Enhancing Profitability with Superior Fruit Quality

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Introduction

Sweet cherry is a perishable crop that requires intensive management in production, storage, and cool-chain transport to reach export markets in good condition and with sufficient shelf-life to allow for marketing and consumption. As with other fruit, the post-harvest quality of cherries is greatly impacted by a number of factors including variety, rootstock, management practices, and environmental factors. Reliable predictors of fruit quality are essential, especially to insure successful export and subsequent grower profitability. In the USA, fruit firmness and size are the primary criteria used to identify appropriate destinations for cherries. To increase cherry exports with the aim of accessing markets in the USA, evidence is needed to satisfy buyers that Australian cherries attain or surpass existing quality criteria.

Various methods of fruit firmness measurement have been evaluated. Researchers at the University of California (1) determined that the most useful tool for quantifying firmness was the FirmTechII (BioWorks, Inc.) for its precision, accuracy and ease of quantification. Research programs and packing houses around the world have adopted the technology for an objective and uniform evaluation of fruit firmness internationally. Additionally, a pull force gauge is a valuable device to estimate the amount of force required to remove the stem and an indicator for stem retention once fruit are harvested and packed (2). Other quality criteria such as fruit size, soluble solids concentration, fruit colour, and pH can be used as indicators of quality (3). Routinely, breeding and research programs in North America, Europe and Chile utilise these tools to benchmark new cultivars, recent releases and introductions, and the impacts of horticultural practices on fruit quality against the USA industry standard 'Bing' and conventional practices.

Prior to the inception of the CherryNet project, Australian growers were lacking appropriate and objective pre and post-harvest measurements to gauge the storability, shelf-life and best markets for cherries. The industry did not have a set of unifying standards for fruit quality. Members of the "CherryNet" group, who produce ~60% of the Victorian cherries and aspire to export up to 50% of their crop, recognised the need to create a standard to insure that high quality cherries are exported and the reputation of Australian cherries is enhanced.

The implications for the research are many. Australian producers will have learned of and implemented the use of tools that will quantify fruit quality and determine destination. Orchardists will have a better sense of how to design on-farm research trials to evaluate the impact of changes in horticultural management on fruit quality. Australian guidelines for fruit quality will be created based on these national and other international data. New varieties can be evaluated and suitable genotypes identified with the requisite guidelines.

Materials and Methods

The aim of the project was to develop objective pre and post-harvest fruit quality measurements to gauge the potential storage and shelf-life of cherries to determine the best marketing strategy. A 2.0 kg sample of fruit of five benchmark varieties were obtained from the collaborators' orchards that were located in northern (Cobram) to southern Victoria (Wandin). The varieties were 'Merchant', 'Van', 'Bing', 'Lapins', and 'Ron's Seedling'. Fruit were stored at 2C in Life Span bags. Twenty-five fruit from each location were subjected to an extensive evaluation of fruit quality within two days after harvest, then again two weeks after storage. In 2003-2004, fruit were stored for an additional two weeks and evaluated. Fruit firmness was measured using the FirmTechII instrument. Fruit size (mm), weight (g), colour (1-7), soluble solids concentration (SSC) (°Brix), pH, stem quality (1-5), stem pull force (g) and cracking (%) data were collected at the harvest sampling. Another 25 fruit sample was stored for ~2 weeks and re-evaluated for fruit size, firmness, and stem pull force.

Other varieties were evaluated to determine their suitability for production and export. Potential cultivars were identified that met certain criteria. These criteria are summarised in the table below.

Table 1. Desired criteria for cherry fruit.

Criteria	Threshold value
Fruit firmness (g/mm^2)	250
Fruit size (mm)	27
Cracking (%)	10
Stem pull force (g)	500
Soluble solids concentration (°Brix)	17.0
pH	3.4

Results and Discussion

The range of values obtained for fruit quality parameters obtained from fruit sampled from orchards in Northern to Southern Victoria at harvest and after storage are summarised in the subsequent tables (Tables 1-5).

Merchant

This early season cultivar may have export market potential in some years and from some locations but quality is generally marginal for those markets. Fruit quality was at its best in 2002-2003. In the other three years, export potential was very site dependent and clearly some fruit would not satisfy the minimum criteria for export. This variety is highly susceptible to stem bowl and some nose cracking. Optimum fruit colour should approach a colour rating of 4.5-5. Generally this cultivar has marginal firmness in most locations, high risk of cracking, and on average a tendency towards the lower end of acceptable SSC. Stem pull force is generally acceptable at harvest but decreases in storage. The earliness of this variety creates a niche where lower values than the proposed criteria may be acceptable.

Ron's Seedling

Fruit firmness was good to exceptional. Fruit size ranged from small to medium. Stem pull force was high and stem quality was exceptional. Fruit acidity is moderate to low while SSC was low to acceptable. Optimum colour at harvest should be between 5 and 6 in order to achieve higher SSC. At a lesser colour, fruit taste will tend to be bland. This cultivar has a tendency to double. Fruit quality remained quite good in storage after 2 weeks and even after 4 weeks. The greatest limiting factor for this variety is its small to moderate fruit size and tendency to double. This variety is extremely well suited for the domestic market because of its long shelf life and good stem quality. Additional horticultural techniques to enhance fruit size such as early season plant growth regulator applications, additional foliar N and B applications, delayed spring heading techniques, multiple gibberellin applications, etc. should be evaluated.

Bing

Fruit firmness was generally good to very good. Fruit size ranged from medium to large. Optimum fruit colour should be between 4 and 5. SSC was generally as good or better than the recommended criteria. Stem pull force was highly variable between years. In 2003-2004, stem quality and retention was excellent. Goemar and Retain treatments at straw colour appeared to further increase stem pull force after two and four weeks in storage in 2003-2004. Dormancy breaking products may have reduced stem pull force especially in unseasonably hot temperatures. In 2004-2005, stem retention was poor and stem pull force was quite low. 'Bing' cherries grown in Victoria generally achieve the desired criteria and are comparable in quality to North American grown cherries. The greatest limiting factor is its susceptibility to rain cracking. This cultivar performs reasonably well is a range of growing conditions.

Van

The firmness of 'Van' fruit has been excellent. Large fruit size was attained. SSC was acceptable and acidity was moderate. Optimum fruit colour was between 4 and 5. The weaknesses of this genotype that will always limit its potential for export are the strong tendency to crack at the stylar end of the fruit and its low stem pull force and retention. Horticultural practices that increase stem retention, for instance balanced cropping, good soil moisture management, foliar N programs, and other plant growth regulators, should be practiced. Shading trees in environments with excessive heat during harvest might be of benefit. Caution should be practiced when planting this variety in hotter districts.

Lapins

Fruit firmness was generally good to very good. Fruit were large with acceptable to high SSC and low acidity. Optimum fruit colour was 5. Stem pull force was highly variable across the seasons. In 2003-2004, stem retention was very good. However, during 2002-2003 and 2004-2005, stem pull force was low to very low and stem retention poor. The factors that appear to reduce stem retention were high heat and excessive rainfall. Additional management strategies such as growth regulator application at straw colour, balanced cropping, tree shading, and consistent intensive irrigation should be evaluated to increase stem pull force. Stylar cracking can be a problem in years of rain at harvest. This genotype has good export potential because of excellent fruit size, firmness and SSC.

General seasonal observations:

<u>2001-2002</u>

The first year of data collection was made in an abnormally, cool and wet season. Fruit firmness tended to be lower than in subsequent years.

<u>2002-2003</u>

This growing season was a dry and hot year. Generally fruit had higher SSC, were very firm, and had substantially less cracking. Stem retention and quality were lower in the benchmark varieties. Concern was raised about the influence of dormancy breakers and Extenday with respect to stem retention. Gibberellin and Retain applications may be helpful in hot years to increase the stem pull force but may delay maturity.

<u>2003-2004</u>

Fruit was generally above average in quality. Fruit size, storability, stem retention, firmness and SSC were high resulting in high quality fruit. One of the major contributing factors was likely the moderately cool climate and light crop load. The incidence of heat related disorders such as sunburn, soft shoulders and loss of stems was minor. Additionally, collaborating orchardists had modified their pruning practices to reduce severe fruit clustering, introduced renewal pruning and used gibberellins routinely. Also, irrigation management at harvest to insure consistent soil moisture likely contributed to higher fruit quality.

Early fruitlet nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and zinc (Zn) concentrations were positively correlated with fruit size for both 'Merchant' and 'Lapins' (Table 6). However, only K had a correlation coefficient above 0.50 in 'Lapins'. The trend should generate some thought. Conversely, as N, P, K, Ca, and Zn concentrations increased, the stem pull force decreased. Only Zn was consistently negatively correlated with colour across the two cultivars.

Contrary to the opinion of horticulturists, these data reveal a strong positive correlation between firmness and mature fruit N concentration (Table 7). No other element was consistently correlated with firmness across both cultivars. However, the firmness of the late season variety (Lapins) may be more influenced by current season's uptake of P, K, Ca, and Zn. Fruit colour was positively correlated with P, K, Mg, B, and Cu concentrations of mature fruit. Boron was positively correlated with soluble solids concentration while sulphur (S) was negatively correlated. No clear trends were observed for nutrient concentration at harvest

that were highly correlated with fruit size. For stem pull force, there were no cross cultivar trends. Although high N concentration had a tendency to decrease stem pull force across the two cultivars.

2004-2005

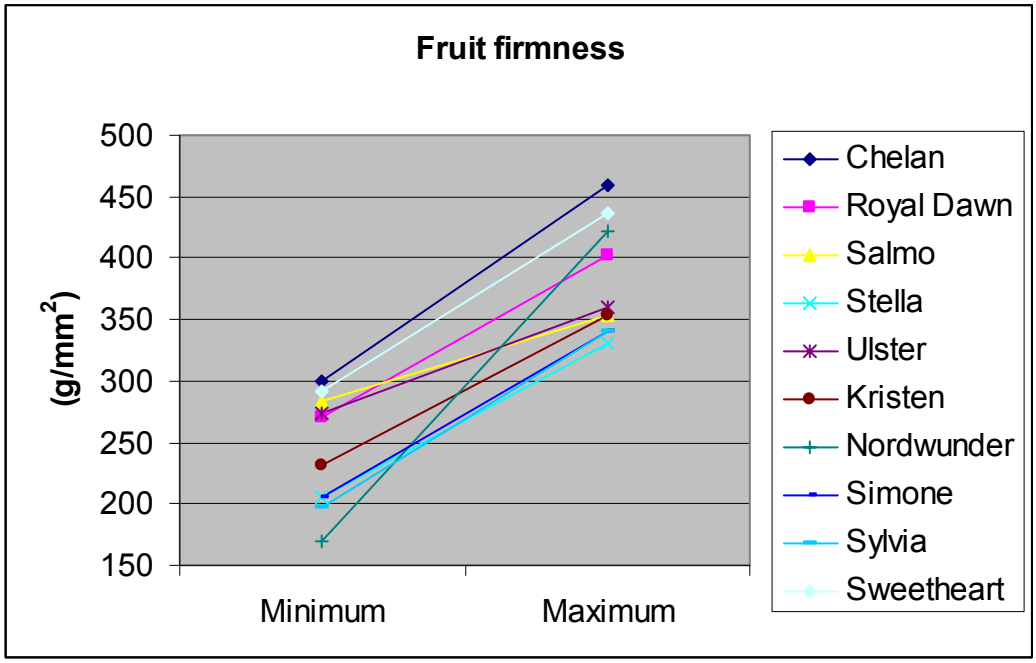
The growing season was very wet and challenging. Overall fruit quality of the benchmark varieties was good to poor. Fruit firmness was good. Stem quality and retention was poor. Fruit cracking was a major problem. Other varieties performed reasonably well if cracked fruit were eliminated from the analysis. The additional varieties that were evaluated also had low stem pull force. Genotypes should be evaluated over a number of years and environments to assess suitability for domestic and export markets.

Fruit quality of other varieties

Table 8 and the figures below report on the maximum and minimum values of additional commercial varieties that were evaluated throughout the duration of the project.

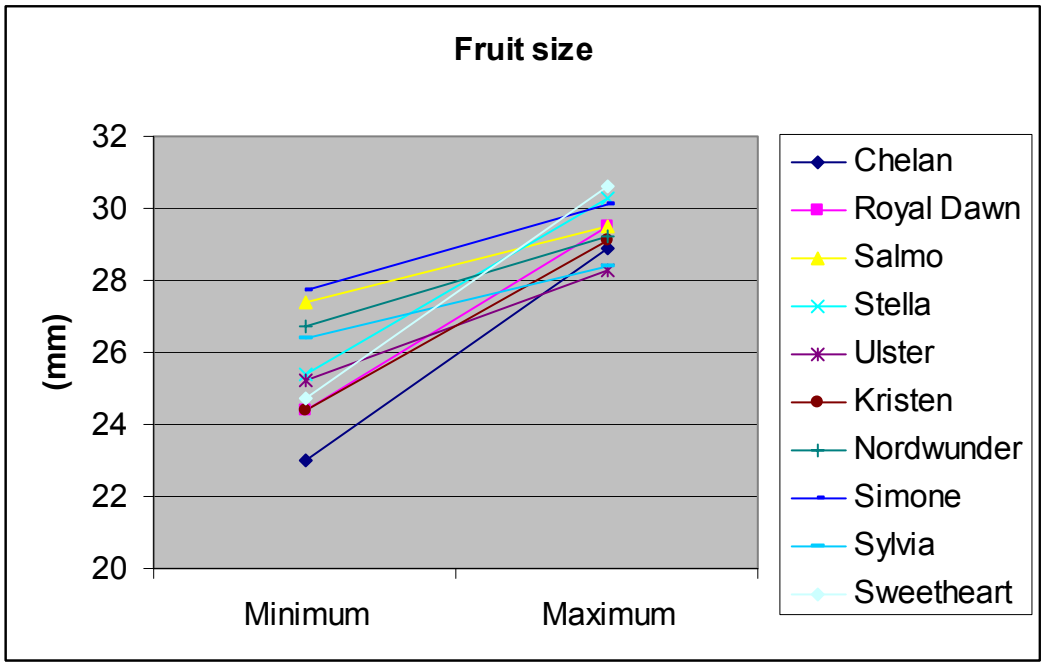
FRUIT FIRMNESS

'Chelan', 'Sweetheart' and 'Royal Dawn' were consistently the firmest varieties evaluated. The minimum values observed for 'Sylvia', 'Simone', 'Kristen' and 'Nordwunder' would not have met the minimum recommended criteria for export in some years.



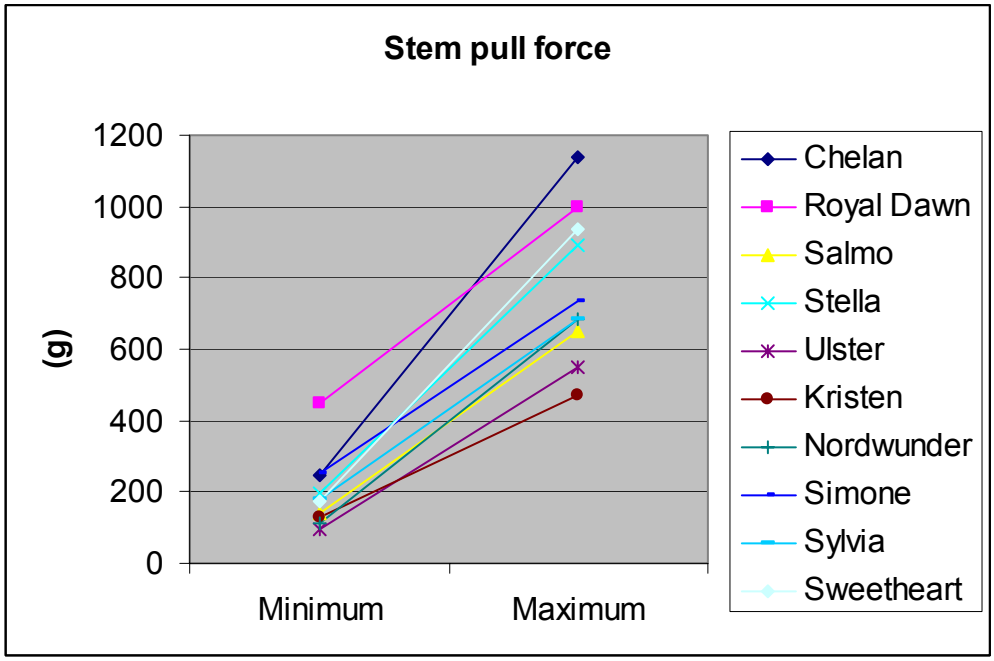
FRUIT SIZE

'Simone', 'Salmo', 'Sylvia', and 'Nordwunder' fruit size had a minimum fruit size above 26mm. Although all cultivars had the ability to obtain relatively large fruit size (28mm+), some cultivars had minimum values that should be heeded and inform horticultural management practices to insure maximum fruit size. These include: 'Chelan', 'Kristen', 'Royal Dawn', 'Sweetheart', and 'Ulster'.



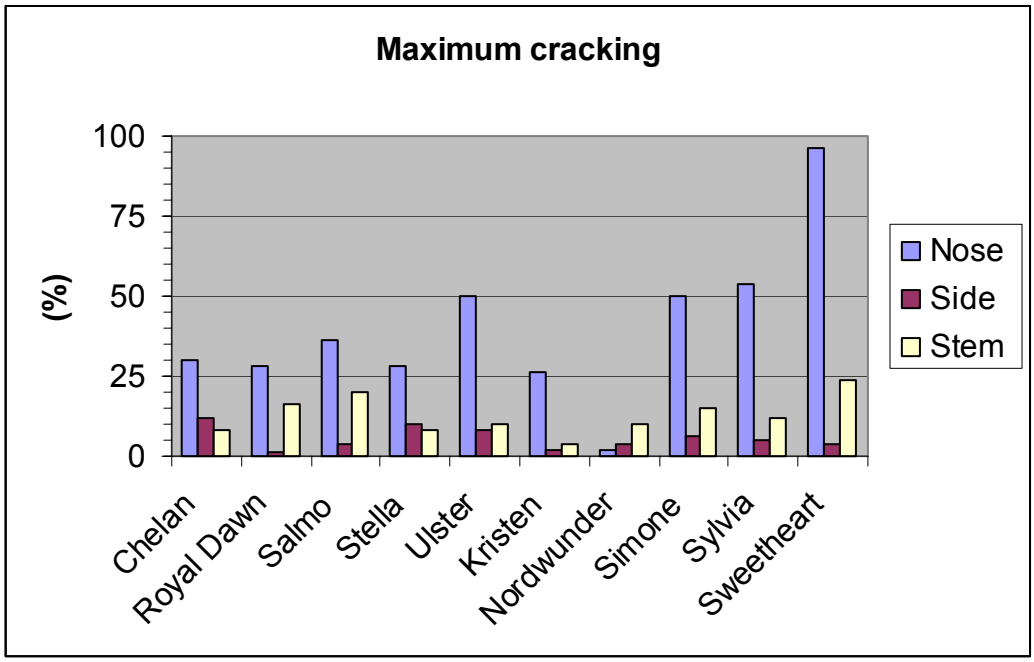
STEM PULL FORCE

'Chelan', 'Royal Dawn', 'Sweetheart', and 'Sylvia' had the highest maximum SPF. The next grouping of 'Simone', 'Stella', 'Nordwunder', and 'Salmo' were intermediate and could have stem retention problems in low SPF years. 'Ulster' and 'Kristen' had the lowest maximum SPF and are of concern with respect to stem retention in low SPF growing seasons.



CRACKING

With the exception of 'Nordwunder', all varieties had a tendency to have minor to major nose cracks.



Conclusions:

As a result of our research findings, and a synthesis of other information from Australian buyers and other international standards, we created (in collaboration with AFFCO, the Australian Cherry Growers' Association) the first publication entitled "Australian Cherry Quality Guide" (4).

Orchard management intensified over the 4 years of the study. Orchardists recognised the need to better balance cropping to improve fruit firmness and increase stem retention. More attention was paid to harvesting fruit at the appropriate colour stages to attain the optimum soluble solids concentrations and quality. Gibberellin and foliar applications of nutrients (based on leaf sufficiency values) and other products became routine practices.

Recommendations:

Many new cultivars are being introduced into Australia. Comprehensive analyses of fruit are essential to insure the sale and distribution of export quality fruit. The next project should expand the varieties that are evaluated and the number of locations from which samples are collected nationally. Export quality varieties should be evaluated for post-harvest longevity in the range of packaging options that are currently available to the industry. The availability of new plant growth regulators also affords an opportunity to further enhance fruit quality by increasing fruit size, firmness and stem pull force. These products should be evaluated in on-farm trials at the appropriate scale to assess impacts on fruit quality and overall tree performance.

Table 1. The range of fruit quality values obtained for 'Merchant' fruit harvested from eight orchardists over four growing seasons in Victoria, Australia.

Year	Storage duration (weeks)	Firmness (g/mm^2)	Fruit size (mm)	Fruit colour (1-7)	Cracking				Stem pull force (g)	SSC (°Brix)	pH
					Nose	Side	Stem	%			
2001-2002	0	157-259	24.6-27.0	4.1-6.0	0-32	0-16	16-70	16-70+	-	15.0-19.4	3.7-3.9
	2	189-256									
2002-2003	0	169-302	24.2-28.7	4.8-6.2	0	0	0-40	0-40	491-844	17.0-24.0	3.5-3.8
	2	238-289							458-677		
2003-2004	0	165-241	26.4-28.8	3.6-4.8	0-16	0-12	0-96	4-96	650-887	13.2-19.6	3.5-3.9
	2	202-365							624-971		
	4	233-303							486-768		
2004-2005	0	171-264	23.6-27.6	4.4-5.6	0	0	4-48	4-48	248-465	16.3-20.0	3.6-3.9
	2	161-330							137-291		
Goal values		250	27					10	500	17.0	3.4

Table 2. The range of fruit quality values obtained for 'Ron's Seedling' fruit harvested from eight orchardists over four growing seasons in Victoria, Australia.

Year	Storage duration (weeks)	Firmness (g/mm²)	Fruit size (mm)	Fruit colour (1-7)	Cracking				Stem pull force (g)	SSC (°Brix)	pH
					Nose	Side	Stem	%			
2001-2002	0	234-351	24.3-27.7	5.0-7.0	0-80	0-2	0-6	0-80	-	15.2-24.9	3.7-4.0
	2	208-432									
2002-2003	0	274-405	25.6-28.1	5.4-7.0	0	0-4	0-28	0-28	677-951	16.8-20.4	3.4-3.9
	2	275-432							567-1069		
2003-2004	0	244-284	24.9-27.2	4.6-5.5	0-12	0	0-4	0-12	592-1168	18.0-19.6	3.7-4.0
	2	312-360							703-1058		
	4	319-435							507-949		
2004-2005	0	267-310	21.5-26.6	4.9-5.4	0-12	0-4	0-24	4-36	174-479	14.2-18.6	3.7-4.1
	2	321-340							252-358		
Goal values		250	27					10	500	17.0	3.4

Table 3. The range of fruit quality values obtained for 'Bing' fruit harvested from eight orchardists over four growing seasons in Victoria, Australia.

Year	Storage duration (weeks)	Firmness (g/mm^2)	Fruit size (mm)	Fruit colour (1-7)	Cracking				Stem pull force (g)	SSC (°Brix)	pH
					Nose	Side	Stem	%			
2001-2002	0	167-311	25.7-28.3	3.7-5.9	0-58	0-4	0-12	0-60	-	16.1-21.3	3.6-4.0
	2	206-323									
2002-2003	0	265-389	25.9-28.1	4.0-5.8	0-4	0-4	0-16	0-16	308-636	18.2-23.0	3.4-3.7
	2	278-371							397-685		
2003-2004	0	209-496	25.8-29.6	3.1-5.7	0-28	0-16	0-20	0-40	447-1056	17.0-23.2	3.8-4.0
	2	301-464							580-956		
	4	316-477							504-937		
2004-2005	0	222-385	27.7-29.5	4.3-5.1	0-32	0-4	0-44	4-44	110-432	17.2-21.0	3.5-3.9
	2	268-400							135-308		
Goal values		250	27					10	500	17.0	3.4

Table 4. The range of fruit quality values obtained for 'Van' fruit harvested from eight orchardists over four growing seasons in Victoria, Australia.

Year	Storage duration (weeks)	Firmness (g/mm^2)	Fruit size (mm)	Fruit colour (1-7)	Cracking				Stem pull force (g)	SSC (°Brix)	pH
					Nose	Side	Stem	%			
2001-2002	0	272-401	25.6-29.3	4.2-5.6	24-70	0-2	0-12	24-70	-	15.7-21.6	3.7-3.8
	2	261-314									
2002-2003	0	343-397	25.6-27.7	3.9-5.0	0-8	0	0	0-8	249-461	17.2-20.0	3.4-3.5
	2	380-436							254-354		
2003-2004	0	339-552	26.5-31.2	3.0-4.4	4-56	0	0-4	4-56	557-892	15.4-19.4	3.6-3.8
	2	400-542							492-802		
	4	457-620							457-802		
2004-2005	0	255-431	24.1-30.1	4.2-5.2	0-24	0-4	0-44	4-44	119-341	16.2-19.0	3.5-3.9
	2	299-401							102-334		
Goal values		250	27					10	500	17.0	3.4

Table 5. The range of fruit quality values obtained for 'Lapins' fruit harvested from eight orchardists over four growing seasons in Victoria, Australia.

Year	Storage duration (weeks)	Firmness (g/mm^2)	Fruit size (mm)	Fruit colour (1-7)	Cracking				Stem pull force (g)	SSC (°Brix)	pH
					Nose	Side	Stem	%			
2001-2002	0	216-395	27.0-32.0	5.1-5.5	0-92	0-4	0-2	0-92	-	17.5-20.1	3.9-4.0
	2	217-280									
2002-2003	0	210-428	26.1-28.6	3.6-5.4	0-4	0-4	0-12	0-16	373-573	16.3-20.8	3.5-3.8
	2	263-412							323-502		
2003-2004	0	262-373	26.2-29.0	3.6-5.2	0-24	0-12	0-24	0-32	607-914	16.2-20.0	3.7-4.0
	2	326-620							457-802		
	4	292-495							437-792		
2004-2005	0	299-359	26.8-31.3	3.8-5.7	0-32	0-8	0-32	8-40	126-289	14.8-17.7	3.7-4.2
	2	301-426							181-270		
Goal values		250	27					10	500	17.0	3.4

Table 6. Correlation coefficients between nutrient concentration during early fruit development (around shuck split) and fruit quality attributes at harvest.

	Firmness		Fruit size		Colour		Stem pull force		SSC	
	Merchant	Lapins	Merchant	Lapins	Merchant	Lapins	Merchant	Lapins	Merchant	Lapins
N	0.34	0.68	0.88	0.37	-0.78	-0.19	-0.62	-0.56	-0.91	-0.23
P	0.28	0.39	0.70	0.49	-0.68	0.32	-0.51	-0.61	-0.73	0.25
K	0.09	0.26	0.55	0.60	-0.53	0.64	-0.39	-0.53	-0.49	0.59
Ca	-0.62	0.02	0.67	0.46	0.01	-0.12	-0.55	-0.57	-0.26	-0.06
Mg	-0.41	0.69	-0.58	0.03	0.77	0.35	0.37	0.09	0.66	0.39
B	0.23	0.06	-0.44	0.10	0.04	0.87	0.65	0.11	0.39	0.83
Zn	0.03	0.03	0.88	0.44	-0.53	-0.55	-0.73	-0.40	-0.79	-0.33
Mn	0.18	-0.71	-0.19	0.30	-0.49	-0.37	-019	-0.06	-0.21	-0.30
Cu	-0.36	0.23	0.43	0.18	0.18	0.96	-0.43	0.15	-0.45	0.90
S	0.06	0.53	0.60	-0.39	-0.39	0.61	-0.02	-0.07	-0.29	0.67

Table 7. Correlation coefficients between nutrient concentration at harvest and fruit quality attributes.

	Firmness		Fruit size		Colour		Stem pull force		SSC	
	Merchant	Lapins	Merchant	Lapins	Merchant	Lapins	Merchant	Lapins	Merchant	Lapins
N	0.72	0.86	0.32	0.11	-0.66	0.27	-0.44	-0.30	-0.84	0.17
P	-0.03	0.73	-0.29	0.23	0.60	0.62	0.64	0.09	0.25	0.59
K	-0.27	0.68	-0.13	0.19	0.72	0.61	0.53	-0.14	0.09	0.54
Ca	0.33	0.88	-0.26	-0.10	0.41	0.44	0.54	0.07	-0.28	0.35
Mg	-0.05	0.22	-0.39	-0.24	0.68	0.69	0.68	0.34	0.44	0.66
B	-0.23	0.19	-0.51	0.04	0.79	0.92	0.71	0.04	0.75	0.89
Zn	-0.08	0.75	0.27	0.21	0.24	0.14	0.20	-0.12	-0.20	0.15
Mn	0.35	0.07	-0.20	0.32	-0.22	-0.70	0.57	0.05	0.07	-0.56
Cu	-0.15	0.21	-0.38	0.00	0.83	0.86	0.64	0.29	0.32	0.85
S	0.59	0.21	0.45	-0.44	-0.69	-0.46	-0.41	-0.21	-0.78	-0.50

Table 8. Range in values for fruit quality attributes across four growing seasons of named cultivars that are commercially grown by project collaborators.

Genotype	Firmness (g/mm^2)	Size (mm)	Colour (1-7)	Maximum Cracking (%)			Stem pull force (g)	SSC (°Brix)	pH
				Nose	Side	Stem			
Chelan	300-459	23.0-28.9	4.9-6.3	30	12	8	249-1139	15.4-22.0	3.3-3.9
Royal Dawn	270-403	24.4-29.5	4.6-5.9	28	1	16	448-997	16.4-25.2	3.7-3.9
Salmo	284-354	27.4-29.5	3.8-5.7	36	4	20	142-650	14.0-17.0	3.6-3.8
Stella	205-330	25.4-30.3	3.1-4.7	28	10	8	195-892	13.6-19.0	3.4-3.7
Ulster	273-360	25.2-28.3	3.6-5.9	50	8	10	96-547	15.2-21.8	3.5-3.9
Kristen	232-354	24.4-29.1	4.2-5.8	26	2	4	128-472	16.9-23.8	3.3-3.6
Nordwunder	169-422	26.7-29.2	4.3-5.7	2	4	10	110-686	15.9-18.9	3.4-4.0
Simone	205-340	27.7-30.1	3.6-5.1	50	6	15	251-734	15.5-21.0	3.5-4.0
Sylvia	197-341	26.4-28.4	4.9-5.9	54	5	12	179-686	16.1-20.0	3.6-3.9
Sweetheart	291-436	24.7-30.6	3.8-5.4	96	4	24	175-939	15.1-21.2	3.3-3.8

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