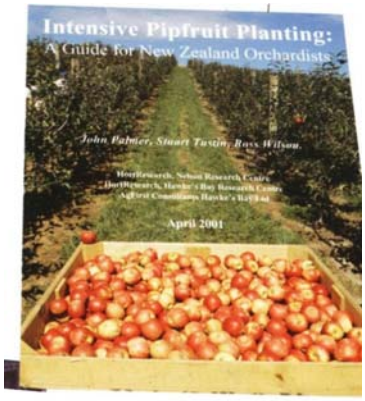
4. Advanced orchard systems lead to top yields for New Zealand apples



At 44 tonnes per hectare New Zealand ranks first equal with the Netherlands when it comes to apple yields (2001-03 data). France is a distant third at 37 tonnes per hectare and perhaps surprisingly Australia is well down the rankings at just 18 tonnes per hectare. New Zealand's climate and soils are well adapted to apple production, but the country's consistent performance as a top producer must be credited in part to (i) the technology and management skills of the orchardists and (ii) the underlying science. The tree management systems used in New Zealand's apple orchards today are testament to the continual innovation of both science and industry: Apple producers must make critical decisions about the components of orchard systems, e.g. apple variety, rootstock, tree density and tree quality, before a new orchard can be planted. These decisions have a greater impact on performance and profitability of the orchard than does the routine management of the orchard after it is planted.

- The search during the 1960s for better light interception and distribution within a tree led scientist Don McKenzie to propose that the traditional 'vase' tree shape be changed to a central leader shape. At the same time he evaluated a new 'semi-dwarfing' rootstock, Malling-Merton 106 (MM106) which gave tree size control and conferred precocious and regular cropping; enabling new semi-intensive orchard systems to be developed.
- Apple plantings expanded during the 1970s and innovative growers emerged who adopted the central leader tree style and more intensive orchard systems. Tree density increased from 275 to 670 trees per hectare. These changes in technology doubled the productive potential of New Zealand apple orchards. This seminal advance encouraged the sector to accepted innovation as a prerequisite for a profitable export industry.
- By the early 1980s apple growers sought improved efficiency and precocity (early fruiting ability) in their orchard systems in order to capture the high market returns of the new apple varieties. Science also produced virus-free rootstocks and budwood.
- Advisers observed European apple orchard systems and encouraged orchardists to increase tree density to around 1,000 trees per hectare using precocious rootstocks and reduced tree vigour with minimal canopy management.
- Excessive shading became a problem as these trees matured. Science moved to design a slender pyramid tree with a well-developed basal tier and improved light distribution. The science focus shifted from productivity to improving the quality of fruit (colour uniformity, size and taste) harvested from the apple production systems.

Intensive orchard systems are the quickest to reach full production, and growers benefit from higher returns from new apple varieties, better fruit quality, lower production and harvesting costs and better spray application efficiency. Science now seeks to combine dwarfing characteristics of rootstocks with disease and pest resistance, to facilitate the development of lower input production systems which are environmentally friendly and sustainable.

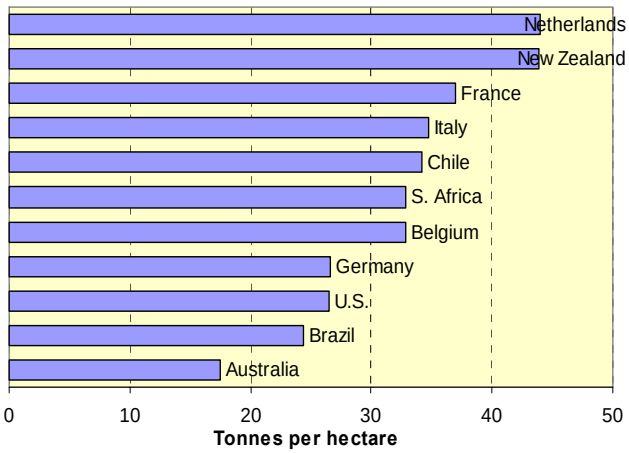
Industry observers argue that a failure to have introduced the central leader tree style during the 1970s would have probably led to a serious fall off in orchard profitability and possibly a consequential failure to successfully establish an apple export industry.

Effective tree management systems are crucial to the successful introduction of new apple cultivars which are at the core of the industry's long term strategy. This case study illustrates how science and industry have interacted over several decades, enabling innovations to be exploited to maintain the viability of the apple export sector.

1. Background

By global standards New Zealand apple yields are high. For the period 2001-03, similar yields of approx 44 tonnes per hectare were reported for New Zealand and the Netherlands. France was some 15% lower at 37 tonnes per hectare whereas Australia was well below at 18 tonnes per hectare. New Zealand's climate and soils are well adapted to apple production, but the country's consistent performance as a top producer must be credited in part to the technology and management skills of the orchardists and the underlying science. The tree management systems used in New Zealand's apple orchards today are testament to the continual innovation of both science and industry.

Average apple yields - 2001- 03



Source: World Apple Review 2004

Apple producers must make critical decisions about the components of orchard systems, e.g. apple variety, rootstock, tree density and tree quality, before a new orchard can be planted. These decisions during the establishment of the orchard system have a greater impact on performance and profitability of the orchard than the routine management of the orchard after it is planted.

The first intervention in tree management occurred during the late 19th Century when woolly apple aphids became a serious problem on New Zealand orchards – there were no natural enemies of the pest. In 1880 a local nurseryman found that the apple variety Northern Spy was resistant to woolly apple aphids and that it could be readily propagated by layering thereby facilitating its use a rootstock. The introduction of the Northern Spy rootstock saved the apple industry from disaster. However, it did not provide all the answers. During the 20th Century rootstocks were developed which had a natural resistance to soil borne diseases such as collar rot and root canker. The recent development of semi-intensive orchard management systems has increased the demand for heavy cropping dwarf and semi-dwarf rootstocks.

The rootstock constitutes the root system and a small portion of the lower trunk of most apple trees. The fruiting part of the tree, the scion (apple variety), is grafted onto the rootstock to form the whole tree. The two components are genetically distinct. There is a need to match the potential vigour of the scion variety with the dwarfing characteristics of the rootstock in order to get the desired tree vigour.

Apple rootstocks are used because apple varieties are usually difficult to propagate on their own roots and they will not grow true to type from seed. Rootstocks confer other benefits to trees such as controlling the vigour of the scion variety, tree habit and precocity (early fruiting ability), efficiency of cropping, and fruit quality. Rootstocks also help the adaptation of scion variety to diverse climates and soil conditions and often provide protection against aerial and soil borne pests and diseases. They are clonally propagated in order to produce uniform plants.

Because rootstocks control vigour, they enable the grower to specify a particular system of tree spacing, pruning and training. The scion variety can be grown on dwarf

and semi-dwarf trees that are small and closely planted making them easier and less expensive to manage. Dwarf trees can be more accurately targeted with crop protection sprays. Intensive orchard systems usually improve the economics of apple production where the unit costs of labour, capital and land are relatively high.

Modern tree management systems aim for high early yields, high sustained yields and excellent fruit quality. During the mid 20th Century most apple orchards were planted at densities of less than 250 trees per hectare. Today, tree densities in modern orchards range from 800 to 2,000 plus trees per hectare. Netherlands (2,110 trees per hectare), Belgium (1929), and Germany (2,056) are at the top of the range; whereas France (1,110), Italy (1,000), South Africa (950), and New Zealand (850) are mid range; and USA (600), Brazil (575), Chile (414), and Australia (412) are significantly lower. Modern orchards expect significant yields in Year 3 after establishment with mature yields reached by Year 5 and 6. Low density orchards begin production in Years 6 or 7 and reach mature yields in Years 10 to 15.

The search for better light distribution within the tree led DSIR scientist, Don McKenzie to propose a change from the traditional 'vase' tree style to a central leader style ('Christmas tree') semi intensive system during the 1960s. The 'vase' style trees were on vigorous rootstocks at 6m X 6m spacing and up to 6m in height, and taking 7 to 10 years to reach reasonable production, because is took that time for the orchard to develop adequate light interception and for full floral development to be achieved within the trees. Semi-dwarf rootstocks were introduced which enabled semi-intensive orchard systems with central leader trees to be established. These rootstocks were precocious (early fruiting ability) and controlled tree size.

New Zealand apple plantings expanded during the 1970s and innovative growers emerged who adopted the new central leader system that enabled more intensive plantings and tree density to be increased from 277 to 670 trees per hectare. This was a seminal advance which encouraged the apple industry to accept the need for innovation as a prerequisite to developing a profitable export industry - an approach which is alive today.

By the early 1980s apple growers sought improved efficiency and precocity in their orchard systems in order to capture the high market returns of the new apple varieties and minimise the high cost of capital. Science also led to improved virus-free budwood and rootstocks with higher tree vigour which needed to be controlled.

Advisers observed European apple orchard systems and encouraged orchardists to increase tree density to around 1,000 trees per hectare using precocious rootstocks and reduced tree vigour with minimal canopy management. However, excessive shading became a problem as these trees matured, and scientist Stuart Tustin and his team moved to design a slender pyramid tree with a well-developed basal tier and better light distribution. Shading was reduced and the individual fruit experienced a more uniform and better light environment leading to higher quality fruit and a greater percentage of fruit reaching export grade standards in size and appearance.

Intensive orchard systems enable growers to benefit from the higher returns of new apple varieties, improve fruit quality, lower production and harvesting costs and improve spray application efficiency. Scientist John Palmer joined HortResearch in the early 1990s and brought with him a wealth of experience of intensive orchard production systems which he attained during his research in the UK. This experience has been shared with New Zealand scientists and strongly supports the moves of New Zealand orchardists towards more intensive systems.

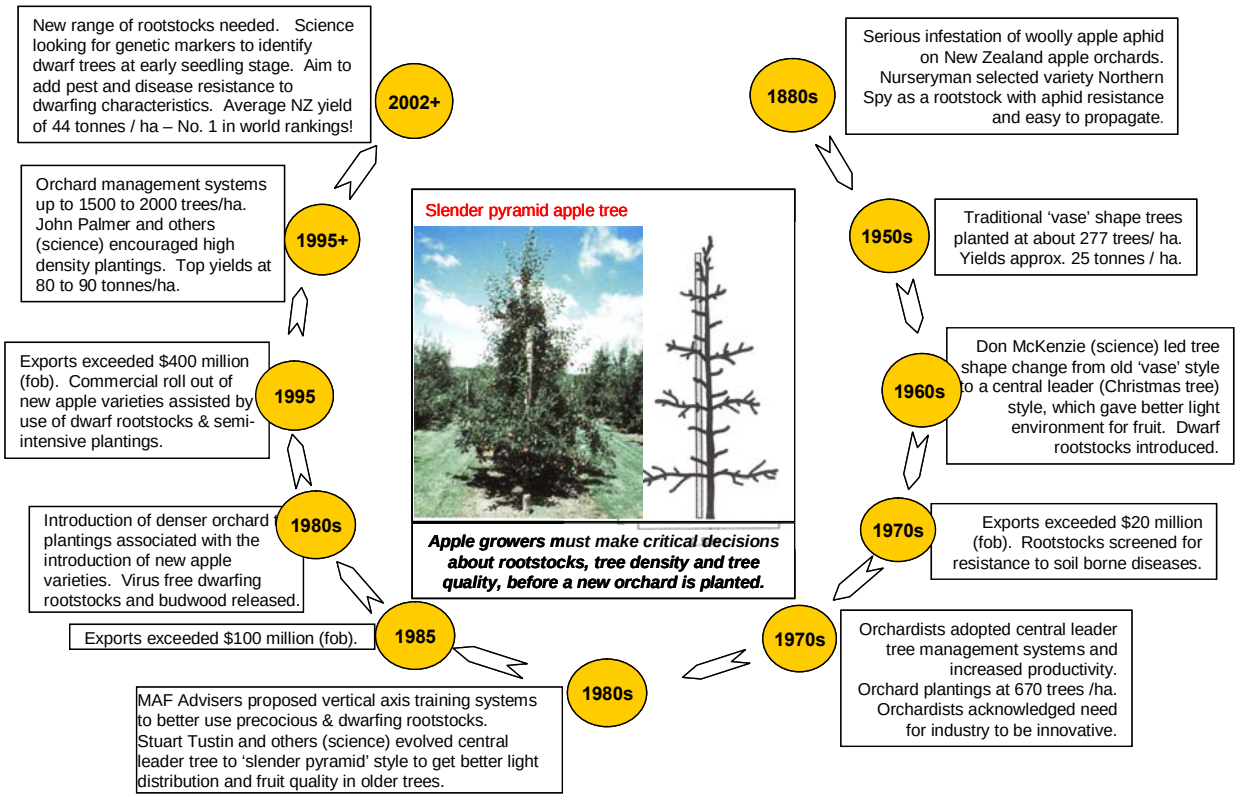
Science is now working to provide growers with a wider choice of rootstocks which combine dwarfing characteristics with disease and pest resistance and facilitate the development of lower input production systems which are environmentally friendly and sustainable.

Many dwarf rootstocks are susceptible to woolly apple aphid, whereas the commercial rootstocks *MM106* and *Merton 793* used since the 1960s were resistant to the aphid. However, the use of the dwarf rootstocks *Malling 9* and *Malling 26* went ahead because the benefits of production efficiency and improved apple quality were judged to out weigh the risks of woolly apple aphid infection. There was also some brief interest in *MARK* dwarf rootstock.

Developments in orchard tree management shifted the economics of apple growing in New Zealand during the 1970s. The improved economics became a necessity when the government refused financial support for the apple export industry during the 1970s. However, this move positioned the apple industry to be better placed to take advantage of export opportunities during 1990s and beyond.

New Zealand orchardists use intensive plantings to improve fruit quality and yield and to introduce new varieties into the orchard mix. New Zealand has around 88% of plantings in new varieties. The plantings of new varieties varies greatly among countries with Brazil at 91%, Belgium and Netherlands at 74%, Japan at 66%, and all other countries below 57%, including Australia at 36%. These figures underline New Zealand's dependence on orchard systems that will enable new varieties to be introduced easily and quickly.

2. Timeline



3. Science and innovation features:

- Improved productivity on-orchard was the focus of orchard tree management. Tree shape was changed from the older 'vase' style, to a central leader (Christmas tree) style.
- Dwarf rootstocks were introduced to control tree vigour and achieve early fruiting. Yield potential has increased from approx. 25 tonnes per hectare during the 1950s to around 80 to 90 tonnes per hectare on fully producing orchards in the 21st Century.
- Orchard management systems were designed to improve fruit quality and reduce variability. A key element was the modification of the central leader tree shape to produce a 'slender pyramid' architecture in which the size of the inner structural branches was reduced. These changes improved the light distribution within the tree and hence fruit quality and colouring.
- Research studies also showed that summer pruning could improve fruit quality especially for Gala and Royal Gala varieties. The uptake of summer pruning by orchardists was reasonably high.
- New apple varieties became available to the industry. The use of dwarf and semi-dwarf rootstocks enabled intensive orchard systems to be established with consequent early fruiting ability (1500 to 2000 trees/ha compared with the previous standard of 600 trees/ha). Science and technology is often involved in overseeing the adaptation of new varieties to various orchard systems and to different localities.
- Virus free rootstocks made available to industry.
- Throughout the past decades science and technology has established excellent networks which have enabled new ideas and technologies to be quickly introduced to New Zealand. The credibility of the New Zealand science with respect to intensive orchard systems is widely acknowledged and recognised by overseas science and technology experts.
- Ongoing challenge to develop a range of rootstocks which combine the dwarfing characteristics and precocity with disease and pest resistance and which will confer these qualities onto the scion. DNA technology is being brought to bear on this task. Gene markers have been identified that allow dwarf plants to be identified when the plants have just four leaves. The choice of rootstock is surprisingly limited when compared with the range of apple varieties. Developing new rootstocks by traditional methods can take up to 25 to 30 years – almost twice the time required to develop a new apple cultivar.

4. Benefits:

- The introduction of the central leader tree style during the 1970s led to increased orchard profitability. This innovation was an important contributor to the successful establishment of an apple export industry.
- Improved apple quality is illustrated by the pack out from slender pyramid trees which could be up to 20 percent above central leader trees for the light sensitive variety Gala.
- Introduction of semi-dwarf and dwarf rootstocks enabled more intensive orchard systems to be developed. The precocity of these rootstocks meant that orchards produced export apples much earlier than previously, i.e. within 2 to 3 years from planting.
- The sophisticated orchard systems employed by the New Zealand apple industry have significantly contributed to world class apple yields reached on New Zealand orchards.

- Experience with semi-intensive orchard systems has encouraged growers to plant new apple varieties in their orchards with an expectation of a reasonably early return. This has been a key factor in placing new apple varieties on the market.

5. Quotes:

"*Then Don (McKenzie) came along and worked with orchard management, rootstocks and breeding. A lot of us became his disciples and we latched onto his semi-intensive apple growing system. He believed that we had the light intensity to get a bigger tree and higher productivity than in Europe. His advocacy of the 106 rootstock and the single leader well–structured tree, formed a package that was the catalyst for the growth of the industry in the latter part of the 1960s and through the 1970s* ***when otherwise apple growing would not have been very profitable****."* John Paynter, 1999, Managing Director and owner of the Johnny Appleseed Group of Companies.

"*Yet back then New Zealand was able to sell a product that was in surplus all over the world - apples - because it had achieved a research-led advantage with the development of 'Granny Smiths', 'Galas', 'Braeburns' and had developed high yield systems of growing such as the Hawke's Bay modified central leader training system using MM106 semi-dwarf rootstock. We were operating in a surplus market, but we were smarter. That's what kept us on top. We were able to produce yields that the rest of the world envied and at costs per unit that were more than competitive. We were working on pretty good margins*." Prof Richard Rowe, Lincoln University 2003.

"*There is a marked trend towards intensive planting on dwarfing rootstocks at densities approximately two to three times the semi-intensive tree densities that were the norm in the past. This increased tree density is having a marked impact on the demand for apple trees. Varieties being planted are Royal Gala, Granny Smith, Fuji and Jazz™, Pink Lady and process pears. There is also renewed interest in planting Braeburn*." MAF Pipfruit Monitoring Report 2004.

"*Much of the future of the New Zealand apple and pear industry is riding on the ability of HortResearch to develop cultivars that can carve out market niches that are large enough and profitable enough to cover development costs and offset New Zealand's transportation disadvantages."* World Apple Review 2004.

6. Return on R&D investment

The return on investment was not assessed because there is a significant difficulty in obtaining a single causal relationship between the tree management systems which are used with many apple varieties and the sale of apples in both the export and domestic markets. Many other factors such as apple variety, integrated fruit production practices, climate, and soil will have an impact on the productivity of the apple orchards. Also results of an innovation such as particular tree management system will become apparent over a timeframe that is measured in years not months.

7. Related activities:

Apple breeding programme: HortResearch has entered a consortium with Pipfruit NZ Ltd, Apple and Pear Australia Ltd. and the Associated International Group of Nurseries to produce new apple varieties for the market. Optimum rootstocks and orchard systems for these new varieties must be identified if their potential is to be realised.

8. Information sources:

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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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