating quality, crisp texture and juicy, sweet flavour. Russet can diminish its appearance.

#### **Fruit Characteristics**

Foreground Colour:	Yellow (10A - 13C)	TSS:	15.2 %
Blush Coverage:	100%	Fruit Firmness:	Firm 8.5 kgF
Shape:	Round Conical	Flesh Browning:	-
Average Fruit Wt:	150-175 g	5 minutes -	Slight
Texture:	Medium, Crisp	30 minutes -	Slight
Shelflife:	8.1 kgF; Poor, over-ripe	60 minutes -	Slight
(14 days)			-

# **Tree Characteristics**

Habit:	Spreading
Fruiting Habit:	Spurs
Vigour:	Medium

#### **Disease Susceptibility**

**Powdery Mildew:** Nil

Alternaria Leaf Spot: Nil

#### Status

'FB11-123' is a 'Golden Delicious' apple type of excellent eating quality, however russet may detract from its appearance. There are three trees of 'FB11-123' at ARS. Additional trees of 'FB11-123' need to be propagated to further evaluate this selection and determine its commercial potential.

# FB17-5



Full Bloom (2011): 5 Oct (overlap with Gala, Fuji) Full Bloom (2012): 10 Oct (overlap with Gala, Red Delicious) Harvest (2012) : 12 - 23 Mar (similar to Fuji) Harvest (2013) : 4 - 14 Mar (similar to Red Delicious)

### Description

'FB17-5' is a large red apple with a light stripe. It is crisp and juicy, with a balanced sweet to sprightly flavour. 'FB17-5' maintains firmness over 14 days at room temperature.

#### **Fruit Characteristics**

Red (46A)	TSS:	13.5 %
>70%	Fruit Firmness:	Medium 6.7 kgF
Flat Round	Flesh Browning:	-
200 g	5 minutes -	Slight
Crisp, Firm	30 minutes -	Slight
6.5 kgF; Satisfactory eating quality	60 minutes -	Moderate
	Red (46A) >70% Flat Round 200 g Crisp, Firm 6.5 kgF; Satisfactory eating quality	Red (46A)TSS:>70%Fruit Firmness:Flat RoundFlesh Browning:200 g5 minutes -Crisp, Firm30 minutes -6.5 kgF; Satisfactory60 minutes -eating quality-

# **Tree Characteristics**

Habit:	Spreading
Fruiting Habit:	Predominantly spurs
Vigour:	Medium

#### **Disease Susceptibility**

Powdery Mildew: Nil

Alternaria Leaf Spot: Nil

#### Status

The attractive appearance and excellent eating quality of 'FB17-5' warrant its further evaluation. There are ten 'FB17-5' trees at ARS. Consumer evaluations would have been undertaken if there were more trees to produce the required fruit numbers. Additional trees need to be propagated.

# FB7-159



**Full Bloom (2011) :** 27 Sep (overlap with Granny Smith, Sundowner) **Full Bloom (2012) :** 26 Sep (overlap with Granny Smith, Fuji) Harvest (2012) : 5 - 16 Mar (similar to Red Delicious) Harvest (2013) : 4 - 15 Mar (similar to Red Delicious, Fuji)

# Description

'FB7-159' is an attractive red apple with a light stripe in the almost solid foreground colour. It is a crisp, medium textured apple of sweet, low acid flavour.

### **Fruit Characteristics**

Foreground Colour:	Red (46A - 59A)	TSS:	13.3 %
Blush Coverage:	>80%	Fruit Firmness:	Firm 7.4 kgF
Shape:	Round Conical	Flesh Browning:	-
Average Fruit Wt:	175-220 g	5 minutes -	Slight
Texture:	Medium	30 minutes -	Slight
Shelflife: (14 days)	6.1 kgF; Poor eating quality	60 minutes -	Slight
Tree Characteristics			
Habit:	Spreading		

Spurs

Low - Moderate

Disease Susceptibility

Fruiting Habit:

Powdery Mildew: Nil

Alternaria Leaf Spot: Nil

### Status

Vigour:

'FB7-159' is an attractive large red apple of good eating quality when fresh, but of poor quality out of storage. It is therefore only suitable for the fresh market. There are 80 trees at ARS. 'FB7-159' did not rate highly in a consumer evaluation (Chapter 7).

# **SP13-12**



Full Bloom (2011): 8 Oct (overlap with Red Delicious) Full Bloom (2012): 12 Oct (overlap with Red Delicious) Harvest (2012) : 12 - 30 Mar (similar to Red Delicious, Fuji) Harvest (2013) : 11 - 29 Mar (similar to Red Delicious, Fuji)

### Description

'SP13-12' is a block red apple with a light stripe and yellow background colour. It is crisp and sweet but lacking somewhat in juice. 'SP13-12' appearance and flavour are similar to 'Fuji'.

#### **Fruit Characteristics**

Foreground Colour:	Red (46A - 53A)	TSS:	14.0 %
Blush Coverage:	>70%	Fruit Firmness:	Medium 7.5kgF
Shape:	Round - Round Conical	Flesh Browning:	
Average Fruit Wt:	165 g	5 minutes -	Slight
Texture:	Crisp, Medium	30 minutes -	Moderate
Shelflife:	7.2 kgF; Quality declined but	60 minutes -	Severe
(14 days)	eats ok		

#### **Tree Characteristics**

Habit:	Spreading
Fruiting Habit:	Spurs
Vigour:	High

#### **Disease Susceptibility**

Powdery Mildew: Moderate

Alternaria Leaf Spot: Nil

#### Status

'SP13-12' is a scab-resistant 'Fuji' apple type. There are three trees of 'SP13-12' at ARS. Consumer evaluations would have been undertaken if there were more trees to produce the required fruit numbers. 30 nursery trees of 'SP13-12' were propagated in 2012-13, grafted onto M.26 rootstock.

**SP7-82** 



Full Bloom (2011): 1 Oct (overlap with Pink Lady, Granny Smith)
Full Bloom (2012): 28 Sep (overlap with Granny Smith, Gala) Harvest (2012) : 19 - 30 Mar (similar to Red Delicious, Fuji) Harvest (2013) : 1 - 12 Mar (similar to Red Delicious, Fuji)

### Description

'SP7-82' is an attractive, bicolour block red apple with a yellow background. 'SP7-82' has a smooth skin and is crisp, somewhat tart, with a medium texture. Shelf life was poor in 2013.

### **Fruit Characteristics**

Foreground Colour:	Red (46A - 53A)	TSS:	13.1 %
Blush Coverage:	50 - 70%	Fruit Firmness:	Medium 7.4 kgF
Shape:	Round - Round Conical	Flesh Browning:	-
Average Fruit Wt:	150-170 g	5 minutes -	Slight
Texture:	Crisp, Medium	30 minutes -	Moderate
Shelflife:	5.5 kgF;	60 minutes -	Moderate
(14 davs)	-		

#### **Tree Characteristics**

Habit:	Weeping		
Fruiting Habit:	Spurs		
Vigour:	Low		

#### **Disease Susceptibility**

Powdery Mildew: Nil

Alternaria Leaf Spot: Nil

#### Status

The tart flavour of the attractive 'SP7-82' apple will have appeal to a particular market segment. There are three trees of 'SP7-82' at ARS. More trees need to be propagated to fully evaluate the postharvest quality of 'SP7-82', and test whether the poor shelf life in 2013 was seasonal or varietal.

# **RS109-15**



Full Bloom (2011) : 10 Oct(overlap with Red Delicious)Full Bloom (2012) : 3 Oct(overlap with Red Delicious)

Harvest (2012) : 21 Mar - 2 Apr (similar to Red Delicious, Granny Smith) Harvest (2013) : 21 Mar - 4 Apr (similar to Red Delicious, Granny Smith)

### Description

'RS109-15' has a pink-red to red foreground stripe on a yellow background. It is a sweet, low acid apple of excellent firmness and texture. Yield and quality can be reduced by *Alternaria* infection.

#### **Fruit Characteristics**

Foreground Colour:	Red (46A)	TSS:	14.5 %
Blush Coverage:	>60%	Fruit Firmness:	Firm 8.9 kgF
Shape:	Round - Round Conical	Flesh Browning:	-
Average Fruit Wt:	175-200 g	5 minutes -	Nil
Texture:	Medium - Firm	30 minutes -	Slight
Shelflife:	10.0 kgF; Crisp, over-ripe but	60 minutes -	Slight
(14 days)	bland		-

### **Tree Characteristics**

Habit:	Spreading	
Fruiting Habit:	Spurs	
Vigour:	Medium	

#### **Disease Susceptibility**

**Powdery Mildew:** Slight

Alternaria Leaf Spot: High

#### Status

'RS109-15' has rated highly in consumer and postharvest evaluations (Chapters 7 and 8), particularly for its outstanding texture and shelf life. There are 80 'RS109-15' trees at ARS. Commercial adoption may be restricted to areas with no *Alternaria*. 'RS109-15' needs to be tested in *Alternaria* free regions such as Vic, Tas, SA, WA.

# **SP5-348**



Full Bloom (2011) :3 Oct(overlap with Gala, Fuji)Full Bloom (2012) :28 Sep(overlap with Gala, Fuji)

Harvest (2012) : 16 Apr - 27 Apr (similar to Pink Lady) Harvest (2013) : 18 Mar - 12 Apr (similar to Granny Smith, Pink Lady)

### Description

'SP5-348' is a medium-sized, block red apple with a light stripe and yellow-green background. It has a smooth skin finish, and is juicy with breaking texture and a sprightly, pleasant flavour.

#### **Fruit Characteristics**

Foreground Colour:	Red (46A)	TSS:	13.6 %
Blush Coverage:	>70%	Fruit Firmness:	Medium 8.6 kgF
Shape:	Round Conical	Flesh Browning:	-
Average Fruit Wt:	160-170 g	5 minutes -	Moderate
Texture:	Medium, Breaking	30 minutes -	Severe
Shelflife:	6.8 kgF; Firm with	60 minutes -	Severe
(14 days)	fair flavour		
Tree Characteristics			
Habit:	Spreading		
Fruiting Habit:	Spurs		
Vigour:	Medium		
Disease Susceptibility			

Powdery Mildew: Nil

Alternaria Leaf Spot: Slight

### Status

The very attractive 'SP5-348' apple should appeal to consumers who enjoy a tart apple. There are four 'SP5-348' trees at ARS. Consumer evaluations would have been undertaken if there were more trees to produce the required fruit numbers. 'SP5-348' warrants expanded testing.

# **RS103-95**



Full Bloom (2011) : 24 Sep (overlap with Sundowner, Braeburn) Full Bloom (2012) : 26 Sep (overlap with Sundowner, Braeburn) Harvest (2012): 23 - 30 Mar (similar to Granny Smith) Harvest (2013): 2 - 10 Apr (similar to Granny Smith)

### Description

'RS103-95' is a red-stripe apple of similar appearance and texture to 'Kalei'. 'RS103-95' tends to have less stem-end russet than 'Kalei', but has a milder flavour and may lack juiciness.

#### **Fruit Characteristics**

Foreground Colour:	Red (46A)	TSS:	14.9 %
Blush Coverage:	>80%	Fruit Firmness:	Firm 9.9 kgF
Shape:	Round - Round Conical	Flesh Browning:	-
Average Fruit Wt:	180 g	5 minutes -	Slight
Texture:	Firm, Breaking	30 minutes -	Slight
Shelflife:	9.5 kgF; Firm, Retained	60 minutes -	Slight
(14 days)	quality		-

#### **Tree Characteristics**

Habit:	Spreading
Fruiting Habit:	Spurs
Vigour:	Medium

### **Disease Susceptibility**

Powdery Mildew: Nil

Alternaria Leaf Spot: Nil

#### Status

'RS103-95' is similar to 'Kalei' in texture and appearance, but has a milder flavour and is less juicy. It can have better skin finish than 'Kalei', so may have adaptation to areas where russet is a problem due to climatic factors. There are three trees of 'RS103-95' at ARS.

# FB14-61



Full Bloom (2011) : 5 Oct (overlap with Fuji) Full Bloom (2012) : 4 Oct (overlap with Red Delicious) Harvest (2012): 12 Apr - 20 Apr (similar to Granny Smith) Harvest (2013): 24 Mar - 6 Apr (similar to Granny Smith)

# Description

'FB14-61' is a medium size block red apple with a light stripe, similar to 'Fuji' in appearance. It is a juicy apple with good texture and sprightly flavour. The skin finish of 'FB14-61' is smooth.

#### **Fruit Characteristics**

Foreground Colour:	Red (46A)	TSS:	14.7 %
Blush Coverage:	>60%	Fruit Firmness:	Medium 8.0 kgF
Shape:	Flat Round - Conical	Flesh Browning:	
Average Fruit Wt:	145 g	5 minutes -	Slight
Texture:	Crisp, Medium	30 minutes -	Moderate
Shelflife:	8.0 kgF; Firm texture but	60 minutes -	Moderate
(14 days)	over-ripe		

### **Tree Characteristics**

Habit:	Spreading
Fruiting Habit:	Predominately spurs
Vigour:	Medium

#### **Disease Susceptibility**

Powdery Mildew: Nil

Alternaria Leaf Spot: Nil

### Status

The appearance and eating quality of 'FB14-61' warrant further evaluation of this selection. There are currently three trees of 'FB14-61' at ARS. Additional trees need to be propagated for future testing.

# SP18-61



Full Bloom (2011):5 Oct(overlap with Gala, Fuji)Full Bloom (2012):29 Sep(overlap with Gala, Fuji)

Harvest (2012) : 6 - 14 Apr (similar to Granny Smith) Harvest (2013) : 8 - 12 Apr (similar to Granny Smith)

### Description

'SP18-61' is a green-yellow apple similar to 'Granny Smith' in appearance. The trees also have similar growth habit to 'Granny Smith'. 'SP18-61' has smooth skin, fine texture and a balanced flavour.

#### **Fruit Characteristics**

Foreground Colour:	YG (150C - 154C)	TSS:	13.0 %
Blush Coverage:	100%	Fruit Firmness:	Med - Soft 6.9 kgF
Shape:	Flat Round	Flesh Browning:	
Average Fruit Wt:	215 g	5 minutes -	Nil
Texture:	Medium - Soft	30 minutes -	Slight
Shelflife:	4.9 kgF; Soft, flowery	60 minutes -	Slight
(14 days)			

### **Tree Characteristics**

Habit:	Spreading
Fruiting Habit:	Long shoots
Vigour:	Medium

#### **Disease Susceptibility**

Powdery Mildew: Nil

Alternaria Leaf Spot: Nil

#### Status

'SP18-61' is a scab-resistant 'Granny Smith' type apple. Texture was soft in 2013, which may have been a seasonal effect. There are currently three trees of 'SP18-61' at ARS. Additional trees must be propagated for further evaluation of this selection.

# **RS103-56**



**Full Bloom (2011) :** 25 Sep (overlap with Sundowner) **Full Bloom (2012) :** 23 Sep (overlap with Sundowner) Harvest (2012) : 20 Apr - 5 May (similar to Pink Lady) Harvest (2013) : 26 Apr - 3 May (similar to Pink Lady)

### Description

'RS103-56' is a very large, red-purple apple with a solid block foreground colour over a yellow green background. It is a medium-textured, sweet apple and trees set heavy crops of large fruit annually.

#### **Fruit Characteristics**

Foreground Colour:	Red (46A - 59A)	TSS:	12.4 %
Blush Coverage:	>80%	Fruit Firmness:	Med - Soft 6.8 kgF
Shape:	Round Asymetrical	Flesh Browning:	
Average Fruit Wt:	210-240 g	5 minutes -	Nil
Texture:	Medium, chewy	30 minutes -	Slight
Shelflife:	4.8 kgF; Soft	60 minutes -	Slight
(14 days)			
Tree Characteristics			
Habit:	Spreading		
Fruiting Habit:	Spurs		
Vigour:	Medium		

#### **Disease Susceptibility**

Powdery Mildew: Nil

Alternaria Leaf Spot: Nil

#### Status

The poor texture, variable fruit shape and excessively large size of 'RS103-56' make this selection unlikely to be a commercial variety for Australia. There is potential for 'RS103-56' to be an easy to grow scab-resistant apple in third world countries, where agronomic skills are poor, water may be limited, and the apples are grown to feed local communities. There are 250 'RS103-56' trees at ARS.

# **SP6-317**



Full Bloom (2011): 2 Oct (overlap with Granny Smith, Gala)
Full Bloom (2012): 27 Sep (overlap with Granny Smith, Pink Lady) Harvest (2012): 7 May - 12 May (similar to Sundowner) Harvest (2013): 29 Apr - 3 May (similar to Pink Lady, Sundowner)

### Description

'SP6-317' is a very attractive block red apple with a light stripe. Apples have very white flesh, fine texture and an appealing tart, lemony flavour.

#### **Fruit Characteristics**

Foreground Colour:	Red (46A - 53A)	TSS:	13.9 %
Blush Coverage:	>80%	Fruit Firmness:	Firm 9.6 kgF
Shape:	Round Oblong	Flesh Browning:	
Average Fruit Wt:	180 g	5 minutes -	Slight
Texture:	Fine, Melting	30 minutes -	Slight
Shelflife: (14 days)	8.0 kgF; Retains eating quality	60 minutes -	Slight

### **Tree Characteristics**

Habit:	Spreading
Fruiting Habit:	Spurs
Vigour:	Low - Moderate

#### **Disease Susceptibility**

Powdery Mildew: Nil

Alternaria Leaf Spot: Nil

### Status

The beautiful appearance and "lemony" flavour of 'SP6-317' is likely to attract consumers for whom many apple varieties are too sweet. There are currently four 'SP6-317' trees at ARS. More trees need to be propagated to produce sufficient fruit for consumer and postharvest evaluations of this selection.

# FB24-108



Full Bloom (2011) : 5 Oct (overlap with Fuji) Full Bloom (2012) : 6 Oct (overlap with Red Delicious) Harvest (2012) : 14 - 25 May (similar to Sundowner) Harvest (2013) : 13 - 30 May (similar to Sundowner)

# Description

'FB24-108' is an attractive pink-red apple with a light foreground stripe over a yellow green background. It is a juicy, sweet apple with good texture and shelf life, and prominent lenticels.

#### **Fruit Characteristics**

Foreground Colour: Blush Coverage	Red (46A - 53A) >50%	TSS: Fruit Firmness:	13.6 % Med 7 3 kgF
Shape:	Round - Round Conical	Flesh Browning:	
Average Fruit Wt:	175-200 g	5 minutes -	Nil
Texture:	Fine Melting	30 minutes -	Slight
Shelflife: (14 days)	7.2 kgF; Eating quality unchanged	60 minutes -	Slight

#### **Tree Characteristics**

Habit:	Spreading Spurs	
Fruiting Habit:		
Vigour:	Medium - High	

#### **Disease Susceptibility**

Powdery Mildew: Slight

Alternaria Leaf Spot: Nil

#### Status

'FB24-108' has excellent eating quality, but the distinctive appearance may deter some consumers. There are three trees of 'FB24-108' at ARS. Additional trees need to be propagated to allow further testing, including consumer and postharvest sensory evaluations.

# **SP7-226**



Full Bloom (2011): 29 Sep (overlap with Granny Smith, Pink Lady)
Full Bloom (2012): 25 Sep (overlap with Sundowner, Pink Lady) Harvest (2012) : 21 - 30 May (similar to Sundowner) Harvest (2013) : 15 - 24 May (similar to Sundowner)

# Description

'SP7-226' has a red-purple solid block foreground colour on a yellow green background. Apples develop sweetness quite late on the tree. 'SP7-226' is sweet, juicy and keeps well in storage.

### **Fruit Characteristics**

Foreground Colour:	Red (46A - 59A)	TSS:	15.5 %
Blush Coverage:	>70%	Fruit Firmness:	Med 7.6 kgF
Shape:	Flat Round - Round Conical	Flesh Browning:	-
Average Fruit Wt:	150-170 g	5 minutes -	Slight
Texture:	Medium, chewy	30 minutes -	Slight
Shelflife:	7.2 kgF; Maintained eating	60 minutes -	Slight
(14 aays)	quality		

# **Tree Characteristics**

Habit:	Spreading
Fruiting Habit:	Spurs
Vigour:	Low - Medium

#### **Disease Susceptibility**

**Powdery Mildew:** Slight

Alternaria Leaf Spot: Nil

#### Status

'SP7-226' is a very late season, scab-resistant, 'Sundowner' style apple, and has rated inconsistently in consumer tastings and postharvest evaluations (Chapters 7 and 8). This likely relates to harvest maturity differences across the studies. There are 100 'SP7-226' trees at ARS. 'SP7-226' should be evaluated at interstate APFIP sites to determine its commercial potential.

# 7. The consumer acceptability of scab-resistant apple selections

# 7.1 Introduction

In addition to field and laboratory assessments and measurements of the fruit quality of superior scabresistant apple selections grown at Applethorpe, a series of consumer evaluations of a number of these were undertaken in Brisbane, Qld. Consumer feedback is an essential component of the evaluation process, and used to assist in the identification of those scab-resistant apple selections deemed to have commercial potential.

The consumer evaluations were undertaken by DAFF Qld consumer scientists based at the Health and Food Sciences Precinct, Brisbane. The consumer studies were necessarily restricted to those apple selections considered as potential candidates for future commercialisation, and that also produced sufficient apples for tastings by over 100 consumers at a time.

In previous project AP05008 (Zeppa and Middleton, 2008), consumer evaluations were completed for the scab-resistant selections 'RS103-130' ('Kalei') in 2006 and 2007, and 'RS103-110' in 2007. The consumer testing of these two selections was done within two months of harvest, and both were rated highly by consumers when compared to commercial apple varieties that included 'Royal Gala', 'Red Delicious', 'Fuji' and 'Pink Lady'<sup>TM</sup> (Zeppa *et al.*, 2006; Zeppa and Middleton, 2008).

This chapter reports on consumer evaluations undertaken between 2009 and 2013. This included further consumer testing of 'RS103-130' ('Kalei') and 'RS103-110' to determine their consumer appeal following long-term storage, and to confirm their suitability for commercialisation. In addition, a further six advanced scab-resistant selections from the ARS apple breeding program were included in consumer studies during this period.

An overview of the results from these consumer evaluations is presented in this chapter. Further detail is available in the consumer evaluation reports provided with milestone reports during the course of this project (Smyth and Reid, 2009; Smyth and Reid, 2010; Smyth and Gething, 2010; Gething and Smyth, 2011).

# 7.2 Materials and Methods

A series of eight consumer evaluations was undertaken between 2009 and 2013 as follows:

- Mar 2009: 'RS103-110'; 'RS109-15'; 'Gala'; 'Red Delicious'; 'Fuji'
- May 2009: 'RS103-130' ('Kalei'); 'RS103-56'; 'Fuji'; 'Jonagold'; 'Pink Lady'<sup>TM</sup>
- Oct 2009: 'RS103-110'; 'Gala'; 'Red Delicious'; 'Pink Lady'<sup>TM</sup>
- Dec 2009: 'RS103-130' ('Kalei'); 'Royal Gala'; 'Red Delicious'; 'Sundowner'<sup>TM</sup>
- Aug 2010: 'SP7-226'; 'Red Delicious'; 'Pink Lady'<sup>TM</sup>; 'Sundowner'<sup>TM</sup>
- Aug 2011: 'FB7-159'; 'SP7-226'; 'Gala'; 'Red Delicious'; 'Sundowner'<sup>TM</sup>
- Mar 2013: 'RS102-50'; 'RS104-1'; 'Kalei'; 'Royal Gala'; 'Red Delicious'
- May 2013: 'RS109-15'; 'Red Delicious'; 'Pink Lady'<sup>TM</sup>

At each consumer evaluation, two or three commercial apple varieties that would be competitors in the marketplace at the same time as the scab-resistant selections were also assessed by consumers, as shown above. Each of the scab-resistant selections is described in detail earlier in this report.

The consumer evaluations in March 2009, May 2009, March 2013 and May 2013 were of apples that had been harvested one to eight weeks prior to the tasting sessions, and stored in ordinary cold storage (2°C- 5°C) in the interim. The exception to this was the 'Kalei' assessed by consumers in March 2013, which was fruit that had been harvested one year earlier, in March/April 2012, and was being compared with new season 'Royal Gala' and 'Red Delicious' apples harvested in February/March 2013. These 'Kalei' apples had been stored in CA (2 % O<sub>2</sub>; 0.5% CO<sub>2</sub>; 0.5°C) for eight months, followed by nearly four months in ordinary cold storage (2°C- 5°C).

The other four consumer evaluations were of scab-resistant apple selections that had been held in medium to long term storage. 'RS103-110' apples assessed in Oct 2009 had been held in CA storage (2 % O<sub>2</sub>; 0.5% CO<sub>2</sub>; 0.5°C) for seven months; 'RS103-130' ('Kalei') apples assessed in Dec 2009 were held in CA storage (2 % O<sub>2</sub>; 0.5% CO<sub>2</sub>; 0.5% CO<sub>2</sub>; 0.5% CO<sub>2</sub>; 0.5% CO<sub>2</sub>; 0.5% CO<sub>2</sub>; 0.5°C) for six months, followed by two months in ordinary storage (4°C- 7°C); 'SP7-226' evaluated in Aug 2010 and Aug 2011 were held in ordinary cold storage (2°C- 5°C) for three months; and the 'FB7-159' apples tasted by consumers in Aug 2011 had been stored for nearly six months in ordinary storage (2°C- 5°C).

The scab-resistant apples used in the consumer evaluations were all sourced from Applethorpe Research Station, Queensland, and delivered by road to Brisbane. Apples of the comparator commercial varieties were purchased as graded, packed cartons of fruit, either directly from a major Stanthorpe apple producer, or from the Brisbane Markets. Hence all apples used in the consumer tastings were produced in the Stanthorpe district. Apples were delivered to the DAFF Qld postharvest facility in Brisbane one to two weeks prior to each consumer tasting session. The samples were stored at  $2^{\circ}$ C until required for consumer testing.

# 7.2.1 Consumer acceptability testing

The day prior to each consumer evaluation session, the apples for that session were washed, dried and returned to storage at 2°C. Damaged, marked or bruised fruit were excluded from consumer acceptability testing. On the day of consumer testing, the apples were removed from storage and held at room temperature for at least two hours before each tasting session.

All consumer testing was completed in the Brisbane metropolitan area. The consumer participants were Queensland government employees from Agriculture, Fisheries and Forestry, or Tourism, Regional Development and Industry, who were recruited by email and volunteered to participate. No specific recruitment selection criteria were employed other than the consumers needed to be apple eaters, and no monetary payment was received by the consumers.

Each consumer was presented with a sample of one apple of each scab-resistant selection and commercial comparator variety. Each apple was presented in an individual clear plastic cup. The individual plastic cups were labelled with 3-digit blinding codes (e.g. 581, 816, 479 etc) to identify the samples and conceal the variety name. The apple samples were presented on a white plastic tray along with a sharp knife and a water cup, as shown in Plate 7.1. All additional consumables required to complete the exercise were on the tables and included spittoons, tissues, pencils and erasers.

Each consumer was given a paper questionnaire to complete. Up to six consumers were seated at a table and each consumer completed the assessment individually. The questionnaire was divided into two sections. Section one related to the acceptance test (appearance, flavour, texture, overall acceptability), and section two gathered demographic information (gender, age, family status, household income, education, apple consumption behaviour) and quantification of basic consumer attitudes (environmental, health, food quality, community ethics, organic). A sample consumer questionnaire is included as Appendix 2.



Plate 7.1. The presentation of apples to consumers for tasting

The consumer acceptability parameters (appearance, flavour, texture, overall acceptability) were measured using hedonic scales. These scales were anchored from 'dislike extremely' (0), through 'neither like nor dislike' (50), to 'like extremely' (100), as shown in Fig 7.1.

How much do you like or dislike the texture of apple sample 231?					
 Dislike extremely	Neither lik	e nor dislike	Like extremely		

# Fig 7.1. Example of the hedonic scale used in the consumer tasting sessions.

Apple samples that scored over 50, towards 100, are samples that are liked for that attribute. The closer to 100 the score is, the more a sample is liked. Conversely, samples rated below 50, toward 0, are samples that are not liked for that attribute. The lower the score, the less the sample is liked for that particular characteristic.

Consumers were also given the opportunity to make comments regarding what they liked or disliked about the samples (refer Appendix 2). At each session there were between 86 and 132 consumers who tasted and evaluated the apples.

In the August 2010 and August 2011 consumer tasting sessions, apple assessments were also conducted in individual tasting booths of the sensory laboratory at the Health and Food Sciences Precinct, Coopers Plains, Brisbane. The individual tasting booths were equipped with day-light equivalent lighting, temperature and humidity control, computers and drinking water for rinsing. The computerised questionnaire was divided into sections as for the paper questionnaire used in the other tastings.

# 7.2.2 Data analysis

The consumer scores marked on the paper copies of hedonic scales were measured by hand using a standard ruler, recorded in a Microsoft Excel spreadsheet and converted, linearly, to a score out of 100. Comments or responses to demographic multi-choice style questions were also manually entered into Microsoft Excel for analysis. The frequency of the comments made by consumers were divided into different broad categories and collated. For example, the frequency of likability comments regarding texture, such as crisp, crunchy, firm, refreshing, etc were collated into one category. A few consumers did not make comments, whilst other consumers made multiple comments for a single question. The results are presented as a frequency of comments made and are not necessarily representative across all the consumers who participated.

When the computerised questionnaire was used in the August 2010 and August 2011 evaluations, consumer acceptability scales were electronically presented to participants via sensory software Compusense®5. As in the paper questionnaires, the consumer scores on the hedonic scales were linearly converted to a score out of 100. Qualitative comments were collated and subjected to content analysis to determine underlying themes. Responses to demographic and behavioural multi-choice style questions were entered into statistical software SPSS.

Analysis of variance (ANOVA) was performed on the consumer data using either GenStat <sup>®</sup>11<sup>th</sup> edition, (Lawes Agricultural Trust) or SPSS. Where a significant (p<0.05) sample F-ratio was found using ANOVA, pair-wise comparisons using Fishers least significant difference (LSD) procedure were completed. Cross tabs were performed on acceptability, demographic and behavioural data using SPSS.

# 7.3 Results and Discussion

# 7.3.1 Demographic data

At each apple evaluation session, consumers responded to a number of demographic questions. Table 7.1 summarises the responses from consumers at the March 2009 and May 2009 apple tastings, which are typical of the responses received across all eight consumer studies. The complete demographic data tables and detailed summaries can be found in the consumer evaluation reports provided with milestone reports during the course of this project (Smyth and Reid, 2009; Smyth and Reid, 2010; Smyth and Gething, 2010; Gething and Smyth, 2011).

Compared to the general population in Brisbane, the respondents typically had a higher level of education and a higher than average household income. The majority of participants were females and most of the participants were regular apple consumers. More than half of respondents were the main shopper of the household and less than one third had any children living at home.

In March and May 2009, the consumers were also asked to indicate their general degree of concern for global issues (environment, health, food quality and ethics in community). Although no statistical analysis was completed on this information, females appeared to be more concerned than males about the environment, health and food quality. These gender differences were also observed in the UK and France (Pettinger *et al.*, 2004), where males were less concerned than females with organic/ethical issues, food quality and health.

Those consumers who bought organic fruit were also more concerned than other consumers about the environment, health and food quality. It has also been documented that when consumers have greater concerns about animal welfare and environmental issues, and strong views on political values and religion, they are more likely to have a positive attitude towards organic foods (Chen, 2007).

Demographic question	March 2009 (n=104)	May 2009 (n=118)
Gender	58% female, 42% male	64% female, 36% male.
Age	77% aged between 30 and 54 years	82% were aged between 30 and 59 years
Grocery shopping	47% main grocery shopper, 40% shared, 13% not	55% main grocery shopper, 39% shared, 6% not
Children at home	61% no children under 18 at home, 20% had 2 children	64% no children under 18 at home, 32% had 1 or 2 children
Apple consumption	77% daily, several times per week or weekly	78% daily, several times per week or weekly
Preferred apple variety	Pink Lady, Gala, Red Delicious, Granny Smith	Pink Lady, Gala, Red Delicious, Granny Smith
Organic fruit purchase	37% purchase several times per week, weekly, several times per month or monthly, 64% never	47% purchase organic fruit several times per week, weekly, several times per month or monthly, 53% never
Organic fruit purchased	banana, apple, orange, mandarin and other citrus, grape and stonefruit (peach, nectarine, plum, apricot and cherry	banana, strawberries or other berries and apple
Where organic fruit purchased	market, supermarket	market, specialist organic shop, supermarket
Level of education	66% completed bachelor degree, graduate diploma or postgraduate degree	72% completed a bachelor degree, graduate diploma or postgraduate degree
Household income	66% greater than \$80,000 per annum	55% greater than \$80,000 per annum

Table 7.1 Summary of consumer demographic responses collected March and May 2009

# 7.3.2 Consumer acceptance testing

For practicality it is only feasible to present a small cross-section of results from the 2009-2013 consumer evaluations in this report. More comprehensive results and information are available in the consumer acceptability reports provided with milestone reports during the course of this project (Smyth and Reid, 2009; Smyth and Reid, 2010; Smyth and Gething, 2010; Gething and Smyth, 2011).

# (a) March 2009: Consumer acceptability of 'RS103-110' and 'RS109-15'

There were significant differences in the consumer appeal of the five apple varieties/selections tasted in March 2009 (Table 7.2). All apples were fresh, new season fruit that had been harvested four to six weeks prior to the consumer tasting. The mean sensory scores of all five varieties for all four attributes (appearance, flavour, texture, overall likability) were scored between the 'neither like nor dislike' and 'like extremely' part of the hedonic scale. Hence none of the apple varieties were, on average, disliked by the consumers.

Apple	n	Appearance	Overall	Flavour	Texture
RS103-110	104	72 a	73 a	71 a	75 a
RS109-15	104	65 bc	71 ab	72 a	77 a
Gala (Galaxy)	104	70 ab	62 cd	61 b	57 b
Red Delicious (Hi Early)	104	73 a	59 d	55 c	60 b
Fuji	104	60 c	66 bc	70 a	75 a
Standard deviation		20.4	19.5	22.7	21.6
Significance level (p)		<0.001	<0.001	<0.001	<0.001
LSD		5.4	5.1	5.9	5.4

Tahla 7 2	The consumer accentabilit	v of 'R\$103_110'	and 'R\$109_15'	(March 2009)
1 able 7.2.	The consumer acceptabilit	Y UL KSIUJ-LIU	anu ksi09-15	(Marcii 2009)

n: the number of assessments made; Different letters within a column indicate a statistically significant difference between samples by ANOVA where p < 0.05.

The two scab-resistant selections performed well compared to the three commercial varieties, and both 'RS103-110' and 'RS109-15' were consistently scored by the consumers amongst the highest apple scores for all four attributes (Table 7.2).

Overall, 'RS103-110' was liked by consumers significantly more than all three commercial varieties. For flavour and texture, 'RS103-110' was preferred by the consumers to 'Gala' ('Galaxy') and 'Red Delicious' ('Hi Early'). The appearance of 'RS103-110' was preferred to 'Fuji', and was scored similarly by consumers to 'Gala' and 'Red Delicious' appearance (Table 7.2).

The texture, flavour and overall acceptability of 'RS109-15' were considered by the consumers as significantly better than 'Gala' ('Galaxy') and 'Red Delicious' ('Hi Early'). The appearance of 'RS109-15' apples was scored similarly to 'Gala' and 'Fuji', but lower than 'Red Delicious'.

Although the appearance of 'Hi Early Red Delicious' was well liked, this variety scored lowest for flavour and texture (Table 7.2). The appearance of the 'Fuji' apples was the least liked of all five varieties. 'Gala' ('Galaxy') was well liked for its appearance, but was the least appreciated of all the varieties for texture.

There were more spontaneous likability comments regarding the texture of 'RS103-110', 'RS109-15' and 'Fuji' than for the 'Gala' and 'Red Delicious' apples (Smyth and Reid, 2009). More consumers also commented positively on the juiciness of 'RS103-110'. The size and shape of the 'RS103-110' and 'Gala' apples were well received by consumers. The consumers frequently made a number of

dislike comments regarding the taste, flavour and texture of the 'Red Delicious' and 'Gala' varieties (Smyth and Reid, 2009). The size, appearance and colour of the 'Fuji' variety received negative comments the most frequently.

# (b) May 2009: Consumer acceptability of 'RS103-130' ('Kalei') and 'RS103-56'

There were significant differences in the consumer appeal of the five apple varieties/selections tasted in May 2009 (Table 7.3). All apples were fresh, new season fruit that had been harvested two to six weeks prior to the consumer tasting. As in the March 2009 consumer evaluations, the mean sensory scores of all five varieties for all four attributes were scored between the 'neither like nor dislike' and 'like extremely' part of the hedonic scale. None of the apple varieties were, on average, 'disliked' by consumers for any of the attributes.

'RS103-130' ('Kalei') was very well liked for all four attributes (Table 7.3), and received the highest score of the five varieties for overall acceptability (however not significantly different to 'Jonagold'). 'Kalei' was equally preferred with 'Jonagold' and 'Pink Lady'<sup>TM</sup> for appearance, and with 'Jonagold' and 'Fuji' for flavour. The texture of the 'Kalei' apples was considered by the consumers as comparable to the three commercial varieties.

'RS103-56' was the least preferred of the five varieties assessed (Table 7.3), and with an overall mean score of 58, was just above 'neither like nor dislike' on the hedonic scale. 'RS103-56' was scored significantly lowest by consumers for texture, was the least preferred apple for appearance (with 'Fuji'), and rated the poorest for flavour (with 'Pink Lady'<sup>TM</sup>).

Apple	n	Appearance	Overall	Flavour	Texture
RS103-130 (Kalei)	118	70 a	72 a	71 a	74 a
RS103-56	118	60 b	58 c	57 c	60 b
Fuji	118	57 b	65 b	67 a	70 a
Jonagold	118	71 a	68 ab	66 ab	72 a
Pink Lady <sup>TM</sup>	118	70 a	65 b	61 bc	72 a
Standard deviation		20.2	19.5	23.1	20.1
Significance level (p)		<0.001	<0.001	<0.001	<0.001
LSD		4.9	4.9	5.8	5.0

# Table 7.3. The consumer acceptability of 'RS103-130' ('Kalei') and 'RS103-56' (May 2009)

n: the number of assessments made; Different letters within a column indicate a statistically significant difference between samples by ANOVA where p < 0.05.

'RS103-130' ('Kalei') and 'Jonagold' apples received the highest number of spontaneous positive comments about their texture and aroma (Smyth and Reid, 2009). All five varieties received a high number of favourable comments regarding their flavour and taste, although 'Pink Lady'<sup>TM</sup> also received a high number of negative comments (70) from consumers for their flavour, frequently described as tart or sour.

'RS103-56' received 58 spontaneous negative comments regarding its texture. Terms used to describe how consumers disliked the texture of this apple included "powdery", "tough skin", "thick skin", "not crispy", "not crunchy", "floury" and "chalky." 'RS103-56' was also considered by many consumers to be too big. The overall appearance of 'RS103-56' did not attract a large number of negative comments, however the fruit colour received some comments such as "too red" and "too dark."

# (c) October 2009: Consumer acceptability of 'RS103-110' held in CA storage for seven months

There were significant differences in the consumer appeal of the four apple varieties tasted in October 2009 (Table 7.4). The 'RS103-110' apples were held in CA storage ( $2 \% O_2$ ;  $0.5\% CO_2$ ;  $0.5^{\circ}C$ ) for the seven months between harvest in March 2009 and the consumer tasting in October 2009. Similarly, the three commercial varieties had been held in CA for seven ('Gala'), six ('Red Delicious') and five ('Pink Lady'<sup>TM</sup>) months since their respective harvests. The mean sensory scores of all four varieties for all four attributes were scored between the 'neither like nor dislike' and 'like extremely' part of the hedonic scale. Hence none of the apple varieties were, on average, 'disliked' by consumers for any of the attributes assessed.

There were few differences in the consumer appeal of the apple varieties for appearance, texture and overall acceptability. For appearance, 'RS103-110' was well liked by the consumers, and scored similarly to the three commercial varieties (Table 7.4). Overall, 'RS103-110' was liked as much as the 'Pink Lady'<sup>TM</sup> and 'Red Delicious', and liked significantly more than the 'Gala'. 'Pink Lady'<sup>TM</sup> was most preferred for flavour, with 'RS103-110' and 'Red Delicious' flavour equally liked and preferred to 'Gala' (Table 7.4). 'RS103-110' texture after seven months in storage was considered comparable to 'Pink Lady'<sup>TM</sup> and 'Red Delicious', and superior to 'Gala'.

Apple	n	Appearance	Overall	Flavour	Texture
RS103-110	105	70 ab	71 a	71 b	72 a
Pink Lady <sup>TM</sup>	105	74 a	75 a	78 a	76 a
Red Delicious	105	67 b	70 a	72 b	75 a
Gala	105	75 a	63 b	56 c	63 b
Standard deviation		18.5	19.9	22.7	21.5
Significance level (p)		0.005	<0.001	<0.001	<0.001
LSD		5	5	6	6

Table 7.4.	The consumer acceptability of 'RS103-110	' held for seven months in controlled
	atmosphere storage (October 2009)	

n: the number of assessments made; Different letters within a column indicate a statistically significant difference between samples by ANOVA where p < 0.05.

The consumers were also asked to comment on what they liked and disliked about each apple variety. There were more spontaneous positive comments made about the texture of 'RS103-110' and 'Red Delicious' than for the other two varieties. All four varieties received positive spontaneous comments regarding their colour, and the shape and size of 'RS103-110' and 'Gala' apples were well received. The taste, flavour and in particular, texture of 'Gala' were very frequently (71) disliked.

# (d) December 2009: Consumer acceptability of 'RS103-130' ('Kalei') held in CA storage for six months, followed by two months in ordinary cold storage

'RS103-130' ('Kalei') apples assessed by consumers in December 2009 were held in CA storage (2 %  $O_2$ ; 0.5%  $CO_2$ ; 0.5°C) for the six months immediately after harvest, followed by two months in ordinary storage (4°C-7°C) prior to the consumer evaluation. Apples of the three comparator varieties were held in commercial CA for the nine ('Gala'), eight ('Red Delicious') and six ('Sundowner'<sup>TM</sup>) months following their respective harvests.

The mean sensory scores of all four varieties for all four attributes were scored between the 'neither like nor dislike' and 'like extremely' part of the hedonic scale. Hence none of the apple varieties were, on average, 'disliked' by consumers for any of the attributes assessed.

'Kalei' was well liked by consumers for appearance and overall acceptability, and was not rated as significantly different in terms of preference to the three commercial varieties (Table 7.5). The flavour of 'Sundowner'<sup>TM</sup> and 'Red Delicious' apples was most preferred, followed by 'Kalei'. 'Kalei', 'Red Delicious' and 'Sundowner'<sup>TM</sup> apples were all considered by the consumers to have excellent texture (Table 7.5). The texture and flavour of 'Gala' was the least preferred.

Most spontaneous positive comments by consumers pertained to liking the texture and flavour across all four varieties (Smyth and Reid, 2010). It should be noted that the three commercial apple varieties were held in CA for their entire storage period, whereas the 'RS103-130' ('Kalei') had to be held in ordinary cold storage for the two months immediately prior to the tastings. This was not ideal, with the temperature at 4°C-7°C for this period and peaking at 11°C for several days due to a malfunction. This is likely to have adversely affected the quality of the 'Kalei' apples relative to the other varieties.

Apple	n	Appearance	Overall	Flavour	Texture
RS103-130 (Kalei)	108	68	67	65 b	75 a
Red Delicious	108	70	69	70 ab	73 a
Sundowner <sup>TM</sup>	108	75	71	71 a	76 a
Royal Gala	108	77	66	56 c	59 b
Standard deviation		36.8	36.7	22.4	21.7
Significance level (p)		NS	NS	<0.001	<0.001
LSD		NS	NS	5.8	5.5

 Table 7.5. The consumer acceptability of 'RS103-130' ('Kalei') held for six months in controlled atmosphere storage, followed by two months in ordinary cold storage (October 2009)

n: the number of assessments made; NS: Not Significant; Different letters within a column indicate a statistically significant difference between samples by ANOVA where p < 0.05.

# (e) August 2010: Consumer acceptability of 'SP7-226'

'SP7-226' apples assessed in August 2010 were held in ordinary cold storage (2°C- 5°C) for the twelve weeks between their harvest and the timing of the consumer evaluations. Apples of the three comparator varieties were held in commercial cold storage for the eighteen ('Red Delicious'), fourteen ('Pink Lady'<sup>TM</sup>) and eleven ('Sundowner'<sup>TM</sup>) weeks following their respective harvests.

The mean sensory scores of all four varieties for all four attributes were scored between the 'neither like nor dislike' and 'like extremely' part of the hedonic scale. Hence none of the apple varieties were, on average, 'disliked' by consumers for any of the attributes assessed.

The appearance of 'SP7-226' apples was rated comparably by consumers to 'Red Delicious' and 'Sundowner'<sup>TM</sup> (Table 7.6), and superior to 'Pink Lady'<sup>TM</sup>. Qualitatively, the novel shape and colour of 'SP7-226' held certain appeal for many consumers, but opinion was divided on the colour and oblate shape of this apple. Some found the "russet colour" and the "slightly squat shape" appealing, whereas others deemed the apple to look "dark, flat and dull".

Apple	n	Appearance	Overall	Flavour	Texture
SP7-226	107	66 a	56 b	60 b	53 c
Red Delicious	107	67 a	60 b	54 c	65 b
Pink Lady <sup>TM</sup>	107	59 b	66 a	66 a	75 a
Sundowner <sup>TM</sup>	107	64 a	66 a	67 a	65 b
Standard deviation		20.5	20.8	22.1	22.0
Significance level (p)		<0.005	< 0.005	<0.001	<0.001
LSD		3.8	4.4	4.8	4.0

 Table 7.6. The consumer acceptability of 'SP7-226' held in ordinary cold storage for 12 weeks (August 2010)

n: the number of assessments made; Different letters within a column indicate a statistically significant difference between samples by ANOVA where p < 0.05.

The strengths of 'SP7-226' invariably lay in the attractive and multifaceted flavour profile (Smyth and Gething, 2010). The sensory preference data indicated that participants found SP7-226 to be more flavoursome than 'Red Delicious', but not as acceptable as 'Pink Lady'<sup>TM</sup> or 'Sundowner'<sup>TM</sup> (Table 7.6). Consumers gave more complex descriptions of the flavour of 'SP7-226', with frequent observations on the balanced mix of the sweet and acidic, and floral notes.

For texture, 'SP7-226' was the least acceptable of the four varieties (Table 7.6). Qualitative comments confirmed this, with a significant number of negative comments pertaining to this particular attribute and some consumers describing the selection as "floury" and "powdery". A particular waxiness or oiliness to the skin was noticeable for 'SP7-226' apples during washing and drying of the fruit prior to tasting. Combined with the relatively poor texture, this suggested that the 'SP7-226' apples were not harvested at optimum timing and were of advanced maturity when picked.

For overall acceptability, consumers found 'SP7-226' comparable to "Red Delicious', and of lower acceptability than 'Pink Lady'<sup>TM</sup> and 'Sundowner'<sup>TM</sup> (Table 7.6). Despite possessing good colour, the unacceptable flavour and skin toughness of 'Red Delicious' reduced its appeal to consumers.

Texture and flavour were the attributes that consumers gave the most qualitative weight to. Considering this, it would seem that for this particular consumer evaluation, 'Pink Lady'<sup>TM</sup> was the most agreeable apple cultivar to the consumers. Pink Lady was repeatedly described as crunchy and crisp, however sensory data revealed that consumers found this variety to be less acceptable in appearance than the other three varieties (Table 7.6). The relatively low appearance scores for 'Pink Lady'<sup>TM</sup> were supported by negative qualitative comments, with the variety described as "anaemic", "pastel" in colour and "rough with many bumps and ridges".

# (f) August 2011: Consumer acceptability of 'SP7-226' and 'FB7-159'

'SP7-226' and 'FB7-159' apples evaluated by consumers in August 2011 had been held in ordinary cold storage (2°C- 5°C) at Applethorpe Research Station for the three months ('SP7-226') and nearly six months ('FB7-159') since their respective harvests. Apples of the three comparator varieties were held in commercial cold storage for the five ('Gala'), four ('Red Delicious') and three ('Sundowner'<sup>TM</sup>) months following their respective harvests.

The flavour of 'SP7-226' was very acceptable to consumers, and was scored significantly higher than the other four varieties evaluated (Table 7.7). As in 2010, 'SP7-226' flavour was distinct due to its sugar/acid balance, as described in consumer comments, and was well liked by consumers. The texture of 'SP7-226' also rated highly, and with 'Gala', was considered superior to 'Red Delicious' and 'Sundowner'<sup>TM</sup> texture (Table 7.7). 45% of consumers provided spontaneous positive comments about the "crunchy/crispy" nature of 'SP7-226'.

Apple	n	Appearance	Overall	Flavour	Texture
SP7-226	131	57 b	68 a	69 a	73 a
FB7-159	131	70 a	50 b	49 c	49 c
Gala	131	73 a	67 a	63 b	75 a
Red Delicious	131	69 a	62 a	60 b	64 b
Sundowner <sup>TM</sup>	131	67 a	55 b	54 c	60 b
Standard deviation		18.6	20.8	22.8	20.8
Significance level (p)		<0.01	<0.01	<0.01	<0.01
LSD		6.5	6.5	5.5	5.0

Table 7.7. The consumer acceptability of 'SP7-226' and 'FB7-159' held in ordinary storage for<br/>three ('SP7-226') and six ('FB7-159') months (August 2011)

n: the number of assessments made; Different letters within a column indicate a statistically significant difference between samples by ANOVA where p < 0.05.

In contrast to 2010, the 'SP7-226' apples assessed in August 2011 were harvested close to optimum maturity. Hence the texture, flavour and overall acceptability of 'SP7-226' to consumers was significantly higher in 2011 and compared more than favourably to 'Gala', 'Red Delicious' and 'Sundowner'<sup>TM</sup>.

Consumers found the appearance of 'SP7-226' less acceptable than the other four varieties (Table 7.7), which again is in contrast to the 2010 results when its appearance was more highly rated (Table 7.6). Perusal of comments revealed this to be primarily due to the colour of 'SP7-226', with some consumers describing it as "too red" or "too purple". The somewhat novel shape and colour of 'SP7-226' held certain appeal for more of the consumers in 2010 than 2011.

'FB7-159' was of pleasing appearance to consumers, with acceptability scores comparable to the three commercial apple varieties (Table 7.7). The appearance of 'FB7-159' apples solicited spontaneous positive responses from 22% of the consumers for its "pleasing skin colour" and "the most evenly coloured apple of all samples".

The mean consumer scores for 'FB7-159' flavour and texture (Table 7.7) were just below the acceptable threshold (50). This occurred due to the extremely low ratings for these two attributes given by 37 of the 131 consumers. Conversely, a subset of consumers enjoyed the texture and flavour of this selection, such that the mean consumer score for 'FB7-159' flavour and texture was lifted to 49. For flavour, this was statistically the same as 'Sundowner'<sup>TM</sup> (Table 7.7).

The high level of sweetness of 'FB7-159' was a positive trait for some consumers, but a negative for others. The relatively poor texture of 'FB7-159' would likely be the greatest deterrent to consumer purchase of this apple selection, with many negative comments such as "too soft", "floury", "mealy" or "chalky".

The 'FB7-159' apples used in the August 2011 consumer evaluations were harvested up to three months before the other varieties and were held for nearly six months in less than ideal ordinary cold storage (2°C- 5°C) at Applethorpe Research Station. The temperature of this cold room frequently reached >10°C over this period with regular entry made into the room to remove and store other apples. It is questionable however, whether better storage conditions would improve the texture, flavour and overall acceptability of 'FB7-159' sufficiently to compete with current commercial apple varieties.

# (g) March 2013: Consumer acceptability of 'RS102-50', 'RS104-1'& 'RS103-130' ('Kalei')

The consumer evaluations in March 2013 were of fresh, new season apples that had been harvested one to five weeks prior to the consumer tasting, and stored in ordinary cold storage  $(2^{\circ}C-5^{\circ}C)$  in the interim. The notable exception to this was 'Kalei', which was harvested one year earlier, in March/April 2012, and was being compared with new season 'Royal Gala' and 'Red Delicious' apples harvested approximately 12 months later, in February/March 2013. The 'Kalei' apples had been stored in CA (2 % O<sub>2</sub>; 0.5% CO<sub>2</sub>; 0.5°C) until early December 2012, followed by nearly four months in ordinary cold storage (2°C- 5°C) at Applethorpe Research Station.

The mean sensory scores of all five varieties for all four attributes were scored between the 'neither like nor dislike' and 'like extremely' part of the hedonic scale. Hence none of the apple varieties were, on average, 'disliked' by consumers for any of the attributes assessed.

'RS102-50' was very well liked across all four attributes. Consumers in particular considered the texture and overall acceptability of 'RS102-50' as significantly superior to the other four apple varieties (Table 7.8). Spontaneous consumer comments about 'RS102-50' were especially positive about the flavour and texture of this apple. Consumers also liked the appearance of 'RS102-50' and overall considered it as attractive as 'Royal Gala' and 'Kalei' (Table 7.8).

Apple	n	Appearance	Overall	Flavour	Texture
RS102-50	86	71 ab	76 a	73 a	79 a
RS104-1	86	74 a	67 bc	69 a	65 cd
Kalei (Mar 2012 pick)	86	75 a	63 cd	59 b	72 b
Royal Gala	86	74 a	70 b	70 a	69 bc
Red Delicious	86	69 b	58 d	53 b	62 d

# Table 7.8. The consumer acceptability of 'RS102-50', 'RS104-1' and 'Kalei' (March 2013)

n: the number of assessments made; Different letters within a column indicate a statistically significant difference between samples by ANOVA where p < 0.05.

The scab-resistant apple selection 'RS104-1' was also well liked by consumers, most especially for appearance and flavour (Table 7.8). This selection was rated as of comparable acceptability to 'Royal Gala' for all four attributes assessed, and superior to 'Red Delicious' for appearance, flavour and overall acceptability (Table 7.8).

Both 'RS104-1' and 'RS102-50' are early season red apples that in 2013 were harvested at Applethorpe on 7 February. Based on the consumer feedback provided in March 2013, they are candidates with potential for further evaluation, testing and consideration for commercialisation.

Despite the 'Kalei' apples being one-year-old fruit, their appearance was very well liked by consumers, with a mean appearance rating similar to recently harvested 'Royal Gala' and superior to new season 'Red Delicious' (Table 7.8). Of more importance, the texture of the one-year-old 'Kalei' apples was comparable to the new season 'Royal Gala' and significantly better than the new season 'Red Delicious' (Table 7.8). The retention of excellent texture after a long period of storage is a highly desirable characteristic for a new variety to have.

The flavour of one-year-old 'Kalei' apples, whilst still considered acceptable by consumers, was rated significantly lower than the flavour of the new season 'Royal Gala', which in turn impacted on the mean overall consumer acceptability rating for 'Kalei' (Table 7.8). The flavour of the 'Kalei' apples was described by many consumers as "bland" relative to 'RS102-50', 'RS104-1' and 'Royal Gala'.

After being removed from CA storage in early December 2012, the 'Kalei' apples were held for nearly four months in less than ideal storage conditions (2°C- 5°C, with regular fluctuations to >10°C) at Applethorpe Research Station. Notwithstanding these conditions, the 'Kalei' still retained excellent texture, albeit with some loss of their characteristic flavour.

'Red Delicious' was consistently the least preferred of the five varieties across all four attributes (Table 7.8). In particular, the texture of 'Red Delicious' was considered by many consumers to be "too soft and floury".

As an adjunct to the March 2013 tastings, consumers were also asked, of the apples tested, which ones would they be willing to purchase at a price of \$4.50/kg. Consumer willingness to buy 'RS102-50' and 'Royal Gala' at this price (each 37-40% of consumers) was significantly higher than for 'RS104-1' and one-year-old 'Kalei' apples (27-29% each), with 'Red Delicious'' (< 10%) by far attracting the fewest potential purchasers at that price. 25-30% of consumers were unsure of their potential purchase intention of the three scab-resistant apples and 'Royal Gala' at this price point, however 45% of consumers were definite in their intention not to purchase 'Red Delicious' at \$4.50/kg.

# (h) May 2013: Consumer acceptability of 'RS109-15'

The consumer evaluations in May 2013 were of apples that were harvested two days ('Pink Lady'<sup>TM</sup>), four weeks ('Red Delicious') and eight weeks ('RS109-15') prior to the tasting session. The 'Pink Lady'<sup>TM</sup> and 'Red Delicious' apples were sourced direct from a large commercial grower in the Stanthorpe district, and the 'RS109-15' were harvested from the Applethorpe Research Station and held in ordinary cold storage (2°C- 5°C) for the eight weeks between harvest and the consumer evaluation in Brisbane.

The mean sensory scores of all three varieties for all four attributes were scored between the 'neither like nor dislike' and 'like extremely' part of the hedonic scale. Hence none of the apple varieties were, on average, 'disliked' by consumers for any of the attributes assessed.

'Pink Lady'<sup>TM</sup> was very clearly preferred by the consumers for all four attributes assessed (Table 7.9). The 'Pink Lady'<sup>TM</sup> apples were harvested just two days prior to the tastings, so were very fresh fruit compared to the 'Red Delicious' and 'RS109-15' apples that were respectively harvested four and eight weeks prior to this. The large significant difference in consumer acceptability between 'Pink Lady'<sup>TM</sup> and the other two varieties suggests that, whilst the different storage periods of the three varieties may potentially have had some impact on consumer acceptability ratings, there would nevertheless still have been a strong preference by these consumers for 'Pink Lady'<sup>TM</sup> over 'Red Delicious' and 'RS109-15'.

Apple	n	Appearance	Overall	Flavour	Texture
RS109-15	86	63 b	62 b	59 b	73 b
Red Delicious	86	68 ab	57 b	53 b	60 c
Pink Lady <sup>TM</sup>	86	76 a	77 a	78 a	81 a

Table 7.9.	The consumer	acceptability of	<b>'RS109-15'</b>	(May 2013)
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n: the number of assessments made; Different letters within a column indicate a statistically significant difference between samples by ANOVA where p < 0.05.

The texture of the 'RS109-15' apples was well liked by the consumers, although rated lower than 'Pink Lady'<sup>TM</sup> texture (Table 7.9). Consumer comments were particularly positive about 'RS109-15' texture, with frequent spontaneous remarks about its crispness and crunch. Many consumers also liked the sweet taste and juiciness of 'RS109-15', with some describing the flavour as "unique/original for an apple".

The appearance of 'RS109-15' was considered unattractive by some consumers, due primarily to poor colour. The characteristic pink blush of 'RS109-15' did not fully develop in the 2013 season, primarily due to high temperatures prior to harvest, and excessive preharvest leaf drop caused by *Alternaria*.

'Red Delicious' was the least preferred of the three varieties (Table 7.9), and was criticised by many consumers for its lack of taste and poor texture.

# 7.4 Conclusions

Whilst appearance is important to attract a consumer to an apple, texture and flavour were the two key attributes that gave the most quantitative and qualitative weight to the acceptability and likability of apples by the consumers across all eight tastings.

Participants of the studies tended to be representative of a mid to high socio-economic demographic, and the results are therefore indicative of this. Consumers seemed to be reasonably familiar with apples as a food commodity, given that over one third of them reported eating apples every day, and few consumers professed to eating apples rarely.

The consumer tastings demonstrated that the eight scab-resistant apple selections tested were scored, on average, in the acceptable range of the hedonic scale, and were within the range of scores obtained for the six commercial apple varieties used as comparators. With the exception of FB7-159 for flavour (49) and texture (49), none of the scab-resistant selections or the commercial varieties were, on average, scored below 'neither like nor dislike' for any of the four consumer attributes tested (overall acceptability, appearance, texture and flavour). In most cases the scab-resistant selections performed on par with or better than the commercial varieties.

'Kalei' ('RS103-130') and 'RS103-110' confirmed their appeal to consumers across several tastings that included fruit assessed within one to two months of harvest, and apples held in medium to long term storage. The robustness of 'Kalei' texture was conclusively demonstrated in the March 2013 tasting, when one-year-old 'Kalei' apples were considered by consumers to have comparable texture to new season 'Royal Gala' and superior texture to new season 'Red Delicious'. The consumer evaluations supported the decision to commercialise 'Kalei' and commence the commercialisation of 'RS103-110'.

Based on the consumer feedback provided in March 2013, the early season red scab-resistant apple selections 'RS102-50' and 'RS104-1' are strong candidates for further evaluation and testing, and warrant consideration for potential commercialisation. 'RS102-50' was very well liked by consumers across all four attributes tested, and 'RS104-1' was also well liked by consumers, most especially for appearance and flavour.

Both 'RS109-15' and 'SP7-226' hold some potential for commercialisation, but received mixed reviews from consumers. 'RS109-15' was well liked for texture and flavour (March 2009), but less well liked for appearance. The late season apple 'SP7-226' was well received by consumers for its taste and texture but its appearance divided consumers. The colour and oblate shape of 'SP7-226' held appeal for some consumers, but not others. The differing results for 'SP7-226' acceptability between 2010 and 2011 illustrates the importance of undertaking several consumer evaluations to build a true profile of a particular apple selection's commercial potential.

Consumer feedback regarding 'RS103-56' and 'FB7-159' suggests that, whilst these two scabresistant apple selections may have some desirable traits, they are likely to fall short of Australian consumer expectations. Relative to other apples, 'RS103-56' in particular did not rate highly, with its texture, flavour and large fruit size not liked by many consumers. The attractive appearance of 'FB7-159' was a positive feature of this apple, however the high level of sweetness was either a positive or negative trait for consumers. The relatively poor texture would likely be the greatest deterrent to consumer purchase of 'FB7-159'.

'Red Delicious' was the least preferred apple across the four years of tastings, and received the highest number of negative comments. Despite possessing a good colour, the unacceptable flavour and skin toughness of 'Red Delicious' meant it was unappealing to many consumers. Many participants also found the texture of 'Red Delicious' to be too "soft". If 'Red Delicious' was a scab-resistant selection, it would not be considered for commercial release, due to the consistently poor consumer feedback received for this variety.

# 8. Postharvest sensory quality of scab-resistant apples

# **8.1 Introduction**

For a new apple variety to be adopted by growers and succeed in the market, it not only has to be productive in the orchard and well-liked by consumers, but must also retain postharvest quality after being held in medium to long term storage and when left at room temperature for several days or weeks.

In previous project AP05008 (Zeppa and Middleton, 2008), postharvest sensory evaluations were completed by Brisbane-based DAFF Qld staff for the scab-resistant selections 'RS103-130' ('Kalei') in 2006 and 2007, and 'RS103-110' in 2007. The postharvest laboratory testing of these two selections for shelf life over 22 days at room temperature, and flesh browning over 90 minutes at room temperature, was done on new season apples harvested two weeks prior ('RS103-110') and seven weeks prior ('RS103-130'/'Kalei') to the commencement of the shelf life and flesh browning measurements.

The shelf life of 'RS103-130' ('Kalei') in these experiments was superior to 'Red Delicious' and as good as other commercial varieties, including 'Royal Gala', 'Fuji' and 'Pink Lady'<sup>TM</sup>. The rate of flesh browning of 'RS103-130' ('Kalei') was comparable to 'Red Delicious', 'Royal Gala' and 'Pink Lady'<sup>TM</sup>, and significantly lower than 'Fuji'. The shelf life of 'RS103-110' over 22 days at room temperature (20°C) was superior to 'Royal Gala', 'Jonagold' and 'Red Delicious' (Zeppa and Middleton, 2008).

This chapter reports on postharvest laboratory work undertaken between 2009 and 2013. These evaluations included further testing of 'RS103-130' ('Kalei') and 'RS103-110' to confirm the postharvest quality of these two apple selections immediately following harvest, and after medium to long term storage. In addition, a further twelve advanced scab-resistant selections from the ARS apple breeding program were included in postharvest sensory evaluations during this period.

An overview of the results from the postharvest sensory evaluations is presented in this chapter. Further detail is available in the postharvest apple quality reports provided with milestone reports during the course of this project (Smyth and Reid, 2009; Smyth and Reid, 2010; Smyth and Gething, 2010; Gething and Smyth, 2011).

# 8.2 Materials and Methods

A series of eight postharvest laboratory sensory evaluations was undertaken between 2009 and 2013 as follows:

- Mar 2009: 'RS103-110'; 'RS109-15'; 'FB22-47'; 'Gala'; 'Red Delicious'; 'Fuji'
- May 2009: 'RS103-130' ('Kalei'); 'RS103-56'; 'FB7-159'; 'Fuji'; 'Jonagold'; 'Pink Lady'<sup>TM</sup>
- Oct 2009: 'RS103-110'; 'Gala'; 'Red Delicious'; 'Pink Lady'<sup>TM</sup>
- Dec 2009: 'RS103-130' ('Kalei'); 'Royal Gala'; 'Red Delicious'; 'Sundowner'<sup>TM</sup>
- Aug 2010: 'SP7-226'; 'RS108-96'; 'SP13-169'; 'RS109-15'; 'FB6-94'; 'Red Delicious'; 'Pink Lady'<sup>TM</sup>; 'Sundowner'<sup>TM</sup>
- Aug 2011: 'FB7-159'; 'SP7-226'; 'RS102-121'; 'SP15-207'; 'SP1-175'; 'FB6-94'; 'RS102-50'; 'Gala'; 'Red Delicious'; 'Sundowner'<sup>TM</sup>
- Mar 2013: 'RS103-110'; 'Royal Gala'
- May 2013: 'RS103-130' ('Kalei'); 'Red Delicious'; 'Pink Lady'<sup>TM</sup>

For each postharvest testing of scab-resistant apple selections, commercial apple varieties that would be competitors in the marketplace at the same time were also assessed, as shown above. Each of the scab-resistant selections above are described in detail earlier in this report.

The postharvest evaluations in March 2009, May 2009, March 2013 and May 2013 were of apples that had been harvested one to eight weeks prior to the laboratory testings, and stored in ordinary cold storage  $(2^{\circ}C-5^{\circ}C)$  in the interim.

The other four postharvest evaluations were of scab-resistant apple selections that had been held in medium to long term storage. 'RS103-110' apples assessed in Oct 2009 had been held in CA storage (2 %  $O_2$ ; 0.5% CO<sub>2</sub>; 0.5°C) for seven months; 'RS103-130' ('Kalei') apples assessed in Dec 2009 were held in CA storage (2 %  $O_2$ ; 0.5% CO<sub>2</sub>; 0.5% CO<sub>2</sub>; 0.5°C) for six months, followed by one month in ordinary storage (2°C- 5°C); and the scab-resistant apple selections evaluated in Aug 2010 (five selections) and Aug 2011 (seven selections) had been held in ordinary cold storage (2°C- 5°C) since they were harvested three to four months previously.

The scab-resistant apples used in the postharvest work were all sourced from Applethorpe Research Station, Queensland, and delivered by road to Brisbane. Apples of the comparator commercial varieties were purchased as graded, packed cartons of fruit, either directly from a major Stanthorpe apple producer, or from the Brisbane Markets. Hence all apples used were produced in the Stanthorpe district.

Apples were delivered to the DAFF Qld postharvest facility in Brisbane one to two weeks prior to the commencement of each of the eight postharvest evaluations. The apple samples were stored at 2°C until required for postharvest laboratory testing of shelf life (8.2.1) and flesh browning (8.2.2).

#### 8.2.1 Shelf life testing

The shelf life of scab-resistant apple selections and comparator commercial apple varieties was measured on eight occasions between 2009 and 2013, as per the schedule above.

On each occasion, a room temperature storage trial was conducted to compare the shelf life potential (in terms of texture) of each apple variety or selection. Typically, 30 apples of each variety/selection were stored in a temperature controlled cabinet at 20°C, and were removed for testing at time points every three to four days over a continuous period of three to four weeks.

At each time point, three apples per variety were randomly selected, and two opposite sites of each apple were tested by penetrometry, giving a total of six penetrometer measurements for each variety at each time point. In the 2013 experiments there were ten apples (20 penetrometer readings) of each variety for each time point. The penetrometer test was conducted with an automated Instron Model 5543, which measured the force required to push an 11 mm fruit probe a depth of 8 mm into the fruit, as described by Williamson and Sargent (1999). Immediately prior to taking a penetrometer reading, each apple was peeled at the site of measurement, then positioned on the testing plate of the instrument such that the core was always perpendicular to the probe, as shown in Plate 8.1.

Each individual apple tested was also weighed (g), and measured across the widest point with callipers to give a measurement of diameter (mm).



Plate 8.1. Apple penetrometer measurements with an automated Instron Model 5543

### 8.2.2 Flesh browning experiments

The flesh browning rates of a wide range of apple varieties across the six experiments between 2009 and 2011 were recorded to measure the flesh browning of a total of twelve scab-resistant apple selections against standard commercial varieties. In each experiment, two or three samples of each apple variety or selection were cut in half. Colour readings were taken at time zero, then at ten minutes, 20 minutes, 30 minutes, 60 minutes and 90 minutes after cutting. In some experiments, photographs were also taken at each time point (shortly after colour measurements were made) to record the visual degree of browning.

As individual fruit may vary in terms of flesh colour within a variety and within an individual fruit, two measurements were taken of each of the two or three samples (one either side of the core midway into the flesh). The colour measurements were taken with a Chroma Meter (Model CR-300 Minolta Co. Ltd. Osaka, Japan) using the CIE  $L^*a^*b^*$  system, and photographs were taken with a digital camera (Olympus  $\mu$ -Tough 6000). The value  $\Delta E^*$  was calculated from the data obtained from the Minolta Meter. The formula for calculating  $\Delta E^*$  is presented in Fig 8.1.  $\Delta E^*$  calculation provides a method of evaluating the total amount of colour change in the  $L^*$ ,  $a^*$  and  $b^*$  colour dimensions of the apple flesh, as represented in Fig 8.1, and was considered the most appropriate method of quantifying the amount of browning of cut apple surfaces.



Fig 8.1. Definitions of  $L^*$ ,  $a^*$  and  $b^*$  and the formula for calculation of  $\Delta E^*$ 

### 8.2.3 Data analysis

The automated Instron Model 5543 penetrometer generated a Microsoft Excel file for penetration force, and also entered individual apple weight and diameter data which could be sorted and statistically analysed. The Chroma Meter used in the flesh browning experiments generated a paper printout of the data, which was subsequently entered manually into an Excel file for statistical analysis.

Analysis of variance (ANOVA) was performed on instrumental data (penetrometer force, flesh colour, apple weight and diameter) using SPSS or JMP (SAS, version 6.0.0). Where a significant (p<0.05) difference was found using ANOVA, pairwise comparisons were completed using Fishers least significant difference (LSD) or Tukey-Kramer highest significant difference (HSD). Where equal variances cannot be assumed, Dunnet's T3 was used in post hoc analysis using SPSS.

# 8.3 Results and Discussion

#### 8.3.1 Fruit size

#### (a) March 2009 and May 2009

Prior to the shelf life testing conducted in each of the eight postharvest sensory evaluations between 2009 and 2013, the individual apple weights (g) and diameters (mm) were measured. The average fruit sizes of the apples tested in March and May 2009 are summarised in Table 8.1.

The largest apples were 'RS103-56', which at mean fruit weight of 258 g and mean diameter of 87 mm were considered too large by consumers. The smallest apples were 'Gala' ('Galaxy') at 147 g average fruit weight and 68 mm average diameter (Table 8.1). Interestingly, the smaller size of the 'Gala' apples attracted many positive comments from the consumers. Most of the scab-resistant selections and commercial varieties tested were large, and in the 196-224 g weight range and 77-81 mm diameter range. 'RS103-110' apples were slightly smaller than this (average 178 g, 75 mm), but of very acceptable size to consumers.

Apple	n	Weight (g)	Diameter (mm)
RS103-110	42	178 f	75 f
RS109-15	42	208 d	81 de
Gala (Galaxy)	42	147 g	68 g
Red Delicious	42	196 de	77 de
FB22-47	42	197 de	80 c
RS103-130 (Kalei)	48	224 c	79 c
RS103-56	48	258 a	87 a
Fuji	48	198 de	77 ef
Jonagold	48	204 de	79 cd
Pink Lady <sup>TM</sup>	48	196 e	78 cde
FB7-159	48	203 de	80 c
Significance level		<0.001	<0.001
LSD		13	2

 Table 8.1. The average weight (g) and diameter (mm) of apples tested in shelf life experiments

 March and May 2009

n: the number of apples measured; Different letters within a column indicate a statistically significant difference between samples by ANOVA where p < 0.05.

#### (b) October 2009 and December 2009

The average fruit sizes of the apples tested in October and December 2009 are summarised in Table 8.2. The largest apples (averaging 212-216 g) were the 'Gala' (October 2009), and the 'Red Delicious' and 'Sundowner'<sup>TM</sup> (December 2009). Apples of the other varieties/assessment timings averaged 151-178 g and were of more acceptable size. It should be noted that the 'RS103-110' apples assessed in October 2009 (average weight 153 g, average diameter 72 mm) were of more typical size for this selection than the larger 'RS103-110' tested in March 2009 (Table 8.1). Consumer comments in October 2009 and December 2009 again indicated a preference for the smaller sized apples.

 Table 8.2. The average weight (g) and diameter (mm) of apples tested in shelf life experiments

 October and December 2009

Apple	n	Weight (g)	Diameter (mm)
RS103-110 (Oct)	24	153 d	72 bc
Pink Lady <sup>TM</sup> (Oct)	24	167 c	74 abc
Red Delicious (Oct)	24	170 c	73 abc
Gala (Oct)	24	216 a	78 a
Kalei (Dec)	21	178 b	69 cd
Red Delicious (Dec)	21	216 a	76 ab
Sundowner <sup>TM</sup> (Dec)	21	212 a	75 abc
Royal Gala (Dec)	21	151 d	66 d
Significance level		<0.001	<0.001
LSD		6	6

n: the number of apples measured; Different letters within a column indicate a statistically significant difference between samples by ANOVA where p < 0.05.

#### (c) August 2010

The apples tested in August 2010 were all of preferred size for high consumer acceptance, and averaged 147-182 g weight and 71-76 mm diameter (Table 8.3). Significant differences were measured between the varieties in their weights and diameters. 'RS109-15' and 'SP7-226' were the largest apples, averaging 182 g and 179 g respectively, whilst 'FB6-94' were the smallest (Table 8.3). The 'SP7-226' apples were not significantly heavier than the 'Pink Lady'<sup>TM</sup>, 'Red Delicious' and 'Sundowner'<sup>TM</sup> commercial comparator varieties, but were significantly (slightly) broader in diameter (Table 8.3), and hence flatter, than 'Pink Lady'<sup>TM</sup> and 'Red Delicious'.

Apple	n	Weight (g)	Diameter (mm)
Pink Lady <sup>TM</sup>	24	167 ab	71 cd
Red Delicious	24	169 ab	73 bcd
Sundowner <sup>TM</sup>	24	170 ab	73 abcd
SP7-226	24	179 a	76 a
RS108-96	24	162 bc	74 abc
SP13-169	24	158 bc	72 cd
RS109-15	24	182 a	75 ab
FB6-94	24	147 c	71 d
LSD (p<0.001)		16	2.8

Table 8.3.	The average we	eight (g) and	diameter (mm)	of apples tested	d in shelf life	experiments
	August 2010					

n: the number of apples measured; Different letters within a column indicate a statistically significant difference between samples by ANOVA where p < 0.05.

#### (d) August 2011

The average fruit sizes of the apples tested in August 2011 are summarised in Table 8.4.

Table 8.4.	The average weight (g) August 2011	and dia	ameter (mm) of apples	tested in shelf life expe	riments
	Amula		Waight (g)		

Apple	n	Weight (g)	Diameter (mm)
Gala	30	169 c	73 c
Sundowner <sup>TM</sup>	30	166 c	74 bc
Red Delicious	30	174 c	75 bc
RS102-121	18	141 d	70 d
SP15-207	30	191 b	77 b
SP1-175	18	164 c	75 bc
SP7-226	30	207 a	81 a
FB6-94	18	154 d	71 cd
RS102-50	24	168 cd	71 cd
FB7-159	24	206 a	80 a
LSD (p<0.001)		15	2.8

n: the number of apples measured; Different letters within a column indicate a statistically significant difference between samples by ANOVA where p < 0.05.

Of the ten varieties and selections assessed, the scab-resistant apples 'SP7-226' (207 g, 81 mm diameter) and 'FB7-159' (206 g, 80 mm diameter) were significantly larger than the other apples (Table 8.4). 'SP15-207' (191 g, 77mm) was also a large apple, however the remaining seven were all of optimal size for high consumer acceptability (70-75 mm diameter). 'RS102-121' and 'FB6-94' were significantly the smallest (Table 8.4), but with average fruit weights of 141 g and 154 g respectively, they were still considered of very acceptable size by consumers.

#### (e) March and May 2013

The average fruit sizes of all five apple varieties tested in March and May 2013 are summarised in Table 8.5. The apples of all varieties were of optimum 69-75 mm diameter. 'Kalei' apples were slightly, but significantly heavier (175 g) than the other four varieties. 'RS103-110' was the smallest apple in both weight and diameter (Table 8.5). 'Kalei' is a dense apple, as evidenced in comparison with 'Pink Lady'<sup>TM</sup>. For the same average diameter (73 mm) and shape as 'Pink Lady'<sup>TM</sup>, 'Kalei' apples were each on average 7 g heavier (Table 8.5).

Table 8.5. The average weight (g) and d	iameter (mm) of apples tested in shelf life experiments
in March and May 2013	

n	Weight (g)	Diameter (mm)		
80	167 b	71.5 c		
80	143 c	69.0 d		
70	168 b	75.0 a		
70	175 a	73.0 b		
70	168 b	73.0 b		
	6	1.2		
	n 80 80 70 70 70 70	n         Weight (g)           80         167 b           80         143 c           70         168 b           70         175 a           70         168 b           6         6		

n: the number of apples measured; Different letters within a column indicate a statistically significant difference between samples by ANOVA where p < 0.05.

#### 8.3.2 Shelf life

Following fruit weight and diameter measurements (Section 8.3.1), shelf life testing of these fourteen scab-resistant selections and six commercial apple varieties was undertaken according to the procedure described in Section 8.2.1. The shelf life testing was carried out in a series of eight separate evaluations during the period between 2009 and 2013, as summarised in Section 8.2.

An overview of the results from these evaluations is presented here. Further detail is available in the postharvest apple quality reports provided with milestone reports during the course of this project (Smyth and Reid, 2009; Smyth and Reid, 2010; Smyth and Gething, 2010; Gething and Smyth, 2011).

#### (a) March 2009 and May 2009: Shelf life of 'RS 103-110', 'RS109-15', 'FB22-47', 'RS103- 130' ('Kalei'), 'RS103-56', 'FB7-159'

The shelf life evaluations in March and May 2009 were of fresh, new season apples harvested four to six weeks prior to the commencement of the experiments. Across the two timings, the flesh firmness of a total of six scab-resistant selections and five commercial apple varieties held at room temperature (20°C) was measured, over a period of 27 days in March 2009 and 25 days in May 2009.

The results from these two experiments are summarised in Tables 8.6 and 8.7. As can be expected, the flesh firmness of all the apple varieties and selections declined over time when held at room temperature ( $20^{\circ}$ C).

		Compressive load (Newtons) to 8mm depth							
Apple	n	Day 0	Day 4	Day 8	Day 13	Day 18	Day 22	Day 27	
RS103-110	6	79 a	76 ab	63 b	55 b	57 ab	62 a	60 ab	
RS109-15	6	81 a	83 a	78 a	69 a	66 a	63 a	67 a	
FB22-47	6	67 ab	68 bc	63 b	59 b	55 ab	52 b	48 c	
Gala (Galaxy)	6	57 b	48 d	51 c	39 c	37 d	40 c	36 d	
Red Delicious	6	62 b	53 d	50 c	42 c	41 cd	33 c	31 d	
Fuji	6	60 b	60 cd	66 ab	54 b	51 bc	52 b	51 bc	

# Table 8.6. Fruit texture as measured with an Instron Model 5543, comparing the shelf life of sixapple varieties held at room temperature (20°C) over 27 days (March 2009)

n: the number of assessments made at each time point; Different letters within a column indicate a statistically significant difference between samples by ANOVA and application of Tukey-Kramer HSD where p<0.05.

<b>Table 8.7.</b>	Fruit texture as measured with an Instron Model 5543, comparing the shelf life of six
	apple varieties held at room temperature (20°C) over 25 days (May 2009)

		Compressive load (Newtons) to 8mm depth								
Apple	n	Day 0	Day 4	Day 8	Day 12	Day 15	Day 19	Day 22	Day 25	
RS103-130	6	77 a	68 a	69 a	63 a	66 a	56 a	60 a	52 ab	
RS103-56	6	60 b	59 ab	46 d	43 b	35 c	34 c	32 d	32 c	
FB7-159	6	59 b	64 a	52 cd	55 a	50 b	51 ab	46 bc	54 ab	
Fuji	6	59 b	62 ab	54 bcd	57 a	49 b	47 ab	47 bc	55 a	
Jonagold	6	60 b	52 b	61 abc	52 ab	59 ab	44 bc	55 ab	55 a	
Pink Lady <sup>TM</sup>	6	66 ab	66 a	63 ab	58 a	52 b	46 ab	43 c	41 bc	

n: the number of assessments made at each time point; Different letters within a column indicate a statistically significant difference between samples by ANOVA and application of Tukey-Kramer HSD where p<0.05.

The scab-resistant apples 'RS109-15' and 'RS103-110' had the best shelf life (Table 8.6), with 'RS109-15' the firmest of all eleven apple varieties throughout the 25 to 27 day duration of shelf life testing. Although, like all varieties, the 'RS109-15' and 'RS103-110' apples declined in firmness over time, after 27 days at 20°C they were as firm or firmer than the 'Gala', 'Red Delicious' and 'Fuji' at day 0 (Table 8.6).

'RS103-130' ('Kalei') apples were also among the firmer fruit (Table 8.7) over 25 days at 20°C.

The firmness of 'Fuji', 'Jonagold' and 'FB7-159' apples, although all at a comparatively softer texture than other varieties at day 0, appeared to change the least during shelf life testing (Table 8.7). In comparison, the 'Pink Lady'<sup>TM</sup>, which began with a much firmer texture (day 0) than these three varieties, had a much more rapid rate of flesh softening over the 25 days shelf storage at room temperature. Similarly, the 'RS103-56' and 'Red Delicious' experienced a more rapid decline in texture integrity than the other varieties.

Overall, 'RS103-56', 'Red Delicious' and 'Gala' ('Galaxy') had the softest texture and poorest shelf life of the apples tested. The 'FB22-47' and 'FB7-159' were mid-range in texture throughout the experiments (Tables 8.6 and 8.7).

#### (b) October 2009 and December 2009: Shelf life of 'RS 103-110' and 'RS103-130' ('Kalei')

The shelf life evaluations in October 2009 and December 2009 were of fruit that had been held in long term storage. The 'RS103-110' apples were held in CA storage (2 %  $O_2$ ; 0.5% CO<sub>2</sub>; 0.5°C) for the seven months between harvest in March 2009 and the shelf life testing in October 2009. Similarly, the three commercial varieties used as comparators in October 2009 had been held in CA for seven ('Gala'), six ('Red Delicious') and five ('Pink Lady'<sup>TM</sup>) months since their respective harvests.

'RS103-130' ('Kalei') apples assessed in December 2009 were held in CA storage (2 %  $O_2$ ; 0.5%  $CO_2$ ; 0.5°C) for the six months immediately after harvest, followed by two months in ordinary storage (4°C-7°C). Apples of the three comparator varieties assessed in December 2009 were held in commercial CA for the nine ('Gala'), eight ('Red Delicious') and six ('Sundowner'<sup>TM</sup>) months following their respective harvests.

The 'RS103-110' apples were significantly firmer than 'Gala', 'Red Delicious' and 'Pink Lady'<sup>TM</sup> from day 14 onwards at room temperature (Table 8.8). At day 3 there was no significant difference in the texture of all four varieties, however the texture of 'Gala' and 'Red Delicious' declined significantly after being held at room temperature for 14 to 24 days. 'RS103-110' retained full firmness and texture for the entire 24 days at room temperature (Table 8.8). 'Pink Lady'<sup>TM</sup> also retained firmness over this period, but were significantly softer than the 'RS103-110'.

			Compressive load (Newtons) to 8mm depth						
Apple	n	Day 0	Day 3	Day 7	Day 10	Day 14	Day 17	Day 21	Day 24
RS103-110	6	85 a	80	83 a	84 a	83 a	86 a	83 a	82 a
Gala	6	68 ab	74	75 ab	69 b	57 b	51 c	55 b	35 c
Red Delicious	6	61 bc	67	77 a	76 ab	66 b	64 b	47 b	39 c
Pink Lady <sup>TM</sup>	6	63 b	67	64 b	66 b	64 b	59 bc	53 b	59 b

<b>Table 8.8.</b>	Fruit texture as measured with an Instron Model 5543, comparing the shelf life of
	four apple varieties held at room temperature (20°C) over 24 days (October 2009)

n: the number of assessments made at each time point; Different letters within a column indicate a statistically significant difference between samples by ANOVA and application of Tukey-Kramer HSD where p<0.05.

The 'RS103-130' ('Kalei') apples kept in CA for six months followed by ordinary cold storage for two months also retained their texture and firmness when subsequently held at room temperature for 23 days (Table 8.9). This was despite the poorer storage conditions in which the 'Kalei' were kept compared to the commercial varieties, which were held in CA for the entire period between harvest and shelf life testing. Both 'Kalei' and 'Sundowner'<sup>TM</sup> were significantly firmer than 'Gala' and 'Red Delicious' in this experiment.

<b>Table 8.9.</b>	Fruit texture as measured with an Instron Model 5543, comparing the shelf life of
	four apple varieties held at room temperature (20°C) over 23 days (December 2009)

			Compressive load (Newtons) to 8mm depth								
Apple	n	Day 0	Day 5	Day 9	Day 12	Day 16	Day 19	Day 23			
RS103-130	6	81 a	83 a	77 a	82 a	83 a	85 a	75 a			
Gala	6	53 c	55 b	67 ab	64 b	69 a	70 ab	48 b			
Red Delicious	6	61 bc	59 b	60 b	53 b	53 b	53 b	59 b			
Sundowner <sup>TM</sup>	6	74 ab	74 a	72 a	66 b	75 a	68 ab	70 a			

n: the number of assessments made at each time point; Different letters within a column indicate a statistically significant difference between samples by ANOVA and application of Tukey-Kramer HSD where p<0.05.

#### (c) August 2010: Shelf life of 'SP7-226', 'RS109-15', 'RS108-96', 'SP13-169' and 'FB6-94'

Apples of the five scab-resistant selections were held in ordinary cold storage (2°C-5°C) at Applethorpe Research Station for the twelve ('SP7-226'), fourteen ('FB6-94'), eighteen ('SP13-169') and 22 weeks ('RS109-15', 'RS108-96') between their respective harvests and the commencement of the shelf life tests in August 2010. The three comparator apple varieties were held in commercial cold storage for the eighteen ('Red Delicious'), fourteen ('Pink Lady'<sup>TM</sup>) and eleven ('Sundowner'<sup>TM</sup>) weeks following their harvests.

There was a significant decrease in the flesh firmness of four of the eight apple varieties over the 24 day duration of the shelf life tests conducted in August 2010. The texture of 'SP7-226', 'FB6-94', 'Red Delicious' and 'Sundowner'<sup>TM</sup> all declined during this period (Table 8.10), with 'Red Delicious' apples showing the most dramatic fall in flesh firmness over the 24 days at room temperature.

Significant differences in fruit firmness were measured between apple varieties at each time point in the shelf life experiment. 'SP13-169' and 'Pink Lady'<sup>TM</sup> were consistently the firmest fruit, whilst 'RS108-96' and 'SP7-226' were always amongst the softest textured apples (Table 8.10).

'RS109-15' retained good firmness over the 24 days (Table 8.10), and was only slightly (not significantly) less firm than 'SP13-169' and 'Pink Lady'<sup>TM</sup>. All the scab-resistant selections were within the range of commercial fruit varieties in terms of texture firmness throughout the shelf life testing period.

			Compressive load (Newtons) to 8mm depth								
Apple	n	Day 0	Day 3	Day 6	Day 10	Day 13	Day 17	Day 21	Day 24		
SP13-169	6	78 a	78 a	79 a	77 a	73 ab	78 a	73 ab	78 a		
RS109-15	6	70 ab	72 ab	74 ab	73 ab	72 ab	70 ab	61 bc	70 ab		
SP7-226	6	57 cd	55 cd	55 de	54 de	53 cd	51 cd	51 cd	48 cd		
FB6-94	6	57 cd	57 cd	50 e	59 cde	42 d	46 cd	40 d	45 cd		
RS108-96	6	51 d	52 d	49 e	46 e	53 cd	47 cd	48 cd	44 cd		
Pink Lady <sup>TM</sup>	6	74 ab	75 ab	77 ab	74 ab	76 a	78 a	77 a	74 a		
Sundowner <sup>TM</sup>	6	65 bc	68 abc	66 c	57 cde	59 bc	60 bc	57 c	53 bc		
Red Delicious	6	65 bc	65 bcd	62 cd	62 bcd	54 cd	43 d	48 cd	35 d		

Table 8.10. Fruit texture as measured with an Instron Model 5543, comparing the shelf life of<br/>eight apple varieties held at room temperature (20°C) over 24 days (August 2010)

n: the number of assessments made at each time point; Different letters within a column indicate a statistically significant difference between samples by ANOVA and application of Tukey-Kramer HSD where p<0.05.

# (d) August 2011: Shelf life of 'SP7-226', FB7-159', 'RS102-121', 'SP15-207', 'SP1-175', 'FB6-94', 'RS102-50'

Apples of the seven scab-resistant selections were held in ordinary cold storage  $(2^{\circ}C-5^{\circ}C)$  at Applethorpe Research Station for the twelve ('SP7-226'), fourteen ('FB6-94'), fifteen ('SP1-175'), eighteen ('SP15-207', 'RS102-121') and 22 weeks ('RS102-50', 'FB7-159') between their respective harvests and the commencement of the shelf life tests in August 2011. The three comparator apple varieties were held in commercial cold storage for the twenty ('Gala'), sixteen ('Red Delicious') and twelve weeks ('Sundowner'<sup>TM</sup>) following their harvests.

The results from the shelf life experiment conducted in August 2011 are summarised in Table 8.11. Unfortunately, the fruit samples for 'FB6-94', 'RS102-121', 'FB7-159' and 'SP1-175' degraded substantially due to infection from *Glomerella* and postharvest rots. Hence there were no apples of these selections remaining on which to complete the 21 and 28 day penetrometer readings (Table 8.11).

The seven scab-resistant selections used in this experiment were sourced from a block of trees at Applethorpe Research Station that consisted of over 100 selections with a wide harvest maturity range (January to May). This precluded the use of sprays during this period, as apples from this block were being harvested and tasted twice a week. Coupled with the very wet spring and summer of 2010-11 with flooding rains (560mm Sept-Dec 2010; 450 mm Jan-Mar 2011) it was inevitable that there would be fruit quality and postharvest storage issues.

Despite this, apples of the scab-resistant selection 'RS102-50' grown under these conditions did not suffer from postharvest rots, and were the firmest fruit of all ten apple varieties over the 28 days of shelf life testing at 20°C (Table 8.11). 'Sundowner'<sup>TM</sup> apples (sourced from a commercial Granite Belt grower) also did not experience a significant change in texture over the 28 days at room temperature (Table 8.11), however were much softer than the 'RS102-50'. 'Gala' (also sourced from a commercial Granite Belt grower) was consistently the second firmest apple over the 28 day shelf life test (Table 8.11), but by the third and fourth week at 20°C was of significantly poorer texture than 'RS102-50'.

		Co	mpressive lo	oad (Newtons) to 8mm depth					
Apple	n	Day 0	Day 7	Day 14	Day 21	Day 28			
RS102-50	6	89 a	80 a	80 a	81 a	81 a			
SP15-207	6	68 c	63 b	57 c	52 c	58 c			
SP7-226	6	64 cd	55 c	50 c	50 c	48 d			
FB6-94	6	70 c	59 bc	51 c					
RS102-121	6	51 e	50 cd	55 c					
FB7-159	6	49 e	50 cd	45 cd	40 d				
SP1-175	6	44 e	37 d	37 d					
Gala	6	79 b	75 ab	72 a	69 b	69 b			
Red Delicious	6	73 bc	70 b	65 b	58 c	58 c			
Sundowner <sup>TM</sup>	6	60 cd	64 b	57 c	62 c	61 bc			

Table 8.11. Fruit texture as measured with an Instron Model 5543, comparing the shelf life of<br/>ten apple varieties held at room temperature (20°C) over 28 days (August 2011)

n: the number of assessments made at each time point; Different letters within a column indicate a statistically significant difference between samples by ANOVA and application of Tukey-Kramer HSD where p<0.05. Empty cells due to sample deterioration and inability to test.

'Red Delicious' texture over the 28 days was comparable to the scab-resistant 'SP15-207' (Table 8.11). The texture of 'SP7-226' decreased significantly between day 0 and day 14, but remained relatively stable after that. In contrast to this, the texture of 'FB7-159' apples was unchanged for the first seven days at room temperature, but declined thereafter, with fruit unacceptably soft (Table 8.11).

#### (e) March and May2013: Shelf life of 'RS 103-110' and 'RS103-130' ('Kalei')

The shelf life testings conducted in March 2013 ('RS103-110', 'Royal Gala') and May 2013 ('Kalei', 'Red Delicious', 'Pink Lady'<sup>TM</sup>) were of fresh, new season apples that had been harvested one to five weeks prior to the experiments, and stored in ordinary cold storage (2°C- 5°C) in the interim.

The results summarised in Table 8.12 are for the two experiments combined. 'RS103-110' apples were of far superior texture to the 'Royal Gala' at each time point across the 28 days in which the apples were held at room temperature (20°C). For both varieties, there was a decrease in firmness from day 0 to day 28, however for 'RS103-110' there was no measureable decline in firmness until day 12 (Table 8.12). On the other hand, the firmness of 'Royal Gala' apples fell significantly from the outset (between days 0 and 4), and by day 12 at room temperature the apples were soft (Table 8.12).

In the May 2013 experiment, there was no significant difference between 'Kalei' and 'Pink Lady'<sup>TM</sup> firmness at each time point across the 25 days the apples were kept at room temperature (Table 8.12). As with all five varieties, there was a decline in the firmness of 'Kalei' and 'Pink Lady'<sup>TM</sup> between days 0 and 25. At day 25 however, the 'Kalei' and 'Pink Lady'<sup>TM</sup>, as well as the 'RS103-110', were still firm edible apples.

In contrast to this, the 'Red Delicious' had very poor shelf life, and softening texture as early as day 8 (Table 8.12). The firmness of 'Red Delicious' and 'Royal Gala' was significantly lower than the other three varieties from the outset (day 0) of the shelf life experiments. From there, the texture of 'Red

Delicious' and 'Royal Gala' apples deteriorated rapidly at room temperature, such that by day 12 they were quite soft, and inedible by the conclusion of the experiments.

			Compressive load (Newtons) to 8mm depth							
Apple	n	Day 0	Day 4	Day 8	Day 12	Day 15	Day 21	Day 25	Day 28	
Royal Gala *	20	59 c	45 d	41 c	35 c	32 c	33 d	32 c	29 b	
RS103-110 *	20	68 b	69 b	65 b	54 b	50 b	48 c	51 b	44 a	
Kalei	20	77 a	76 a	70 a	67 a	62 a	54 b	58 a		
Pink Lady <sup>TM</sup>	20	74 a	71 b	68 ab	67 a	65 a	60 a	62 a		
Red Delicious	20	57 c	57 c	43 c	37 c	34 c	30 d	29 c		

# Table 8.12. Fruit texture measured with an Instron 5543, comparing the shelf life of five apple varieties held at room temperature (20°C) over 25-28 days (March and May 2013)

n: the number of assessments made at each time point; Different letters within a column indicate a statistically significant difference between samples by ANOVA and application of Tukey-Kramer HSD where p<0.05. \* 'Royal Gala' and 'RS103-110' shelf life testing in March 2013; the other three varieties in May 2013.

It should be noted that the 'Royal Gala' and 'Red Delicious' in particular, were of poorer texture and much softer than apples of these varieties assessed in the shelf life experiments of previous years (refer to 2009-2011 experiments in Section 8.3.2). The 2012-13 season in the Stanthorpe district was characterised by heat stress conditions to the trees in Nov/Dec 2012, followed by 300 mm rainfall in Jan/Feb 2013. As a consequence of this, there was a high turnout of soft apples produced on the Granite Belt in 2013. That both 'Kalei' and 'RS103-110' still showed excellent shelf life and texture when grown under these conditions is testament to the robustness of these two new scab-resistant apple varieties.

## 8.3.3 Flesh browning

The apple flesh browning of fourteen scab-resistant selections and six commercial apple varieties was measured in a series of six experiments between March 2009 and August 2011, as summarised in Section 8.2. In each experiment, two or three apples of each variety or selection were cut in half, and colour readings taken with a Chroma Meter at time zero, then at ten minutes, 20 minutes, 30 minutes, 60 minutes and 90 minutes after cutting. The procedure used is fully described in Section 8.2.2.

#### (a) March 2009 and May 2009: Flesh browning of 'RS 103-110', 'RS109-15', 'FB7-159' 'RS103-130' ('Kalei'), 'RS103-56'

Apple flesh browning experiments in March and May 2009 used fresh, new season apples harvested four to six weeks previously. Across the two timings, the flesh browning of a total of five scab-resistant selections and five commercial apple varieties was measured. The results are summarised in Table 8.13.

All apples increased in flesh brownness over time (Table 8.13), and the five scab-resistant selections were all within a 'normal' post-cut browning range compared to the commercial varieties.

			Rate of flesh browning ( $\Delta E$ )						
Apple	Month	0 min	10 min	20 min	30 min	60 min	90 min		
RS103-110	March	0.00	0.48	0.89	1.02	2.55	3.77		
RS109-15	March	0.00	0.48	1.24	0.82	2.58	1.01		
Gala (Galaxy)	March	0.00	1.73	2.28	2.35	4.77	4.65		
Red Delicious	March	0.00	0.82	0.91	0.59	0.95	1.13		
Fuji	March	0.00	2.97	2.73	4.22	3.64	5.32		
RS103-130 *	May	0.00	1.51	1.05	0.99	1.81	3.69		
RS103-56	May	0.00	0.46	1.15	2.53	4.70	4.30		
FB7-159	May	0.00	0.26	0.78	1.46	4.52	3.90		
Fuji	May	0.00	2.65	4.75	4.41	5.68	6.42		
Jonagold	May	0.00	0.44	1.64	1.20	0.39	0.64		
Pink Lady <sup>TM</sup>	May	0.00	3.59	7.12	6.00	6.23	6.74		

Table 8.13. The rate of flesh browning (△E) at room temperature (20°C) of ten apple varieties 0- 90 minutes after being cut in half (March and May 2009)

\* 'Kalei' was tested as 'RS103-130' prior to its naming in 2012

Across the March and May 2009 experiments, the 'Fuji', 'Gala' and 'Pink Lady'<sup>TM</sup> varieties showed the most extreme post-cut browning over time (Table 8.13), whereas 'RS109-15', 'Red Delicious' ('Hi Early') and 'Jonagold' showed the least amount of post-cut browning.

The flesh browning of 'RS103-130' ('Kalei'), 'RS103-110', 'FB7-159' and 'RS103-56' was in the mid range of the apples measured, with 90 minute  $\Delta E$  values of 3.69, 3.77, 3.90 and 4.30 respectively (Table 8.13). These values were all lower than 'Gala', 'Fuji' and 'Pink Lady'<sup>TM</sup>. The 'Fuji' and 'Pink Lady'<sup>TM</sup> apples in particular showed high levels of post-cut flesh browning.

Overall, the scab-resistant selections were either equal to or better than the major current commercial apple varieties in terms of retaining their original flesh colour and resisting browning over 90 minutes at room temperature. 'RS109-15' was the standout scab-resistant selection, with minimal flesh browning over 90 minutes.

#### (b) Oct 2009 and Dec 2009: Flesh browning of 'RS 103-110' and 'RS103-130' ('Kalei')

Apple flesh browning experiments in October and December 2009 used fruit that had been held in long term storage. The apples assessed in October 2009 were stored in commercial CA for the seven ('RS103-110', 'Royal Gala'), six ('Red Delicious') and five months ('Pink Lady'<sup>TM</sup>) from harvest.

'RS103-130' ('Kalei') apples assessed in December 2009 were held in CA for the six months immediately after harvest, followed by two months in ordinary storage (4°C-7°C). Apples of the three comparator varieties were stored in commercial CA for the nine ('Gala'), eight ('Red Delicious') and six ('Sundowner'<sup>TM</sup>) months following their respective harvests.

		Rate of flesh browning ( $\Delta E$ )							
Apple	Month	0 min	10 min	20 min	30 min	60 min	90 min		
RS103-110	Oct	0.00	0.51	0.91	0.44	1.10	1.12		
Pink Lady <sup>TM</sup>	Oct	0.00	1.30	1.21	1.08	1.29	1.98		
Red Delicious	Oct	0.00	0.76	0.75	1.52	1.05	2.35		
Royal Gala	Oct	0.00	3.59	6.05	6.78	5.34	7.08		
RS103-130 *	Dec	0.00	0.82	0.52	0.68	1.10	1.72		
Red Delicous	Dec	0.00	1.27	1.22	1.31	3.34	2.96		
Sundowner <sup>TM</sup>	Dec	0.00	4.18	6.07	7.48	7.09	4.89		
Royal Gala	Dec	0.00	4.39	7.13	6.30	9.08	8.08		

Table 8.14. The rate of flesh browning (△E) at room temperature (20°C) of six apple varieties 0- 90 minutes after being cut in half (October and December 2009)

\* 'Kalei' was tested as 'RS103-130' prior to its naming in 2012

Apples of the scab-resistant selections 'RS103-110' and 'RS103-130' ('Kalei') showed the least amount of post-cut flesh browning over time (Table 8.14). The rate of browning of the two selections at all time points across the 90 minutes at room temperature was lower than the commercial comparators.

In both experiments, the 'Royal Gala' apples showed the most extreme post-cut flesh browning (Table 8.14). 'Sundowner'<sup>TM</sup> apple flesh also browned very rapidly after cutting, with a mean  $\Delta E$  value already at 4.18 after ten minutes. By comparison, 'RS103-110' and 'RS103-130' ('Kalei') apples showed little tendency to turn brown after being cut in half, and after 30 minutes at room temperature their respective  $\Delta E$  values of 0.44 and 0.68 were still very low (Table 8.14).

#### (c) Aug 2010: Flesh browning 'SP7-226', 'RS109-15', 'RS108-96', 'SP13-169', 'FB6-94'

Apples of the five scab-resistant selections tested for flesh browning in August 2010 were stored in a cold room (2°C-5°C) at Applethorpe Research Station for the three to five months following their respective harvests between March and May 2010. The 'Red Delicious', 'Pink Lady'<sup>TM</sup> and 'Sundowner'<sup>TM</sup> commercial comparator apples were held in commercial cold storage for a similar period prior to the flesh browning experiment.

The flesh of all eight apple varieties 'browned' during the 90 minutes they were held at room temperature (Fig 8.2). Over the first 30 minutes there was no significant difference in the rate of browning ( $\Delta E$ ) between any of the apple varieties, however after 60 and 90 minutes, the rate of flesh browning of 'Sundowner'<sup>TM</sup>, 'Red Delicious' and 'Pink Lady'<sup>TM</sup> was greater than the five scabresistant apples (Fig 8.2).

'RS108-96' and 'FB6-94' had the lowest flesh browning rates at 30, 60 and 90 minutes (Fig 8.2), but were not significantly different to the other three scab-resistant apple selections, 'SP7-226', 'SP13-169' and 'RS109-15'. All five scab-resistant apple selections were either equal to or better than the three commercial apple varieties in resisting flesh browning over the 90 minutes at room temperature.

A typical example of the progression of flesh browning at 0, 10 and 90 minutes after cutting is shown in Plate 8.2 for scab-resistant selection 'SP7-226'.



Fig 8.2. The rate of flesh browning (△E) at room temperature (20°C) of eight apple varieties 0- 90 minutes after being cut in half (August 2010)



Plate 8.2. Photographic record of the flesh browning of 'SP7-226' at room temperature (20°C) 0, 10 and 90 minutes after being cut in half

#### (d) August 2011: Shelf life of 'SP7-226', FB7-159', 'RS102-121', 'SP15-207', 'SP1-175', 'FB6-94', 'RS102-50'

Apples of the seven scab-resistant selections tested for flesh browning in August 2011 were stored in a cold room (2°C-5°C) at Applethorpe Research Station for the three to five months following their respective harvests between March and May 2011. The 'Red Delicious', 'Gala' and 'Sundowner'<sup>TM</sup> commercial comparator apples were held in commercial cold storage for a similar period prior to the flesh browning experiment.

With the exception of 'SP15-207', the other six scab-resistant selections all performed well, and experienced less flesh colour change ( $\Delta E$ ) after cutting than the three commercial apple varieties (Fig 8.3). 'Red Delicious' was significantly faster (within 10 minutes) than the other apples to reach a high degree of brown colouration. At 20 minutes, the apple flesh of 'Red Delicious', 'Sundowner'<sup>TM</sup> and 'SP15-207' was significantly browner (higher  $\Delta E$ ) than all the other varieties, and this remained the case for all subsequent measurements (30-90 minutes).



Fig 8.3. The rate of flesh browning (ΔE) at room temperature (20°C) of ten apple varieties 0- 90 minutes after being cut in half (August 2010)

The scab-resistant selections 'RS102-50', 'FB6-94', 'RS102-121', 'SP15-175' and 'SP7-226' all experienced significantly less flesh browning at room temperature (20°C) than 'Gala', 'Red Delicious' and 'Sundowner'<sup>TM</sup> (Fig 8.3). A typical example of the progression of flesh browning in these scab-resistant selections is shown in Plate 8.3 for 'RS102-50'.



Plate 8.3. Photographic record of the flesh browning of 'RS102-50' at room temperature (20°C) 0, 10 and 90 minutes after being cut in half

'FB6-94' consistently exhibited the lowest rate ( $\Delta E$ ) and least amount of flesh browning, as did 'RS102-50' at 30, 60 and 90 minutes after cutting. The relative lack of flesh browning over 90 minutes at room temperature in cut apples of these two scab-resistant selections is a particularly desirable trait.

## **8.4** Conclusions

The postharvest sensory evaluations conducted between 2009 and 2013 demonstrated that for shelf life and flesh browning, most of the fourteen scab-resistant selections included in these experiments performed on a par with, or better than, the current apple varieties commercially grown in Australia. All of the scab-resistant apples were also in the size range of the commercial apple varieties, with the exception being the excessively large 'RS103-56' selection.

'RS103-130' ('Kalei') and 'RS103-110' apples typically had excellent texture and shelf life. The firmness of these two scab-resistant selections deteriorated relatively little when the apples were held at room temperature for three to four weeks. They were consistently of superior texture to 'Gala', 'Red Delicious' and 'Fuji', and equivalent to or better than 'Pink Lady'<sup>TM</sup> and 'Sundowner'<sup>TM</sup> to a more variable extent. The flesh browning of 'Kalei' and 'RS103-110' at room temperature was typically much less than that of current commercial apple varieties.

The most robust apple over the storage experiments was 'RS102-50'. This scab-resistant selection is an early season red apple that retained very firm texture over 28 days at room temperature, and had far superior texture to the commercial comparator varieties it was tested against ('Gala', 'Red Delicious' and 'Sundowner'<sup>TM</sup>). Such excellent postharvest firmness in an early season apple is rare. 'RS102-50' also showed very little flesh browning over 90 minutes; and much less than 'Gala', 'Red Delicious' and 'Sundowner'<sup>TM</sup>. Coupled with strong consumer feedback, serious consideration of 'RS102-50' for potential future commercialisation is warranted.

'RS109-15' is another scab-resistant selection that performed very well in postharvest sensory evaluations. Apples of 'RS109-15' consistently retained excellent texture and shelf life when held for three to four weeks at room temperature, and showed minimal flesh browning over 90 minutes.

Most of the remaining scab-resistant selections evaluated, were, to varying degrees, equivalent or superior to the commercial apple varieties in terms of initial flesh firmness and rate of softening. 'RS108-96', 'FB6-94', 'SP7-226', 'SP13-169' and 'SP15-207' all fall into this category, with 'RS108-96' and 'FB6-94' also particularly noteworthy for their low tendency to flesh browning. 'FB7-159' and 'FB22-47' were mid range in terms of texture.

Of all the scab-resistant selections, 'RS103-56' had particularly poor texture and shelf life. 'RS103-56' apples also exhibited moderate to high flesh browning when held at room temperature for 90 minutes, although no worse than 'Gala', 'Fuji' and 'Pink Lady'<sup>TM</sup>. The excessively large fruit size of 'RS103-56' is also a factor in now discounting this apple as a commercial possibility for Australian apple producers.

The postharvest quality of 'Gala', 'Red Delicious', 'Fuji' and 'Sundowner'<sup>TM</sup> apples was generally poor, and at best variable, across the 2009-2013 experiments. 'Gala' and 'Red Delicious' in particular had poor shelf life and significantly reduced fruit firmness over several weeks at room temperature. All four varieties showed high levels of flesh browning. 'Pink Lady'<sup>TM</sup> tended to have good to excellent firmness and shelf life, but was prone to high levels of flesh browning.

# 9. Molecular marker screening for apple scab resistance

## 9.1 Introduction

The work reported in this chapter was undertaken and largely written by Dr Natalie Dillon, Senior Biotechnologist, DAFF Qld.

Resistance due to major apple scab resistance genes was first found in the small fruited Asian *Malus* species *M. floribunda* 821 (*Vf*), *M. pumila* R12740-7A (*Vh2 / Vr*), *M. baccata jackii* (*Vbj*), 'Hansen's baccata #2' (*Vb*), 'PI172623' (*Va*), *M. micromalus* 245-38 (*Vm*), and *M. atrosanguinea* 804 (*Vm*) (Williams and Kuc, 1969; Lespinasse, 1989). Also identified are the scab resistance genes of 'Golden Delicious' (*Vg*), 'GMAL 2473' (*Vr2*), 'Durello di Forli' (*Vd*), differential host 4 (*Vh4 / Vx / Vr1*) (derived from *M. pumila* 'R12470-7A') and *M. sylvestris* 'W193B' (*Vh8*).

This chapter presents the results of screening a range of 18 apple accessions (selections) from the DAFF Qld apple breeding program, for the apple scab resistance markers Vh2 (Vr), Vr1 (Vh4 / Vx), Vf, Vm and Vbj. The background to the identification of these five scab resistance genes is outlined below.

Assessment still needs to be undertaken for the apple scab resistance markers *Va*, *Vb*, *Vd*, *Vg*, and *Vh8* in the DAFF Qld scab-resistant apple selections.

#### *Vh2 (Vr) resistance*

The *Vh2* gene was identified by Dayton and Williams (1968) from *Malus pumila*, accession R12740-7A. The Russian apple R12740-7A is the designation for an accession grown from seed collected in Russia found to be highly resistant to apple scab. This non-specific race gene (initially designated Vr) conditions resistance to all known apple scab resistance races. Aldwinckle *et al.* (1976) associated the name Vr with a scab resistance gene conditioning distinctive stellate necrotic reactions. The term stellate necrosis (SN) was coined by Shay and Hough (1952) to describe the distinctive star-shaped reactions to distinguish it from other Class 2 resistance reactions. The gene has since been named Vh2 and maps to the distal end of LG2 of the apple genetic map (Liebhard *et al.*, 2002).

#### Vr1 (Vh4 / Vx) resistance

The Vr1 gene was initially identified in the apple cultivar 'Regia' derived from the *Malus pumila* scab resistance source R12740-7A. The Vr1 locus is closely linked to Vx (Hemmat *et al.*, 2002), Vr2 (Patocchi *et al.*, 2004) and the Vh4 (Bus *et al.*, 2005a) genes. A co-dominant, multi-allelic sequence characterised amplified region (SCAR) marker (AD13-SCAR) was developed from a random amplified polymorphic DNA (RAPD) marker identified by bulk-segregant analysis (Boudichevskaia *et al.*, 2006). Gene Vr1 is now confirmed to be identical to Vx and Vh4 genes, and maps to the opposite side of LG2 from the Vh2 gene.

#### Vf resistance

The Vf gene is derived from the small-fruited species Malus floribunda Sieb. clone 821 (Hough et al., 1953). Almost all scab-resistant apple cultivars released from different apple breeding programs in the world carry the Vf scab resistance gene. Until recently, Vf had not been overcome by the pathogen, and therefore, for about 50 years this type of scab resistance was thought to be durable. SCAR primers (AL07-SCAR and AM19-SCAR) were developed from RAPD markers (Tartarini et al., 1999).

#### Vm resistance

The *Vm* gene is derived from *Malus* x atrosanguinea 804 (Dayton and Williams, 1970). The *Vm* gene produces a pit-type (type 1) resistance reaction. A second source of *Vm* is *Malus micromalus* 245-38. *Vm* confers resistance to races 1 through 4 of *V. inaequalis* and is vulnerable to race 5 (Williams and Brown, 1968). A 687 bp sequence tagged site (STS) marker was developed from a RAPD marker identified by bulk-segregant analysis (Cheng *et al.*, 1998).

#### Vbj resistance

The *Vbj* apple scab resistance gene is derived from the crab apple *Malus baccata jackii*. A 410 bp SCAR marker (T06-SCAR) was developed from a RAPD marker using BSA (Gygax *et al.*, 2004).

## 9.2 Materials and Methods

Eighteen scab-resistant selections from the DAFF Qld apple breeding program were screened for the five apple scab resistance markers Vh2 (Vr), Vr1 (Vh4 / Vx), Vf, Vm and Vbj. The eighteen selections are listed in Table 9.1, with the corresponding accession numbers (1-18) used to identify each of them in the screening work.

Accession No	Selection	Selection Accession No	
1	FB6-94	10	RS102-121
2	FB7-119	11	RS103-110
3	FB7-159	12	RS103-130 (Kalei)
4	FB12-23	13	RS104-1
5	FB12-49	14	RS108-96
6	FB13-36	15	RS108-103
7	FB26-1	16	RS109-15
8	RS102-38	17	SP1-175
9	RS102-50	18	SP17-270

# Table 9.1. The eighteen DAFF Qld scab-resistant selections screened for Vh2 (Vr), Vr1 (Vh4 / Vx), Vf, Vm and Vbj scab resistance markers

#### **DNA** Isolation

DNA was isolated from young leaves of the 18 evaluated genotypes. DNA extractions were performed using DNeasy<sup>®</sup> Plant extraction kits (Qiagen, Germany) according to the manufacturer's instructions. The DNA concentration and integrity was assessed by 1% (w/v) agarose/TBE gel electrophoresis (Fig 9.1). Extracted DNA was stored at 4°C and diluted to a final concentration of 20 ng/µl prior to PCR amplification.

#### PCR Marker Analysis

PCR amplifications were carried out in a PTC-100<sup>™</sup> Programmable Thermal Controller (MJ Research Inc., Waltham, MA, USA). Amplified DNA fragments were visualised under U.V. light following separation in 2.5% agarose horizontal gel electrophoresis. *Taq* DNA polymerase and PCR buffers used in all PCR amplifications were from MBI Fermentas The 10 x *Taq* buffer with KCl consisted of 100

mM Tris-HCl (pH 8.8 at 25°C), 500 mM KCl, 0.8% Nonident P40. The 10 x *Taq* buffer with  $(NH_4)_2SO_4$  consisted of 750 mM Tris-HCl (pH 8.8 at 25°C), 200 mM  $(NH_4)_2SO_4$ , 0.1% Tween 20.



Fig 9.1. The total genomic DNA concentration of the 18 scab-resistant selections

#### *Vh2 (Vr)*

Primers (OPL19-SCAR) were according to Bus *et al.* (2005a; 2005b) and amplify a co-dominant marker for *Vh2*. The 433 bp SCAR fragment characterises the dominant allele *Vh2* and the 1200 bp SCAR fragment characterises the recessive allele *vh2*. Amplification reactions contained 20 ng genomic DNA in a 20 µl volume containing 1x PCR Buffer (+KCl), 1.76 mM MgCl<sub>2</sub>, 0.52 mM dNTPs, 1% formamide, 0.14 µM forward primer, 0.14 µM reverse primer, 0.6 U *Taq* DNA polymerase. Amplification conditions were: 1 x (94 °C – 2 min 45 s); 40 x (94 °C – 55 s; 55 °C – 55 s; 72 °C – 1 min 39 s) followed by a final extension at 72 °C for 10 min.

#### Vr1 (Vh4 / Vx)

Primers (AD13-SCAR) for the detection of the 950 bp SCAR fragment for *Vr1* were according to Boudichevskaia et *al.* (2006). The AD13-SCAR marker can be used as a co-dominant marker to differentiate between heterozygous and homozygous resistant plants. A total of at least four different alleles have been identified in *Malus* genotypes tested for this marker (Boudichevskaia *et al.*, 2006). In apple cultivars the most common alleles are 1300 bp and 1100 bp, whereas the "resistance allele" of 950 bp is present in resistant accessions such as R12740-7A. The fourth allele of 750 bp has been found in one accession of *M. baccata*. PCR amplification of the specific SCAR fragment was performed using 20 ng genomic DNA in a 20 µl volume containing 1x PCR Buffer (+(NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>), 1.5 mM MgCl<sub>2</sub>, 0.4 mM dNTPs, 0.2 µM primer AD13-SCAR-for, 0.2 µM primer AD13-SCAR-rev, 1.2 U *Taq* DNA polymerase. Amplification conditions were: 1 x (94 °C – 2 min), 30 x (94 °C – 1 min; 58 °C – 3 min; 72 °C – 2 min) followed by a final containing elongation step of 1 x (94 °C – 1 min; 58 °C – 3 min; 72 °C – 10 min).

A second marker for *Vr1* was trialled. The S22-SCAR primers were according to Hemmat *et al.*, (2002). The *Vr1* gene associates with pinpoint pit (P) resistance. An allele of 1300 bp associates with the resistant genotypes (*Vr1*) and is absent in susceptible genotypes (*vr1*). PCR amplification of the specific SCAR fragment was performed using 20 ng genomic DNA in a 20 µl volume containing 1x PCR Buffer (+KCl), 1.76 mM MgCl<sub>2</sub>, 0.52 mM dNTPs, 1% formamide, 0.14 µM primer S22-SCAR-for, 0.14 µM primer S22-SCAR-rev, 0.6 U *Taq* DNA polymerase. Amplification conditions were: 1 x (94 °C – 2 min 45 s), 20 x (94 °C – 55 s; 65 °C to 55 °C – 55 s; 72 °C – 1 min 39 s) -0.5 °C per cycle, 20 x (94 °C – 55 s; 55 °C – 55 s; 72 °C – 1 min 39 s) followed by a final containing elongation step of 1 x (72 °C – 10 min).

Vf

Primers for the detection of the dominant allele Vf and the recessive allele vf were according to Vejl *et al.*, (2003). Primers A and B (AL07-SCAR) amplify a co-dominant marker, 466 bp fragment characterises the dominant allele Vf and 724 bp fragment characterises the recessive allele vf. The

primer pair C and D (AM19-SCAR) amplifies a 526 bp fragment marker of dominant allele *Vf*. The composition of 20 µl multi-PCR was: 1x PCR Buffer ( $+(NH_4)_2SO_4$ ; MBI Fermentas, Ontario, Canada), 1.5 mM MgCl<sub>2</sub>, 0.2 mM dNTPs, 0.2 µM primer A, 0.2 µM primer B, 0.1 µM primer C, 0.1 µM primer D, 0.8 U *Taq* DNA polymerase and 20 ng genomic DNA. Amplification conditions were: 1 x (94 °C – 2 min 30 s; 60 °C – 60 s; 72 °C – 2 min), 35 x (94 °C – 30 s; 60 °C – 60 s; 72 °C – 2 min) followed by a final extension at 72 °C for 10 min.

The primer pairs A/B and C/D were also run in separate PCR amplifications to ensure clear identity of bands in the agarose gel.

#### Vm

Primers for the detection of *Vm* were according to Cheng *et al.*, (1998). Amplification reactions contained 20 ng genomic DNA in a 20  $\mu$ l volume containing 1x PCR Buffer (+(NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>), 1.5 mM MgCl<sub>2</sub>, 1.2 mM dNTPs, 0.13  $\mu$ M forward primer, 0.13  $\mu$ M reverse primer, 0.75 U *Taq* DNA polymerase. Amplification conditions were: 1 x (94 °C – 5 min); 35 x (94 °C – 30 s; 55 °C – 1 min; 72 °C – 1 min) followed by a final extension at 72 °C for 10 min.

#### Vbj

Primers (T06-SCAR) were according to Gygax *et al.*, (2004). The 410 bp SCAR fragment characterises the dominant allele *Vbj* and the 790 bp SCAR fragment characterises the recessive allele *vbj*. Amplification reactions contained 20 ng genomic DNA in a 20  $\mu$ l volume containing 1x PCR Buffer (+KCl), 1.5 mM MgCl<sub>2</sub>, 0.4 mM dNTPs, 0.2  $\mu$ M forward primer, 0.2  $\mu$ M reverse primer, 1.4 U *Taq* DNA polymerase. Amplification conditions were: 1 x (94 °C – 2 min 30 s); 35 x (94 °C – 30 s; 60 °C – 30 s; 72 °C – 1 min) followed by a final extension at 72 °C for 10 min.

## 9.3 Results and Discussion

#### Vh2 (Vr) Apple Scab Marker

The 1200 bp band indicates the recessive allele vh2. The 433 bp band indicates the dominant allele Vh2.

Accessions 2 ('FB7-119'), 6 ('FB13-36'), 7 ('FB26-1'), 9 ('RS102-50'), 13 ('RS104-1'), 17 ('SP1-175') and 18 ('SP17-270') contain the *Vh2* gene. The remaining samples only show the 1200 bp band and are therefore recessive for the *vh2* gene (Fig 9.2).





#### Vr1 (Vh4 / Vx) Apple Scab Marker

The most common alleles are 1300 bp and 1100 bp, both being recessive for *vr1*. The dominant *Vr1* allele is 950 bp. A fourth allele of 750 bp has only been identified in one accession of *M. baccata*.

Accessions 1 ('FB6-94'), 2 ('FB7-119'), 3 ('FB7-159'), 4 ('FB12-23'), 8 ('RS102-38'), 9 ('RS102-50'), 13 ('RS104-1'), 15 ('RS108-103'), 16 ('RS109-15'), 17 ('SP1-175') and 18 ('SP17-270') contain the dominant *Vr1* gene of 950 bp (Fig 9.3). Accessions 3 ('FB7-159') and 13 ('RS104-1') only show the dominant *Vr1* allele size of 950 bp, while accessions 1 ('FB6-94'), 2 ('FB7-119'), 4 ('FB12-23'), 8 ('RS102-38'), 9 ('RS102-50'), 15 ('RS108-103'), 16 ('RS109-15'), 17 ('SP1-175') and 18 ('SP17-270') show the common allele sizes of 1300 bp and 1100 bp in addition to the dominant *Vr1* 950 bp allele size (Fig 9.3). The remaining accessions only show the common allele size of 1100 bp, and are therefore recessive for the *vr1* gene. No accessions showed the allele size of 750 bp.



Fig 9.3. PCR amplifications for the Vr1 (Vh4 / Vx) marker in 18 scab-resistant apple selections

The second Vrl apple scab marker SCAR22 was not successful (Fig 9.4). The dominant Vrl allele is 1300 bp in size, while the absence of a PCR product at this size indicates a recessive allele (vrl). With the SCAR22 marker, only accession 18 ('SP17-270') showed a band at 1300 bp. The previous Vrl marker indicated that accession 18 ('SP17-270') carried both the dominant (Vrl) and the recessive (vrl) alleles (Fig 9.3). The remaining accessions did not show a band at 1300 bp (Fig 9.4), indicating they do not carry the Vrl allele. These results need to be investigated further.



Fig 9.4. PCR amplifications for Vr1 (Vh4 / Vx) SCARR22 marker in 18 scab-resistant apples

#### Vf Apple Scab Marker

The primer pairs for apple scab marker *Vf* were run independently rather than as a multiplex. The results for primer pair A and B are as follows:

The 724 bp band indicates the recessive allele *vf*. The 466 bp band indicates the dominant allele *Vf*.

Accessions 1 ('FB6-94'), 4 ('FB12-23'), and 16 ('RS109-15') are homozygous for the dominant Vf gene, with only the 466 bp present and no band at 724 bp (Fig 9.5). Accessions 10 ('RS102-121'), 11 ('RS103-110'), 12 ('RS103-130' synonym 'Kalei') and 13 ('RS104-1') are homozygous for the recessive vf gene, with only the 724 bp band present and no band at 466 bp (Fig 9.5). The remaining accessions show the dominant Vf gene at 466 bp and the recessive vf gene at 724 bp. These accessions also show a third PCR product slightly larger than the 724 bp band, which is of unknown origin.



Fig 9.5. PCR amplifications for the Vf marker (primer pairs A and B) in 18 scab-resistant apples

The results for primer pair C and D are as follows:

The 526 bp band indicates the dominant allele Vf.

The results from the second set of primers for Vf determination correlate with the results for primer pair A and B. Accessions 1-9 and 15-18 all contain the 526 bp band for the dominant Vf allele (Fig 9.6). Accessions 10-14 do not show any band at 526 bp (Fig 9.6), and are therefore recessive for vf.





#### Vm Apple Scab Marker

The dominant allele (Vm) is 687 bp while the recessive allele (vm) has no amplification product at this size.

The PCR failed to amplify any product at the indicated annealing temperature of 58°C. Reducing the annealing temperature to 55°C allowed amplification of products, but these need further investigation into whether they are valid or not. Accessions 1 ('FB6-94'), 5 ('FB12-49'), 6 ('FB13-36'), 8 ('RS102-38'), 9 ('RS102-50'), 10 ('RS102-121'), 11 ('RS103-110'), 13 ('RS104-1'), 15 ('RS108-103'), 16 ('RS109-15'), and 18 ('SP17-270') all show amplification products at 687 bp (Fig 9.7), and therefore the dominant Vm allele. The remaining accessions do not show the 687 bp amplification product and therefore have the recessive vm allele.



Fig 9.7. PCR amplifications for the Vm apple scab marker in 18 scab-resistant apple selections

#### Vbj Apple Scab Marker

The dominant allele (Vbj) is 410 bp while the recessive allele (vbj) is 790 bp. None of the screened 18 DAFF Qld scab-resistant apple selections contain the Vbj gene for apple scab resistance.



Fig 9.8. PCR amplifications for the Vbj apple scab marker in 18 scab-resistant apple selections

## **9.4 Conclusions**

The screening results for the presence of *Vh2* (*Vr*), *Vr1* (*Vh4/Vx*), *Vf*, *Vm* and *Vbj* scab resistance genes in the 18 selections from the DAFF Qld apple breeding program are summarised in Tables 9.2 and 9.3.

The genotyping has identified Vf, Vh2, Vr1 and Vm scab resistance genes across the 18 selections tested. The presence of these genes in a cross-section of the scab-resistant selections at ARS warrants the genotypic screening of other advanced scab-resistant selections as described in Chapters 3 and 6. Based on the results presented here, it is likely that some of this material will have polygenic resistance to apple scab; a very desirable trait for a new variety.

Apple	Vh2	Alleles	ize (bp)	Vr1	Allele size (bp)			Vr1 SCAR22	Allele size (bp)
FB6-94	S		1200	R	950	1100	1300	S	
FB7-119	R	433	1200	R	950	1100	1300	S	
FB7-159	S		1200	R	950			S	
FB12-23	S		1200	R	950	1100	1300	S	
FB12-49	S		1200	S		1100		S	
FB13-36	R	433	1200	S		1100		S	
FB26-1	R	433	1200	S		1100		S	
RS102-38	S		1200	R	950	1100	1300	S	
RS102-50	R	433	1200	R	950	1100	1300	S	
RS102-121	S		1200	S		1100		S	
RS103-110	S		1200	S		1100		S	
Kalei	S		1200	S		1100		S	
RS104-1	R	433	1200	R	950			S	
RS108-96	S		1200	S		1100		S	
RS108-103	S		1200	R	950	1100	1300	S	
RS109-15	S		1200	R	950	1100	1300	S	
SP1-175	R	433	1200	R	950	1100	1300	S	
SP17-270	R	433	1200	R	950	1100	1300	R	1300

 Table 9.2. The status of scab resistance of 18 DAFF Qld scab-resistant selections screened for

 Vh2 (Vr) and Vr1 (Vh4/Vx) scab resistance genes (R-resistant; S-susceptible)

Apple	Vf (A/B)	Allel (t	e size op)	Vf (C/D)	Allele size (bp)	Vm	Allele size (bp)	Vbj	Allele size (bp)
FB6-94	R	466		R	526	R	687	S	790
FB7-119	R	466	724	R	526	S		S	790
FB7-159	R	466	724	R	526	S		S	790
FB12-23	R	466		R	526	S		S	790
FB12-49	R	466	724	R	526	R	687	S	790
FB13-36	R	466	724	R	526	R	687	S	790
FB26-1	R	466	724	R	526	S		S	790
RS102-38	R	466	724	R	526	R	687	S	790
RS102-50	R	466	724	R	526	R	687	S	790
RS102-121	S		724	S		R	687	S	790
RS103-110	S		724	S		R	687	S	790
Kalei	S		724	S		S		S	790
RS104-1	S		724	S		R	687	S	790
RS108-96	R	466	724	S		S		S	790
RS108-103	R	466	724	R	526	R	687	S	790
RS109-15	R	466		R	526	R	687	S	790
SP1-175	R	466	724	R	526	S		S	790
SP17-270	R	466	724	R	526	R	687	S	790

Table 9.3. The status of scab resistance of 18 DAFF Qld scab-resistant selections screened forVf, Vm and Vbj scab resistance genes (R-resistant; S-susceptible)

None of the 18 screened scab-resistant apple selections contain the *Vbj* gene for apple scab resistance (Table 9.3).

The five markers run to date are all SCAR markers that can be assayed in agarose gels. The two SCAR markers used to identify the presence of Vr1 scab resistance gave conflicting results (Table 9.2), except for 'SP17-270'. This needs to be investigated further. The Vm scab resistance screening should be repeated to confirm the validity of the results obtained at the lower annealing temperature.

Genotyping still needs to be undertaken for the apple scab resistance markers *Va*, *Vb*, *Vd*, *Vg* and *Vh8*, which are mostly SSR (simple sequence repeat) markers.

It must be noted that in the scab resistance screening to date, the genetic source(s) of resistance for 'Kalei' have yet to be identified.

# **10.** Commercialisation Plan

'Kalei' (tested as 'RS103-130') is the first scab-resistant apple to be commercialised from the DAFF Qld apple breeding program. The commercialisation pathway presented in this chapter is a synopsis of the steps taken that culminated in the public release of 'Kalei' on 3 May 2012, by the Minister for Agriculture, Fisheries and Forestry, Queensland, the Hon. John McVeigh.

# 10.1 'Kalei' commercialisation

#### (a) PBR protection

'RS103-130' was granted provisional (Part 1) Australian Plant Breeder's Rights (PBR) protection under the Plant Breeder's Rights Act 1994 (application number 2005/278) in December 2005.

A United States Plant Patent for further IP protection of 'RS103-130' was issued on 26 May 2009 (PP 20,028).

'RS103-130' trees in the Plant Breeder's Rights (PBR) apple planting at ARS (described in Section 2.1) were used to provide the information required in the preparation and submission of these applications for IP protection of 'RS103-130'.

As a component of the Part 2 Australian PBR application for 'RS103-130', the PBR planting at ARS was examined by Nik Holtz, Senior Examiner, Plant Breeder's Rights Office, in March 2011. 'Braeburn' was used as "the most similar variety of common knowledge" to 'RS103-130' in the Australian PBR application. The visit by Nik Holtz was to visually confirm the integrity of the design of the ARS tree planting for PBR purposes, and that 'Braeburn', not any other apple variety, was indeed "the most similar variety of common knowledge".

The detailed description of 'RS103-130' as required for the Part 2 Australian PBR application was subsequently accepted, and published in the Plant Varieties Journal, Volume 24 Issue 2. The six month "public notice period" required prior to the granting of full PBR protection for 'RS103-130' expired in October 2011. With the naming of 'RS103-130' as 'Kalei' in May 2012, it was necessary to add the synonym 'Kalei' to the original PBR application. This required an additional six month "public notice period", but was deemed necessary to protect the 'Kalei' name.

#### (b) Selection of a commercial partner

A stakeholder committee to guide the commercialisation of 'RS103-130' was formed in June 2008. The members of the committee were Garry Fullelove (DAFF Qld), Philip Roeth (HAL), Tony Russell (APAL) and Garry Langford (APFIP). Seven apple industry representative names were also tabled for consideration in expanding the committee.

The stakeholder committee agreed to the development of a draft Expression of Interest (EOI) document seeking a licensee to commercialise 'RS103-130' for Australia, with an option for international development. The EOI was fully developed over the following ten months, and publically released in April 2009. Applications were sought from potential partners for the commercialisation of 'Kalei', and closed on 1 May 2009.

Terms of reference in lodging an EOI included propagation of 'RS103-130'; implementing a successful marketing plan to advertise, promote and sell 'RS103-130'; sub-license agreements through the supply chain to securely manage the IP in 'RS103-130'; and reporting on progress and sales volumes to DAFF Qld for compliance and royalty purposes.

A detailed commercialisation plan, including a copy of the publically available EOI document, was forwarded to HAL in May 2009.

EOI applications were assessed by a committee comprising representatives of DAFF Qld and HAL, in addition to an independent industry representative.

Coregeo® Australia, a division of APAL, was accepted as the successful applicant, and was licensed the right to commercialise 'RS103-130'. Coregeo® was instrumental in developing the 'Kalei' name for the scab-resistant apple selection previously known and tested as 'RS103-130'.

#### (c) The Coregeo® commercialisation plan

The following information is provided with the permission of Garry Langford, Manager, Coregeo® Australia.

The 'Kalei' variety will be produced in two streams (Fig 10.1):

- (a) A conventional stream where apples are sold as 'Kalei'
- (b) A commercial organic stream, where premium fruit may be sold under licensing arrangements using the AZANA® brand name. AZANA® is a trade mark of APAL



Fig 10.1. The two streams for commercial production of 'Kalei' in Australia. (Image provided by Garry Langford, Coregeo®)

The strategy is to create a new "evo" (environmental) category in the apple market for the AZANA® brand and other commercially produced organic apples. Commercial organic apples will have the

attributes of existing apples (high quality, long seasons of availability due to appropriate use of modern postharvest practices), but will comply with one of the certified organic codes.

At the same time, for those producers not interested in organic production, 'Kalei' apples will provide excellent appearance and eating quality, produced with reduced input costs due to scab-resistance.

Further details of the two production streams are listed below.

#### **Conventional stream**:

- No requirement for certified organic production.
- No controls on marketing.
- Apples from 'Kalei' variety trees sold as 'Kalei' apples. No trade marks or associated licence requirements.
- Some promotion paid for with royalties.
- Tree royalty. Annual "per hectare" royalties to apply from year four after planting.
- No export marketing controls.
- Grafting existing trees is permitted, but grafting wood must be purchased from licensed suppliers.

#### **Commercial organic stream:**

- Produced under a certified organic production system.
- Supply chains licensed the right to use the AZANA® brand for apples from 'Kalei' trees that meet the AZANA® licensing arrangements, including quality specifications.
- Tree royalty and production royalty.
- Strong promotion program to create a point of difference in consumer's minds. Tightly controlled and disciplined marketing arrangements.
- Controlled export program.
- Grafting existing trees is permitted, but grafting wood must be purchased from licensed suppliers.

'Kalei' trees will be available through licensed nurseries that comply with the APFIP Tree Certification standards, or similar schemes. The right to produce AZANA® brand apples will be licensed to Australian supply chains/marketers.

'Kalei' trees will be available for planting in winter 2013.

For further details contact Garry Langford, Manager, Coregeo® Australia (glangford@apal.org.au).

#### (d) Provision of 'Kalei' budwood

Virus-indexed budwood of 'Kalei' has been provided annually to Coregeo®, and is sourced from the budwood multiplication block at ARS (Section 2.1). 'Kalei' budwood from other trees has also been provided, for despatch to growers who are top-working existing trees to 'Kalei' and therefore do not require virus-indexed material.

Coregeo® has forwarded budwood of 'Kalei' to the Netherlands, for virus indexing in quarantine prior to testing 'Kalei' at sites in Europe.

# 10.2 'RS103-110' commercialisation

'RS103-110' will likely be the second scab-resistant apple to be released from the DAFF Qld apple breeding program. An Australian Plant Breeder's Rights Part 1 application has been prepared and submitted to secure provisional Australian PBR protection for this selection.

'RS103-110' trees in the Plant Breeder's Rights (PBR) apple planting at ARS (described in Section 2.1) were used to provide the information required in the Part 1 Australian PBR application. 'Royal Gala' was identified as "the most similar variety of common knowledge" to 'RS103-110'. Trees in this planting will be used to provide the necessary data for future submission of the Part 2 Australian PBR application, and for a United States Plant Patent for IP protection of 'RS103-110'.

The process to identify and license a commercial partner to commercialise 'RS103-110' in the future will be similar to that described for 'Kalei'.

# **11. Technology Transfer**

#### (a) Grower farm walks, seminars, tastings

A strong focus of the project was the dissemination of information to growers through regular farm walks at ARS, particularly during the harvest period. On each occasion, growers were able to view trees of 'Kalei', 'RS103-110' and other scab-resistant selections, as well as taste the apples.

For growers to see heavily cropped trees of 'Kalei' producing consistently high quality apples in intensive planting systems has been a very effective means of promoting this new scab-resistant apple variety. This has helped generate a high industry demand for 'Kalei' trees to plant as soon as possible.

The semi-commercial high density plantings of 'Kalei' and 'RS103-110' at ARS were also used as a grower resource and link to 'Future Orchards 2012', and have been made continuously available for ad hoc visits by Australian growers considering future planting of these two scab-resistant apples.

International growers, researchers and nurserymen from France, Germany, the Netherlands, New Zealand, USA and Italy have visited ARS, to observe 'Kalei' trees in the orchard and taste the apples. This is with a view to introduce and test 'Kalei' in their own countries.

Farm walks and/or apple tastings were held at ARS on:

- 18 February 2009
- 6 April 2009
- 14 April 2009
- 15 June 2009 (linked with 'Future Orchards 2012')
- 9 November 2009
- 12 November 2009 (linked with 'Future Orchards 2012')
- 11-19 February 2010 \*
- 25 March 2010
- 25 June 2010 (linked with 'Future Orchards 2012')
- 11-29 April 2011 \*
- 29 March 20 April 2012 \*

\* These farm walks were conducted as open ended events, where growers could visit ARS at any time between these dates. This strategy worked very well, as growers could see the cropping trees when it best suited them during this busy period of the harvest season. This helped maximise the number of growers able to observe heavily cropping 'Kalei' trees. Dr Middleton was available at all times during these periods to discuss project results and provide apples for tasting.

As 'Future Orchards 2012' guest speaker, Dr Middleton presented project results to growers in seminars and farm walks at Orange, NSW (29 March 2010), Batlow, NSW (30 March 2010) and Shepparton, Vic (1 April 2010). Samples of 'Kalei' and 'RS103-110' apples were provided at each location so that interstate growers could see and taste these scab-resistant selections.

'Kalei' apples were taken to the national Apple and Pear Conference in Adelaide in August 2011, for growers and industry representatives from all states of Australia to view and sample. 'Kalei' apples will also be available for growers to see and taste at the Combined Fruit Industry Conference on the Gold Coast in July 2013, in collaboration with a promotion of 'Kalei' by Coregeo® Australia.

Apples of 'Kalei' were provided to Coregeo® Australia for international promotion of this new variety in September 2012 at Asia Fruit Logistica, Hong Kong. 'Kalei' apples were also taken to the HAL Board meeting in Brisbane in March 2013 for board members to view and taste. Fresh, as well as 'Kalei' apples one year old, were provided to demonstrate the extended keeping qualities of this apple.

#### (b) Industry articles

Middleton, S. and Smyth, H. (2010). Consumer evaluations and postharvest quality of 'RS103-130'. 'Future Orchards 2012' handout.

Middleton, S. (2010). Queensland high density planting system trials for new scab-resistant apples. APAL website. 9pp.

Reppel, B. journalist (2010). Is this the world's best apple? The Furrow. 3: 24-25.

#### (c) Conference presentations

Middleton, S., Smyth, H., McWaters, A., Wilkie, J. and Reid, C. (2010). 'RS103-130' scab-resistant apple – from orchard to consumer. International Horticulture Congress, Lisbon, Portugal. 22-27 August, 2010.

Middleton, S.G. and Wilkie, J.D. (2012). High density orchard productivity of the new 'Kalei' scabresistant apple. 10<sup>th</sup> International Orchard Systems Symposium. Stellenbosch, South Africa. December 2012.

#### (d) Media publicity

There has been widespread media coverage over the duration of this project, focused in particular on 'Kalei'. Two very intensive periods of mainstream media coverage coincided with consumer tastings of 'Kalei' in Brisbane in December 2009, and the release of 'Kalei' in May 2012.

#### December 2009

Widespread national and international media coverage of 'RS103-130' (synonym 'Kalei') at this time included television interviews by Dr Middleton with all four major Australian networks (7, 9, 10, ABC) and radio interviews with stations in Qld, NSW, ACT, Vic and ACRN (Australian Community Rural Network), which provided the recorded interview to 120 radio stations across Australia. Press coverage included the Brisbane Courier Mail, Sydney Morning Herald, Melbourne Age and regional newspapers. The editorial value of this was calculated at over \$600 000 (Media Monitors).

International television coverage included BBC London, CBS New York and CBC Moscow (100 million viewers). Articles about 'RS103-130' were published in newspapers including the UK Telegraph, London Independent, New York Daily News and Die Welt (Germany).

#### May 2012

Media publicity on this occasion centred on the public release of 'RS103-130'as the variety 'Kalei'. Again, all four major television networks (7, 9, 10, ABC) aired the story and interviews in their news bulletins, with additional coverage on Morning Sunrise (Ch 7). Radio interviews (ABC and many commercial stations) were also conducted by Dr Middleton and by the Minister for Agriculture, Fisheries and Forestry, Qld, Hon. John McVeigh. Published newspaper articles included the Sydney Morning Herald, The Australian, Herald Sun and Brisbane Courier Mail.

#### Other

DAFF Qld conducted a major promotion of 'Kalei' at the RNA Brisbane Show in August 2012. 'Kalei' apples were available for visitors to the show (attended by 400 000 people) to see and taste.

An article on 'Kalei', including interviews with Dr Middleton and growers, is scheduled to appear in the Weekend Australian on 22 June 2013.

# **12. Recommendations**

#### (a) 'Kalei'

Growers are strongly encouraged to plant the new scab-resistant apple variety 'Kalei' (synonym 'RS103-130'), which was released in May 2012. 'Kalei' is an attractive apple with a vibrant red colour and sweet flavour. It has consistently rated highly in consumer evaluations in Brisbane and has excellent eating quality, whether straight off the tree or out of storage. The crisp, firm texture of 'Kalei' is still retained after three weeks at room temperature. Unlike some other apple varieties, 'Kalei' has exceptional long-term storage potential, even when the fruit are harvested eating ripe.

'Kalei' is a very productive variety when grown in high density planting systems (HAL project AP08008), and is also well suited to organic production (HAL project AP01006). In addition to resistance to apple scab, 'Kalei' is tolerant to *Alternaria* and western flower thrip (*Frankliniella occidentalis*).

For conventional production of 'Kalei', a conservative management strategy for apple scab (apple black spot) control may consist of a single, green tip copper spray in early spring, when there is greatest disease pressure from the apple scab fungus. This could be followed by further application of one or two apple scab eradicant sprays at times of heavy infestation risk and significant scab ascospore maturity.

The scab resistance of 'Kalei' has proven robust in the field. No sprays for apple scab control (apart from an annual green tip copper spray) have been applied in eleven seasons of conventional production of 'Kalei' at ARS. No apple scab has been found on 'Kalei' leaves or fruit, despite some very wet, humid seasons. 'Granny Smith' and 'Pink Lady'<sup>TM</sup> planted as pollenisers beside 'Kalei' trees at ARS have shown moderate to severe symptoms of apple scab, with up to 75% crop losses to scab in some years.

As demonstrated in testing at sites in NSW, Vic, Tas and SA, 'Kalei' is also suited to conventional and organic production systems in other apple producing regions of Australia.

It is suggested that growers wishing to grow 'Kalei' as a conventional variety plant trees on semidwarfing or dwarfing rootstocks (M.26, M.9) at densities of 2500 trees per hectare or higher, with a view to annually produce 50-60 tonnes per hectare of apples by the fifth leaf. 'Kalei' trees have a semi-spur growth habit and respond well to limb tying, producing a lot of fruitful spurs and a good, easily-managed balance of fruiting wood and annual growth.

The first 'Kalei' trees for commercial planting will be available from Coregeo® Australia in winter 2013. There is currently a strong demand from Australian growers for trees of 'Kalei', and it will take many years to satisfy this. Provision of 'Kalei' budwood by DAFF Qld to Coregeo® will continue in the coming years to help meet this demand. The more 'Kalei' budwood provided to Coregeo® at this early stage, the sooner significant numbers of 'Kalei' trees can be propagated for uptake by industry.

With the public release of 'Kalei' in May 2012 and the first availability of 'Kalei' trees to industry for planting in winter 2013, it is appropriate for a future project to consider the development of harvest maturity standards for this new variety, ready for when the first significant quantities of commercially produced 'Kalei' apples are harvested and marketed from 2015 onwards.

#### (b) Other scab-resistant selections

'RS103-110' will likely be the second scab-resistant apple to be released from the DAFF Qld breeding program. This is based on positive feedback from consumers in Brisbane, and from growers and other

parties who have seen cropping trees of 'RS103-110' at ARS and/or tasted the fruit. In addition, trees of 'RS103-110' produce high packouts of well-coloured fruit, and the postharvest quality of 'RS103-110' apples is at least comparable to, or better than, most current commercial apple varieties.

'RS103-110' tends to be a small to medium sized apple. Future work with 'RS103-110' should consider the use of "Artificial Spur Extinction", as per the current PIPS Tree Structure project AP09031, as a management strategy to increase the fruit size, and hence orchard productivity, of this selection.

This project has identified a further 34 scab-resistant selections considered to have, to varying degrees, potential for commercialisation. In addition, there are eleven selections that require evaluation for one more season before a definitive decision can be made about their future commercial potential; three selections ('FB18-95', 'FB19-139', 'FB16-79') that are very large, juicy apples with potential as organic processing apples (but with no future as dessert apples); and ten selections that, whilst not suitable to be commercial varieties in their own right, have particular desirable characteristics that make them candidates as potential parents in any future breeding program.

Of the 34 scab-resistant selections considered to have future commercial potential, it is practical that only a few of these may make it through to be fully commercial varieties. With just a few exceptions, the commercial potential of these 34 has been determined from observations and measurements taken from just three or four trees of each selection at ARS. This is a very restrictive sample on which to base decisions of a selection's commercial potential.

The high susceptibility of 'FB22-47' to *Alternaria*, and the low productivity and biennial bearing of 'FB7-159', were both identified in plantings of larger numbers of trees at ARS (project AP08008). This has largely precluded their serious consideration for future commercialisation. It is critical that such issues are identified prior to going down the expensive commercialisation path.

More trees need to be propagated of a core group of the 34 advanced scab-resistant selections to allow more comprehensive evaluation in the field, and to produce sufficient apples for consumer acceptability studies and postharvest sensory evaluations. The evaluation of these selections cannot be confined to Qld, but must include interstate APFIP sites, as was done with 'Kalei' and 'RS103-110'. To commence this process, budwood of 'RS109-15', 'FB12-23', 'RS108-96' and 'SP7-226' has been provided to APFIP, with a view to test the performance of these scab-resistant selections in NSW, Vic, Tas and WA.

The 'RS109-15' selection presents something of a conundrum. It is very well-liked by consumers for its outstanding texture, and has excellent shelf life. However, with its high susceptibility to *Alternaria* in Qld, and consequent excessive leaf drop (> 50%) in midsummer, yields are reduced and many 'RS109-15' apples don't develop the beautiful pink blush characteristic of this selection. 'RS109-15' therefore needs to be tested in Australian locations where *Alternaria* is not a problem. Similarly, if suitable strategies for the control of *Alternaria* can be identified, the status of 'RS109-15' for commercialisation significantly improves.

The large, early season red apple 'RS102-50' is a very strong candidate for potential commercialisation, and rated highly in consumer and postharvest sensory evaluations. Trees of 'RS102-50' need to be propagated for inclusion at interstate APFIP sites.

Trees of several other very promising scab-resistant selections at ARS also need to be propagated as an urgent priority, in part so that sufficient apples can be produced for the consumer acceptability studies and postharvest evaluations required as precursors to their potential commercialisation. There are currently only three to four trees of each.

These selections include 'FB1-97', 'FB1-155', 'FB12-23', 'RS109-70', 'RS108-96', 'FB17-5', 'SP13-12', 'SP5-348', 'FB14-61', 'SP18-61', 'SP6-317' and 'FB24-108'.

The identification of *Vf*, *Vh2*, *Vr1 and Vm* scab-resistance genes in a cross-section of 18 of the scabresistant selections is an exciting development. This suggests it is possible that the resistance of other ARS scab-resistant selections is not confined to *Vf*, but may be polygenic. This adds significant value to the apple germplasm held at ARS.

### (c) Future project

It is important that members of the Apple and Pear Industry Advisory Committee read this report, in the context of considering a follow-on project to build on the outcomes of Project AP08041 presented here. It is proposed to submit a funding application for consideration of a new project commencing in 2014/2015. Future work in a new project proposal may include the following:

- PBR applications for 'RS103-110':
  - Part 2 Australian PBR application
  - United States Plant Patent application
- Scab-resistant apple genotyping:
  - Screening for Va, Vb, Vd, Vg and Vh8 genes in all advanced selections
  - Screening for Vf, Vh2, Vr1, Vm and Vbj in selections not yet tested for these genes
  - Identify the genetic source(s) of apple scab resistance in 'Kalei'
- Propagation and planting of trees of advanced scab-resistant apple selections as identified in the recommendations above, in particular those selections where there are currently only 3-4 trees. Fruit from these trees to be used for:
  - Evaluations at ARS
  - Consumer acceptability studies
  - Postharvest sensory evaluations
- Evaluation of advanced selections at APFIP sites around Australia.
- Virus indexing of wood to establish a repository of virus-indexed trees of advanced selections. This needs to be done as a priority for 'RS103-110'.
- Planting of a further PBR block of trees of advanced superior selections and appropriate comparator varieties, to a statistical design as required by the PBR Office for the collection of robust data for PBR applications. 'RS102-50' is an immediate candidate for such a planting.
- Development of harvest maturity standards for 'Kalei.'
- Planting of a semi-commercial block of trees (50-100 trees per selection) of up to six advanced scab-resistant selections, to provide agronomic information of tree productivity and performance, and a site for growers to visit to observe the potential of these selections for commercial production.
- Maintain the high density planting of 'Kalei' and 'RS103-110' trees at ARS. This block has an ongoing function to facilitate the industry adoption of these two selections, confirm the robustness of their scab-resistance, and provide a site for growers and other parties, both national and international, to observe the fruit and field productivity of these two selections. The site also has a function in the promotion of high density planting systems.

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# Appendix 1. Evaluation sheet used in laboratory assessment of DAFF Qld apples

Cross/Variety											Location
Season:			•••••			Ro	ow an	d Tre	e		
Harvest Dates:			•				•••••		• • • • • • • • • • • •	•••••	• • • •
Rate each criteria using 1-10. Consider a rating of 7 or greater as commercially acceptable											
		<u> </u>	1		I ERIA	A KA	TINC	ý I	1	<u> </u>	
<u>Fruit</u>											
<u>Appearance</u>	1	2	2	4	5	6	7	0	0	10	Commonto
<u>{Importance}</u>	1	2	3	4	5	0	/	0	9	10	Comments
- ground corour {4}	+										
- blush/over cor {5}	-										
SKIII SHIOOUIIICSS											
- shape $\{4\}$											
$- size \{4\}$											
- stalk length {2}											
- lenticels {2}											
$-\sin(2)$											
Overall	Po	or []	Satis	facto	rv[]	Good	[]E	xcelle	ent[]		
Attractiveness	1.0	L J	~~~~		-J L J	2000					
	<u> </u>	r			1	1	1	r	1	r	
Fruit Quality	1	~			~		~			10	
<u>{Importance}</u>	1	2	3	4	5	6	7	8	9	10	
- flesh firmness {5}											
- flesh texture {5}											
- juiciness {4}											
$-$ acidity $\{4\}$											
- acid/sugar bal {5}											
- flavour {5}	Des				. [] (	1 1 1		11	4 [ ]		
Overall eating	P00	r[]	Satist	actory		1000		celler			
Pressure( kg)											
Sun side											
Shade side											
Brix%											
Starch Pattern Index											
(SPI)	<u> </u>										
Flesh Browning											
10 min											
1 15 min											
Shelf Life											
Fruit Damage											List cause of damage below
- insect	Nil	[] S	light	[] N	Moder	ate []	Sev	vere [	]		
- diseases	Nil	[] S	light	[] N	Moder	ate [ ]	Sev	vere [	]		
- russet	Nil	[] S	light	[] N	Moderate [] Severe []						
- mouldy core	Nil	Nil [] Slight [] Moderate [] Severe []									
- bitter pit	Nil	[] S	light	[] N	Moder	ate [ ]	Sev	vere [	]		
- water core	Nil	[] S	light	[] N	Moder	ate []	Sev	vere [	]		
TOTAL SCORE (Importance x Criteria Rating):											
Critical Failure (CF): Assessment Decision:	Yes [ Disc	ard [	N0 [ ] Fi€	J A eld Te	ttribut st [ ]	e caus	sıng ( Paren	JF t[]	See	 again	[]

# Welcome to Consumer Taste Testing of Apples

For this tasting session, there are two sections to complete. Please make sure you complete all the questionnaire before you leave.

# Section 1 – Apple tasting

# You will receive five apples to taste. Before you eat any of the samples, please read the following instructions.

Please:

- trust your own opinion about the apple samples and be honest in your responses,
- mark each scale using a <u>single vertical mark</u> with the pencil provided. You can mark anywhere on the line that best represents your opinion,
- don't distract or talk to other people while they are assessing samples,
- before assessing each sample, check that the sample number on the cup matches the sample number on the paper questionnaire,
- cleanse your palate between samples with fresh water. This is particularly important as residual tastes can affect your perception of the attributes of the next sample

### Please find apple sample 163.

How much do you like or dislike the appearance of apple sample 163? Dislike extremely Neither like nor dislike Like extremely Now taste some of apple sample 163. You don't need to eat all of the sample. Overall, including appearance, how much do you like or dislike the apple sample 163? Dislike extremely Neither like nor dislike Like extremely How much do you like or dislike the flavour of apple sample 163? Dislike extremely Neither like nor dislike Like extremely How much do you like or dislike the texture of apple sample 163? Neither like nor dislike Dislike extremely Like extremely What, if anything, did you like about apple sample 163? ..... ..... What, if anything, did you dislike about apple sample 163? 

#### Make sure you have a drink of water in-between samples to cleanse your palate.

## [THIS PAGE REPEATED FOR ALL SAMPLES PRESENTED]

# Section 2- Background questionnaire

In this section, please provide us with some information about yourself. This information is anonymously collected, will be kept confidential and will not be used to identify individuals. It will help us to better analyse our data and improve our conclusions. So please, read every question and respond as honestly as you can.

### 3.1. What is your gender? please circle one response

••••				•••••					
Male	e Fe	emale							
3.2.	To which a	ge group do yoເ	u belong?	please circle	one response				
Less	than 20	20-24	25-29	30-3	34 35-39	9 40	)-44		
45-4	9	50-54	55-59	60+					
3.3.	Are you the	main buyer of	groceries i	in your hou	Isehold? please	circle one re	sponse		
No		Shared		Yes					
3.4. respo	<b>How many</b> onse	children do you	have (<18	years old)	in the househo	old? please	circle one		
0	1	2		3	4 or more				
3.5. How frequently do you eat apples (not canned or processed apples)? please, circle one response									
Daily	Several	times per week	Weekly	Several ti	mes per month	Monthly	Never		
3.6.	Which varie	eties of apple do	o you prefe	er to eat? ye	ou may tick more	than one box	ſ		
	Bonza				Granny Smith				
	Lady Williar	ns			Brae Burn				
	Jonagold				Fuji				
	Golden Del	icious			Pink Lady				
	Cameo				Sundowner				
	Red Delicio	us			Other				
	Gala				Don't Know				

Please, indicate your general degree of concern for global issues such as: *please*, *mark* your answer on the scale

### 3.7. Environment

Not concerned at all	Very concerned
3.8. Health	
Not concerned at all	Very concerned
3.9. Food Quality	
	1
Not concerned at all	Very concerned
3.10. Ethics in community	
Not concerned at all	Very concerned
3.11. <b>How often do you purchase organic fruit?</b> <i>please, circle one response</i> Daily Several times per week Weekly Several times per month Mont	hly Never
<ul> <li>3.11. How often do you purchase organic fruit? please, circle one response</li> <li>Daily Several times per week Weekly Several times per month Mont</li> <li>3.12. If you purchase organic fruit, what kind of fruit do you purchase? you than one box</li> </ul>	hly Never ou may tick more
<ul> <li>3.11. How often do you purchase organic fruit? please, circle one response</li> <li>Daily Several times per week Weekly Several times per month Mont</li> <li>3.12. If you purchase organic fruit, what kind of fruit do you purchase? you than one box</li> <li>Banana</li> </ul>	hly Never ou may tick more
<ul> <li>3.11. How often do you purchase organic fruit? please, circle one response</li> <li>Daily Several times per week Weekly Several times per month Mont</li> <li>3.12. If you purchase organic fruit, what kind of fruit do you purchase? you than one box</li> <li>Banana</li> <li>Strawberry or other Berries</li> </ul>	hly Never
<ul> <li>3.11. How often do you purchase organic fruit? please, circle one response</li> <li>Daily Several times per week Weekly Several times per month Mont</li> <li>3.12. If you purchase organic fruit, what kind of fruit do you purchase? you than one box</li> <li>Banana</li> <li>Strawberry or other Berries</li> <li>Apple</li> </ul>	thly Never
<ul> <li>3.11. How often do you purchase organic fruit? please, circle one response</li> <li>Daily Several times per week Weekly Several times per month Mont</li> <li>3.12. If you purchase organic fruit, what kind of fruit do you purchase? you than one box</li> <li>Banana</li> <li>Strawberry or other Berries</li> <li>Apple</li> <li>Grape</li> </ul>	hly Never
<ul> <li>3.11. How often do you purchase organic fruit? please, circle one response</li> <li>Daily Several times per week Weekly Several times per month Mont</li> <li>3.12. If you purchase organic fruit, what kind of fruit do you purchase? you than one box</li> <li>Banana</li> <li>Strawberry or other Berries</li> <li>Apple</li> <li>Grape</li> <li>Mango</li> </ul>	hly Never
<ul> <li>3.11. How often do you purchase organic fruit? please, circle one response</li> <li>Daily Several times per week Weekly Several times per month Mont</li> <li>3.12. If you purchase organic fruit, what kind of fruit do you purchase? you than one box</li> <li>Banana</li> <li>Strawberry or other Berries</li> <li>Apple</li> <li>Grape</li> <li>Mango</li> <li>Other:</li> </ul>	hly Never
3.11. How often do you purchase organic fruit? please, circle one response         Daily       Several times per week       Weekly       Several times per month       Month         3.12. If you purchase organic fruit, what kind of fruit do you purchase? you than one box       Banana       Strawberry or other Berries       Apple         Grape       Mango       Other:       Orange/ Mandarin and other Citrus	thly Never
<ul> <li>3.11. How often do you purchase organic fruit? please, circle one response</li> <li>Daily Several times per week Weekly Several times per month Mont</li> <li>3.12. If you purchase organic fruit, what kind of fruit do you purchase? you than one box</li> <li>Banana</li> <li>Strawberry or other Berries</li> <li>Apple</li> <li>Grape</li> <li>Mango</li> <li>Other:</li> <li>Orange/ Mandarin and other Citrus</li> <li>Pineapple</li> </ul>	thly Never
<ul> <li>3.11. How often do you purchase organic fruit? please, circle one response</li> <li>Daily Several times per week Weekly Several times per month Month</li> <li>3.12. If you purchase organic fruit, what kind of fruit do you purchase? you than one box</li> <li>Banana</li> <li>Strawberry or other Berries</li> <li>Apple</li> <li>Grape</li> <li>Mango</li> <li>Other:</li> <li>Orange/ Mandarin and other Citrus</li> <li>Pineapple</li> <li>Stone fruit (Peach/ Nectarine/ Plum/ Apricot/ Cherry)</li> </ul>	thly Never
3.11. How often do you purchase organic fruit? please, circle one response         Daily       Several times per week       Weekly       Several times per month       Month         3.12. If you purchase organic fruit, what kind of fruit do you purchase? you than one box       Image: Comparison of the service of	thly Never

# 3.13. If you purchase organic fruit, where do you most often buy them? *please, circle one response*

Specialist organic shop	Supermarket	Market
Directly from the producer	Other:	

#### 3.14. What is your level of education? please, tick one box only

- □ Finished prior Year 12
- □ Year 12
- □ Certificate
- □ Advanced diploma and diploma
- □ Bachelor degree
- □ Graduate diploma
- □ Postgraduate degree

#### 3.15. What is your approximate household income? optional question

- □ < \$40 000 per year
- □ \$40 000 \$80 000 per year
- □ > \$80 000 per year

# Thank you for your time today. We hope that you enjoyed the session.

Any fruit that you have been unable to eat, you are welcome to take with you. Plastic bags are provided. At the same time, please discard any rubbish (sample cups, unwanted fruit and plastic water cups). Then please hand your completed questionnaire to one of the taste test supervisors before you leave.