6. DNA used to identify pests on export apples - a world first in biosecurity

All exports of fresh fruit and vegetables from New Zealand must meet the phytosanitary requirements of the designated importing country. These requirements vary from country to country. Any breaches of these biosecurity requirements will put both our markets and our inspection procedures at risk. It is to New Zealand's advantage to inspect and approve all horticultural produce before it leaves the country.

Washing apples for export

The issue was well illustrated during the mid 1990s when high rejection rates were experienced with New Zealand apples destined for the USA market. During the mid 1990s there was a sharp rise in the presence of mealy bugs and other hitch hiker pests on NZ apples. Concern focused on a mealy bug species that was not know to be present in USA. The United States Department of Agriculture (USDA) authorised phytosanitary pre-clearance in New Zealand of apples destined for the USA market. As soon as the issue was raised by USDA, the industry set out to address the problem using a wide range of science and technological skills.

Some smart science and innovative technology was used to solve the problem:

- Science showed that mealy bugs are killed by holding the fruit in coolstore for 28 days before export.
- Apple washing technology was developed that removed hitchhiker pests from the fruit without damaging the skin of the apple.
- At first the identification of the mealy bugs took up to 30 days. However, the development of new identification methods using DNA technology, reduced this time to 48 hours. This identification procedure was authorised by USDA in 1998.
- By using some smart science incorporating DNA technology it was established that the mealy bug species of concern was already present in USA. This finding was accepted by USDA and the biosecurity concern surrounding the particular mealy bug species was resolved.
- The risk of hitch hiker pests was reduced further in 2001, when New Zealand achieved 100% selective insect control with zero use of organophosphates in orchard sprays. This is an outcome of the integrated fruit production technology programmes for the production of export apples that were introduced to the industry during the late 1990s.

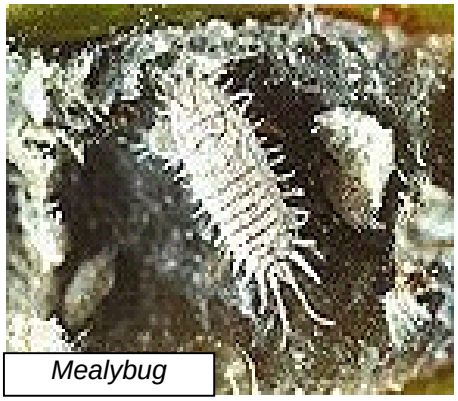
New Zealand was the first country in the world to make use of sophisticated DNA technology to overcome a market access problem. New Zealand horticulture has to accept that similar biosecurity issues will continue to be a risk for these vital fruit exports. As a consequence, experienced scientists must be available to address these issues as and when they occur.

Biosecurity failures impact on the New Zealand apple industry, and other horticultural export industries because they place serious and costly constraints on the industry's overall global marketing plan. Apple exports to USA average $68 million per year.

The internal rate of return on the R&D investment that led to continued phytosanitary pre-clearance of export apples to USA is estimated to be 43%, with a net present value of $16.6 million, in 2004. The equivalent 2009 values are estimated to be 44% and $22.3 million, respectively.

This case study illustrates the close linkage that is needed between the pest and disease management technologies used by the growers on orchards; and the post harvest management and export fruit inspection systems within New Zealand, in order to avoid rejection of fruit as a biosecurity risk in the market.

1. Background:


Mealybug

USA takes about 15% of the apples exported by New Zealand. The value of these exports ranged between $46 million and $92 million (fob) over the period 1994 through 2003. USA is regarded as a significant market for New Zealand apples and any interruption to these exports is viewed with concern by the industry.

From time to time export apples may carry mealy bugs, leafrollers and other hitchhiker pests that may be viewed as biosecurity risks by the importing country. In 1996, the apples destined for the USA market and submitted to the USDA inspection process in Hawke's Bay had a pass rate of only 70 to 80%. The rejected apples were either shipped to another market or sold on the domestic market. Subsequently, the USDA advised the New Zealand exporter to 'clean up their act' or risk losing the approved pre-clearance status. By 2003 the improved pest management technology applied on the orchards had increased pass rate to rise to about 97%.

One commercial consequence of fruit being rejected was that the volume of fruit inspected had to be increased in order to get sufficient volume of acceptable fruit for the USA market. A second consequence was that more New Zealand apples had to be placed on other markets which could then become oversupplied. In 1994 the USA market for NZ Royal Gala was undersupplied by 1.5 million cartons because of the USDA rejections, and that fruit had to be transferred to the European market. That volume represented about 10% of NZ apple exports.

USA regarded certain mealy bug species present in New Zealand as a biosecurity risk whereas these same species was acceptable to most other importing countries. During the early 1990s the organophosphate sprays used on the orchards killed both the mealybugs and their predators with the result that the incidence of mealybugs increased. Alternative sprays used later under integrated fruit production (IFP) systems initially allowed the populations of mealybugs to increase.

The industry was faced with several immediate problems including the need:

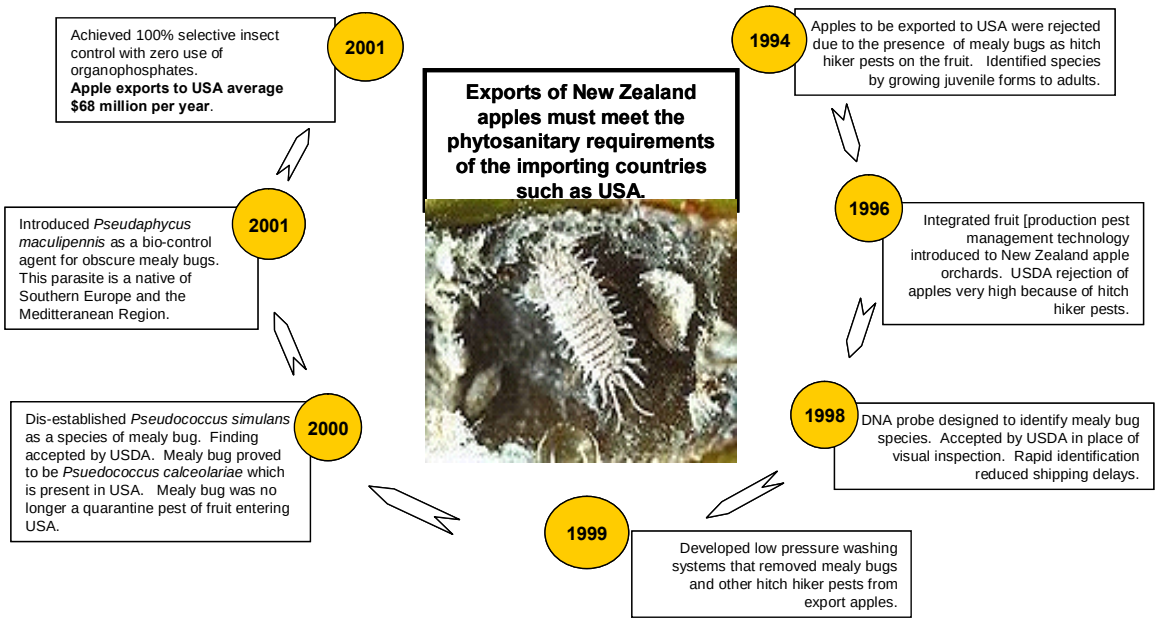
- to develop a method of destroying hitchhiker pests present on export apples, and
- to rapidly identify any mealybug species found on the apples.

HortResearch scientists found that mealybugs do not survive on apples kept in controlled atmosphere (CA) storage for more than 4 weeks. Therefore, the initial response to the USDA rejections of fruit was to keep the apples in CA storage for a period while further investigative work continued. CA storage added further costs to exports, as well as interrupting shipments, because vessels were often held in port awaiting apples too be cleared for export. Delayed entry to the USA market meant that apples missed the early season premiums. A further loss occurred because the period and nature of CA treatment shortened the effective storage and shelf life of the apples by up to 50%.

New Zealand is home to some pest species which are not found in the United States. This requires that all apples are inspected to ensure that unwanted pests are not inadvertently transported on the fruit. One of these unwanted pests is a species of

mealybug. New Zealand has three mealybug species commonly intercepted on export apples. One species was thought to be rare and therefore a quarantine concern. The initial difficulty arose in rapidly identifying the 'rare' species because they all look the same at the juvenile stage. The identification could take up to 30 days. The species of mealybug could not be easily identified because juvenile forms had to be reared to adults before they could be identified.

2. Timeline



3. Science and innovation features:

- HortResearch scientists developed a diagnostic test which can identify the three mealybug species within 24 to 48 hours. DNA from each species of mealybug has been cloned and the sequences of DNA peculiar to that species identified. These sequences can be matched to the unknown mealybug species. New Zealand was the first country in the world to make use of this sophisticated technology to overcome a market access problem.
- The introduction of washing technology for export apples reduced the incidence of hitch hiker pests that appear on fruit near harvest and which could subject the industry to biosecurity risks. The basic washing unit design was imported from Washington State in 1998. Features of the unit such as water pressure and volume, position and shape of brushes, elevator speed and impact of the washing on the subsequent shrivel of NZ varieties had to be optimised. The 'Unit' was developed for the *Washington Red Delicious* variety which is less likely to suffer shrinkage than is the *NZ Braeburn* variety. A further issue was that skin damage to the fruit may promote diseases on NZ export apples which have to be kept in long term storage.
- HortResearch scientists found that the physical characters of the adult females used to identify two of the mealybug species actually varied with environmental conditions, such as temperature. For example, the same mealybugs looked quite different when grown at different temperatures, yet were quite able to interbreed, and hence were the same species. The scientists concluded that the *P. simulans* found in the roots of sow thistle plants was the same species as *P. calceolariae* which is found on plants above ground both in New Zealand and USA. The

differences in DNA were simply due to intraspecific variation. This meant that the New Zealand mealybug species was not a new biosecurity threat within USA.

- New Zealand prefers to undertake phytosanitary checks on fresh horticultural products before they are exported. MAF delegates this responsibility to industry, but audits industry practices. In many countries government agencies do the biosecurity checks. Within the New Zealand horticulture industry strong working partnerships have been established between the market, growers and the science community.
- The rapid uptake of IFP programmes by New Zealand apple producers has helped to reduce the overall incidence of hitch hiker pests.
- A critical factor in resolving the biosecurity issue caused by the presence of mealybugs on export apples was the industry's ability to access a range of experienced science skills and resources, viz. entomology, molecular biology, post harvest physiology and engineering.

4. Benefits:

- DNA technology enabled the time required to identify hitch hiker mealybugs to be reduced from around 28 days to 48 hours. Rapid identification of the mealybugs initially reduced the shipping delays and additional CA store holding costs.
- The target mealybug was eventually shown to be a species that was known to be present in USA and no longer considered to be a biosecurity risk.
- Resolution of the biosecurity problem meant that marketing opportunity costs, such as lost premiums for early season sales, were minimised. Also the impact on the industry's global marketing plan was minimised.
- USDA allowed the NZ based pre-clearance phytosanitary programme for export apples to the USA market to be continued.

5. Return on R&D investment

The return on R&D investment was assessed by comparing the industry performance with the innovation in place to that of a counterfactual[1] situation which identifies a possible industry performance, had the innovation not happened.

Key information used in the analysis:

1. The number of export cartons (18.6 kg each) of apples to USA ranged from 1.3 to 3.8 million during the period 1994 to 2004.
2. The fob value of the apple exports to USA ranged from $45 million to $92 million during that same period.

Counterfactual: (What would have happened if this innovation had not occurred?)

1. Assume that the 1994-1995 costs would be ongoing if the problem had not been resolved.
2. To get sufficient cartons for USA market an additional 33% cartons were inspected. Cost of inspecting extra cartons was assumed to be 50c per carton.
3. Demurrage costs of holding ship were $40,000 per day. Assume 10 days total delay each season; spread over 30 to 40 vessels.
4. Supply chain delays caused 600,000 cartons to be on hold during season at a cool storage cost of 50c per carton.

[1] *Refer Appendix*

5. USDA cool store stacking requirements meant 10% loss of cool store space. i.e. 50,000 carton equivalents at $2.50 per carton
6. DNA identification. Typically 400-500 mealybug samples @ $150 per sample. The initial cost of identifying adult mealybug was assumed to equal DNA identification costs.
7. Market opportunity costs due to delay in fruit arriving in USA and poorer out turn because of longer storage and travel times were assumed to be 1.5% of the return per carton. (i.e. 30c per carton)
8. Assume fruit losses of 1% crop. This fruit is downgraded from export quality to juice quality @ 10% of export return per carton.
9. Cost of extra ENZA staff to manage supply chain and inspections. Assumed to be 1 FTE.

Assessment results:

	as at 2004	as at 2009
Internal Rate of Return[2]	43%	44%
Net Present Value[3]	$16.6 million	$22.3 million

The 2009 assessments are based on the assumptions that:

- Apple exports to USA will continue at present levels until 2009.
- Present prices for export apples will continue until 2009.

6. Quotes:

- "*New Zealand has a nationally coordinated approach to biosecurity problems. Compared with other countries, New Zealand is very innovative in having the infrastructure that enables marketing and market access issues to be coordinated*." Industry observer.
- "*Preclearance program authorization and implementation is contingent upon host country ability to effectively demonstrate that their proposed program meets or exceeds criteria included in APHIS' protocols…… If a program is suspended for pest-risk reasons, the host country must provide details of proposed corrective or additional actions and PPQ must agree on reactivation*." Animal & Plant Health Inspection Service (APHIS), USDA. The following countries have pre-clearance programmes for apples and pears: South Africa, Japan, Argentina and New Zealand. Apples from Japan must be treated before entry to USA, whereas the apples and pears from the other countries have only to be inspected. The Australian and French programmes are inactive. www.aphis.usda.gov
- In 2002, New Zealand, Chile and Canada were the highest volume exporting countries of apples and apple products into the USA.
  Source: *www.agmrc.org/fruit/profiles/appleindustryprofile.pdf*

7. Related activities:

An apple washer was developed to reduce the incidence of hitch hiker pests on export apples. This proposal arose from discussion between a New Zealand scientist and a Washington orchardist. Heath Rush, who produces the washer in Washington State,

[2] *Refer Appendix*
[3] *Refer Appendix*

USA allowed John Thornburrow, Fruit Handling Systems Ltd, Hastings to produce the washer under licence. Other NZ designed washers are now in use. In Washington State, the washer is used to remove rubbish from apples exiting CA storage in order to reveal rots during grading. Apples are placed on the local domestic market within days of washing, but NZ export apples may not reach the consumer market for weeks. The impact of washing on the apples was examined by a combined team of HortResearch (entomology and skin changes), Massey University (change in post harvest attributes including shrinkage) and ENZA (project manager).

There are several recent examples in New Zealand horticulture where science has been able to show that the biosecurity risk to the importing country is negligible. e.g.

- The species of mealybugs on present on New Zealand apples awaiting export to USA was shown to be already present in USA.
- The risk of introducing fire blight to Japanese apple trees through the import of New Zealand apples produced in orchards where fire blight may be present was shown to be negligible.
- A saprophytic fungi on New Zealand squash exported to South Korea was shown to have been mistakenly identified. The fungi is not pathogenic and will not damage rice. Squash can be imported to South Korea without this fungi becoming a biosecurity problem.
- 2-spotted spider mite on kiwifruit into Japan

Resolution of these biosecurity threats frequently requires an input from experienced scientists who are able to demonstrate that the specific pest will not be a biosecurity problem in the importing country.

8. Information sources

Information was supplied by:

- Dr Jim Walker, HortResearch, Hawkes Bay
- Catherine Richardson, (ex-ENZA) CR Consulting, Havelock North.
- Roger Gilbertson, (ex-ENZA) Gilbertson Consulting, Wellington.
- John Charles & Dr Lesley Beuning, HortResearch, Auckland.
- Dr Sandy Lang, (ex-HortResearch) Palmerston North.
- Pipfruit New Zealand Ltd.

Appendix

The working definitions used in this assessment were as follows:

[1]***Counterfactual:*** *Counterfactuals are the statement of what would have happened (or could happen) in the absence of a specific event, programme or action. Counterfactuals are the "what ifs", "thought experiments", "alternatives to actual history"; they imagine what would have happened to an economy, an industry or a business if, contrary to fact, some present conditions were changed, in this case, if a specific R&D advance had not occurred.*

[2]***Net Present Value (NPV)*****:** *Net Present Value represents the stream of benefits, less the stream of costs, converted into equivalent values today, using an appropriate discount rate. In the case of R&D, we have summed the benefits of an identified R&D advance, taken away the stream of costs and used a 7% discount rate to calculate the NPV.*

[3]***Internal Rate of Return (IRR):*** *The Internal Rate of Return calculates the interest rate received for an investment consisting of costs and income that occur over a specific period. By examining the costs, and when they occur, compared to the benefits over time, the IRR*

calculation estimates the return from the project as an interest rate calculation. It is the rate of interest at which the present value of future cash flows is exactly equal to the initial capital investment.

This case study is one of a 21-part case study series aimed at demonstrating the value of science and innovation in New Zealand's leading edge bio-science industries... and their significance to New Zealand.

Martech Consulting Group is a strategic consultancy based in New Zealand. The growing**futures** case study series was in part based upon Martech's extensive work with sector representative groups, science providers and organisations that interact with science providers to achieve consensus on co-ordinated actions, improve governance, develop sector-based strategies and improve innovation processes.

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