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## **Avocado Research by the New Zealand Avocado Industry**

This article describes the approach for avocado research and development taken by the New Zealand Avocado Growers' Association. An overview of the New Zealand avocado industry was provided in 2001 by John White who described the avocado industry in New Zealand as small and well organised in a structure that allowed strong competitive pressures and a high level of co-operation among participants when marketing the crop (2001 CAS Yearbook). In the intervening eight years, the New Zealand avocado industry has grown rapidly and now faces the challenges of rising production and falling value. Phytosanitary issues, export market diversification and meeting customers' sustainability expectations will all need to be managed going forward. The New Zealand avocado industry has been well placed to meet these challenges as a result of a strategic decision made in 1999 to invest in an 'in-house' research and development capability. The Avocado Industry Council Ltd, a wholly owned subsidiary of the New Zealand Avocado Growers' Association, is the organisation that invests heavily in internal research and development (R&D) capabilities. The following article outlines the R&D process

used by the New Zealand avocado industry, the benefits of internalisation and an overview of the outcomes achieved.

The New Zealand avocado industry is estimated to currently be about 12,350 acres with around 3,200 acres in trees less than five years old. There are at least 1,600 avocado growers with 80% of plantings located in the Bay of Plenty region of New Zealand. The Hass cultivar accounts for 95% of plantings and is usually grafted onto a seedling Zutano rootstock. The trees can generally be grown anywhere that is frost free and has free draining soils. Average annual yields vary from 7,100 lbs/acre to 3,400 lbs/acre with high producing orchards achieving over 30,000 lbs/acre. The total industry crop in recent years has varied from almost 59,000,000 lbs to 24,227,000 lbs. From 47% to 54% of the total crop is exported, with the majority of the fruit going to Australia, Japan, USA and South Korea. Domestic avocado consumption is rising and in 2008 was estimated to be about 4 lbs per capita.

While the domestic avocado market in New Zealand is largely unregulated, the export of avocados is regulated by statute under a multi-exporter umbrella. The Avocado Industry council registers exporters, packers and growers for export and sets the rules applying to export fruit including grade and maturity standards. These rules are established following a consultative process which includes the incorporation of relevant research findings into any discussions. Industry management and export activities are funded by a levy on export trays. Governance, promotions and research are funded through compulsory levies on domestic and export fruit. These self imposed levies are set through a consultative process every six years involving a ballot of members and ratified yearly by avocado growers at the Annual General Meeting for the domestic market and exported fruit.

### **Avocado research in New Zealand**

Prior to the year 2000, avocado research was conducted mainly by New Zealand government research agencies. Research funds were generally less than NZ\$50,000 annually and most of the research focused on tactical issues such as pest and disease control and post-harvest management of avocados. Information on the growing of avocados was sourced from Australia, the USA and South Africa and the knowledge applied without necessarily validating if it was

appropriate for New Zealand conditions. In 2000, the New Zealand avocado industry invested in its own research capability. The drivers for this internalisation of research were: the research conducted by the main research provider was perceived to be researcher driven and not responsive to current avocado industry needs, ownership of the intellectual property rights, cost effectiveness and the belief that research providers were more focussed on publication of research papers rather responding to grower's problems. This dissatisfaction coincided with a need to respond to a quality crisis in fruit exported to the USA in 2000. Spending on avocado research by the New Zealand avocado industry has increased since the year 2000 and now accounts for 29% of the Avocado Industry Council and Growers' Association combined budget in 2008. Although in US dollar terms this is less than a third of the CAC research budget, it is obtained off a productive base that is about 10% of the size of the California avocado industry.

### **Research strategy**

As with every avocado industry worldwide, the New Zealand avocado industry has more research questions than can be addressed with the available funding and so must prioritize the research. Research priorities are set through several processes that involve avocado growers and elected grower association representatives. The starting point for R&D investment decisions is the comprehensive R&D strategy which, together with the R&D priorities, sets the business plan on an annual basis. The activity identified as essential in the R&D strategy is linked into the business key performance indicators and ensures that research is relevant, connected to wider industry activities, and above all is for the growers benefit. Budgetary approval for projects is given by the executive committees of the Avocado Growers' Association and Avocado Industry Council.

In brief, the New Zealand R&D strategy has three outcomes: 1) To enhance the competitive advantage of the New Zealand avocado industry; 2) To sustain profitability for New Zealand avocado growers; 3) To position the New Zealand avocado industry for the future. Within each of the outcomes a number of goals have been set that are measurable and are time bound. For example, in Outcome 3 positioning the New Zealand avocado industry for the future there is a goal on market access: To manage pests and diseases to accept-

able levels with maximum residue limits acceptable to all markets by 2015. Another goal in Outcome 3 is on up-skilling avocado growers: To increase avocado growers understanding of factors limiting production such that 90% of industry production key performance indicators are achieved by 2015.

There is no research committee in the traditional sense but an overview of research is given by a R&D Strategy Committee. Grower endorsement and feedback on the proposed annual research plan is obtained by canvassing nominated grower members of the Avocado Growers' Association. Once a year up to 12 avocado growers are nominated by their district representatives to participate in one of the R&D reference groups. These are non-partisan groups, tasked with identifying the avocado problems that require a research approach to resolve. Issues are canvassed 'blind' and individually without coaching to address the "I agree with what everyone else has said" issue. A list of research topics is collated and common themes identified by consensus. These in turn are then compared to the proposed industry research programme to check if it meets grower's needs. The industry executive then decides if the research should be funded.

A similar process is carried out with the post harvest sector of the New Zealand avocado industry. In addition, avocado growers are welcome at anytime to suggest a research topic and the industry welcomes unsolicited approaches from individuals and companies with innovative ideas.

The focus of the internal R&D programme is applied research that can be used to resolve avocado problems rather than an end goal of producing research papers in scientific journals. To provide communication to other avocado researchers and to be sure that all research findings are captured, the results of each project are published in an Annual Research Report. The papers presented in the Annual Research Report explain in detail each research project and are released into the public domain where they are available to all. Over time the Annual Research Report has formed a valuable reference resource for researchers, consultants and technically minded avocado growers. Through the Annual Research Report New Zealand avocado growers have a detailed record of research funded by New Zealand avocado growers written in a scientific format that other avocado researchers can objectively evaluate as a form of peer review.

Funding for research is obtained from two main sources: compulsory levies collected by the industry, and contestable research grants that can leverage growers' research funds dollar for dollar or fully fund a project. External research grants account for a third of the money spent on research by the New Zealand avocado industry.

The research programme run by the New Zealand avocado industry makes extensive use of grower co-operators, with support from packers and exporters. This close industry contact is an important contributing factor for the successful outcomes obtained from research projects over the past few years. Involving industry stakeholders in the research programme also helps the New Zealand researchers keep their "feet in the mud" of the orchard. Where the Avocado Industry Council has the capability to competently carry out research it will do so to save costs. When there are projects that require the use of specialist expertise and equipment not available within the Avocado Industry Council then the research is externally contracted, either as a 'stand alone' project or a joint Avocado Industry Council and research service provider project.

Another rationale for in-house research capability is the ability to respond to an industry crisis with technical expertise to resolve the problem quickly. With an 'in-house' research capability the New Zealand avocado industry is able undertake any necessary research using contingency funding. Since 2000, this capacity to respond to an ongoing crisis has served the avocado industry well with the quality crisis in the USA essentially resolved by 2002, and market access maintained into Australia in 2006.

### **Scope of Research Activity**

In 2009, the New Zealand avocado industry employs two scientists with PhD's, two full time technicians with horticulture or science degrees, and a part time technical assistant. In past years there has been up to four full time technicians and a junior scientist employed for various projects. The Avocado Industry Council has dedicated facilities for avocado fruit quality and plant physiology research. The Avocado Industry Council also maintains a research orchard with a weather station and has several field sites where avocado cultivars are being evaluated and field trials conducted.

There have been 87 project reports in the New Zealand research

yearbook since 2000, with a further 12 projects to be reported in the next yearbook. About 30% of the projects have been outsourced to external research providers. Most of the research effort is focussed on understanding avocado quality, 25% of projects were aimed at understanding avocado tree productivity, with 15% of projects targeting sustainability. There is also an ongoing commitment to importation, evaluation and maintenance of new avocado cultivars. The New Zealand avocado industry does not engage in avocado breeding research. At present the Avocado Growers' Association is funding three projects on germplasm that includes a rootstock trial for phytophthora tolerance and evaluation of fruiting cultivars.

While there have been clearly demonstrable benefits to internalisation of research capability, where the average rate of return has been calculated at \$15.40 for every dollar of levy funds (AvoScene, March 2007), the approach also has inherent limitations. An inevitable consequence of this pragmatic approach is the need for simplification. However, this carries with it the danger of over simplification and the possibility of reaching a false conclusion. Research findings need ongoing confirmation and re-evaluation in light of new information. There is also the perception that a "broad brush approach" results in a poorer quality of science than would otherwise result from publication of a scientific journal/article. The ultimate arbiter of the quality of the research is if the original problem is resolved. Extensive protocols explaining the scientific rationale of the approach taken and detailed methodology are utilised for internal debate and are available for external peer review. An 'in-house' research capability requires a long term commitment to funding R&D that requires strong political support from the avocado industry politicians. The pressure to reduce rather than maintain R&D funding can be strong when returns to growers are low or the crop is irregular with low levy takes in the down years. Competition for limited research funds can create a point of tension with research providers where the funding allocation is though a contestable funding pool. Research results are written up in the form of a research paper to facilitate critical review and the research is presented at scientific conferences. Working collaboratively with research providers and supporting scientists outside of the Avocado Industry Council aims to maintain positive relationships with research providers. The most powerful quality control tool

available to the Avocado Industry Council is to be able to analyse industry statistics to assess the impact of changed management practices on industry performance.

### **Research Reporting**

Effective communication of research findings to avocado growers is of great importance to the New Zealand avocado industry. In addition, publication of scientific reports is recognised as an important quality control element of the research program and possibly a basis for exchanging information with other avocado researchers.

The New Zealand avocado industry uses a variety of methods to communicate research results to avocado growers:

- The Annual Research Report is a formal publication where research projects are presented in a scientific paper format.
- The Growers' Manual is a comprehensive guide for growing avocados in New Zealand.
- Grower guides published as booklets summarising orchard management during important growth stages.
- Tech sheets where specific topics are succinctly summarised in two pages.
- Field days held on orchards where topical issues are described and discussed with avocado growers.
- New Zealand grower conference every second year and a joint conference with the Australian avocado industry every four years and presentations to the World Avocado Congress.
- Articles in the industry magazine 'AvoScene'.
- The New Zealand avocado industry website ([www.nzavocado.co.nz](http://www.nzavocado.co.nz)).

Avocado growers often find it a challenge to apply research findings to the management of their own orchard. The New Zealand avocado industry recognises that the transfer of information to growers can be the most problematic aspect of an industry research programme. The New Zealand avocado industry seeks to have effective implementation of research findings by growers through collating and describing the new information in the wider context of tree management. Such a pragmatic approach is required for successful uptake of new information but distillation of key messages requires simplification and some assumptions to be made in order to facilitate



uptake. Technology transfer is assisted by the detailed descriptions of the research findings in the Annual Research Report with simplified summaries presented in technical bulletins and field days delivered by orchard consultants and Avocado Industry Council staff.

## **Research Outcomes Since 2000**

### **Improved Quality Systems for Export**

The New Zealand avocado industry exports the majority of its avocado crop to distant markets, for example the USA is an 18-21 day voyage by container ship. In 2000, the New Zealand avocado industry implemented an avocado fruit quality system that provided feedback to industry stakeholders. A library tray system was developed along with fruit arrival surveys in California that captured information on fruit quality problems as the harvest season progressed. This system allows any problems to be quickly identified and proactively managed at source as the season progresses. The findings of the fruit quality surveys in California were validated through controlled experiments in New Zealand and verified that the key to good avocado fruit quality was management of fruit age. At the other end of the postharvest handling chain research on the relationship between dry matter content and quality demonstrated that a minimum harvest dry matter standard of 24% provided the best fruit quality for long distance shipping. Further studies were also conducted on postharvest rots aimed at orchard control and packhouse and cool chain management. Packhouse phytosanitary measures have been modified to improve fruit quality. There has been detailed research on understanding the avocado fruit ripening process and the impact of handling systems on ripe fruit quality especially those that promote water loss after harvest.

These research findings were implemented quickly into the general industry systems through inclusion in the Avocado Industry Council export quality manual that forms part of the requirements for exporting. The New Zealand avocado industry requires fruit age to be managed through a maximum on-shore consolidation time allowed before shipping. This is reduced progressively during the harvest season as the fruit become more mature. The combined effect of numerous small improvements to the postharvest handling chain resulted in a significant overall improvement in fruit quality prevent-



ing a reoccurrence of the original quality problems.

### **Commercialisation of New Cultivars**

The comparatively late development of the New Zealand avocado industry has seen a singular focus on Hass in terms of cultivars planted. Longer term, the need to diversify is recognised and the New Zealand avocado industry has adopted a long term strategy to source the best proven avocado cultivars from around the world. The Avocado Industry Council is required by statute to set the rules governing export of avocados and as such needs to understand the extent to which the growing and post harvest handling of a new cultivar may differ from the traditional Hass cultivar. Avocado cultivars introduced into New Zealand are evaluated in a staged process ultimately leading to commercial release. The Avocado Industry Council has leased land for the evaluation of material required to obtain plant varietal rights (the equivalent in California is a patent) and to establish the horticultural merits of any new cultivars. New cultivars that are controlled by the Avocado Industry Council have been imported from South Africa, Mexico and Australia. The owners of the cultivars have appointed the Avocado Industry Council as their agents to manage the intellectual property rights and collect royalties on trees sold. An 'in-house' research capability has allowed the New Zealand avocado industry to conduct research on new avocado cultivars at a lower cost than contracting to external research providers. The knowledge gained about new avocado cultivars can be quickly incorporated into industry management systems. To date there have been releases of Phytophthora tolerant rootstocks from South Africa and there are several new fruit cultivars undergoing postharvest trials.

### **Phytosanitary Successes**

The New Zealand avocado industry regards its phytosanitary obligations very seriously for both incursions of pests and diseases into New Zealand and preventing interceptions in export markets. In recent years there have been two major phytosanitary issues facing the New Zealand avocado industry, avocado scab (*Sphaceloma perseae*) and Avocado Sunblotch Viriod (ASBVd). Both of these diseases have been shown to be not present in New Zealand. Avocado scab was removed from the New Zealand pest list as it had been misidenti-

fied and ASBVd was removed following a comprehensive survey using the latest technology for detecting viroids. While most of the research on each pest was conducted by external research providers expertise within the avocado industry meant research findings were rapidly incorporated into industry practice to meet new phytosanitary needs. When an urgent technical question arose and a knowledge gap was identified there was the 'in-house' capability to do the research required at short notice, contract out any additional research required and then make changes to industry systems, backed by management systems and financial resources.

### **Sustainability Systems**

Responsible use of pesticides, sustainable growing systems and presenting consumers with fruit that is safe to eat are important goals of the New Zealand avocado industry. Responsible use of pesticides is addressed through a pest monitoring program, AvoGreen™, that is based on the principles of Integrated Pest Management (IPM) with sprays only applied according to need. Using a combination of control methods the program aims to keep pest populations at levels below those that can cause economic loss and with careful monitoring and trace-back systems provide overall quality and safety assurances to all customers. Considerable research backs up the AvoGreen™ system. The sampling methodology has been determined through surveys of pests on avocado orchards. Fruit residue compliance is monitored by residue testing of export fruit that forms part of the New Zealand avocado industry food safety program. Included also is a web based electronic spray diary that ensures the fruit to be harvested observes minimum withholding periods for each pesticide for the intended market.

The New Zealand avocado industry relies on copper-based fungicides to control fruit rots. The use of copper fungicides ultimately leads to a long term accumulation of copper in the soil. A survey of over 150 orchards determined that very few orchards had total soil copper levels exceed recommended thresholds. At the levels of soil copper found there were no detrimental effects on yield. Different formulations of copper fungicides, methods of applying copper and the use of a super spreader adjuvant have been researched and can be used in the future to minimize soil copper loadings.

### **Tree Growth Cycles and Horticultural Management**

New Zealand is considered to have a 'warm temperate' climate for growing avocados and is at the limit of where avocado trees can be successfully cropped on a commercial basis. Despite the cool temperatures some avocado orchards achieve crops of over 30,000 lbs/acre and average orchard yields are similar to that observed in many avocado growing countries. Alternate bearing typifies the cropping pattern of avocado trees in New Zealand. Information on growing of avocados was historically imported into New Zealand from Australia, the USA and South Africa. Although this provided a good base of knowledge, as a starting point it has its limitations. For example, Hass avocado trees in New Zealand have a very high proportion (60%-100%) of flowering shoots that are determinate in an 'onflowering' year. Development of tree management systems to minimise alternate bearing has been undertaken in New Zealand. This research has yielded new information on the pattern of growth of avocado trees in New Zealand and novel concepts regarding avocado phenology.

New Zealand's cold winters were assumed to place avocado trees in an effectively dormant or quiescent state during the winter months. Research on photosynthetic rates during winter showed that the leaves remain photosynthetically active throughout winter given sufficient light and water. Photosynthetic rates are low at winter temperatures and daylength is reduced, but this is still sufficient to provide, along with mobilisation of starch reserves, photosynthates to size fruit, accumulate dry matter and starch during the coldest months of the year. This also implies that root activity is sufficient to support transpiration and there is likely to be mineral uptake from the soil. Some New Zealand avocado growers are now applying fertiliser during the winter period to support heavy crops. Analysis of orchard temperatures over several years has shown that fruit set is not wholly dependent on temperature at pollination and that good fruit set can occur at temperatures that researchers outside of New Zealand would claim to be too low.

Flower induction/initiation on Hass trees in New Zealand was thought to occur at the approach of winter. Research by the Avocado Industry Council indicates that flower induction occurs at the end of summer or early fall but the timing varies by several weeks depend-

ing on the cropping history of the trees. Interestingly, this timing is similar to that reported from Mexico. Hass avocado trees in New Zealand appear to set most fruit on the spring growth flush (the flush that grows with the flowering) rather than the summer flush. Therefore having sufficient growth that occurs with the flowering is important on New Zealand avocado trees to ensure a return crop. Detailed studies of the growth flushes have revealed that in addition to indeterminate flowering shoots where a new shoot grows out of the flower panicle there is another type of shoot growth where vegetative buds break and grow from behind the flower panicle on determinate flowering shoots. This growth, while occurring in spring, begins several weeks after growth on indeterminate flowering shoots. The growth consists of multiple weak shoots that have fewer flower buds than shoots from indeterminate flowering branches. This new knowledge has been presented to New Zealand avocado growers in booklet format as grower guides.

The phenology research has driven a critical examination of the basic growth cycle of the trees with a view to seeking drivers of yield. Development of avocado tree management strategies for New Zealand requires both a detailed understanding of tree phenology but also to re-examine options for achieving high yields. Events preceding harvest are viewed as parts of a two year growth cycle commencing with shoot initiation of the flowering wood in the year before flowering. This revised paradigm has arisen from individual results of many projects and explaining the research in the context of the horticultural management of avocado trees. These research results have been communicated to growers from the perspective of a 'big picture' view of how the avocado tree grows and fruits in New Zealand.

### **Knowledge exchange**

The New Zealand avocado industry research programme is only a small fraction of the worldwide avocado research effort. The New Zealand avocado industry continues to support New Zealand avocado researchers outside of the Avocado Industry Council through networking, sharing of research results and by supporting collaborative projects with international avocado researchers. Support for attendance at international conferences by industry scientists and scientists from research providers is considered to be a valuable way

to share research findings that lead to new ideas. In this way avocado research in New Zealand can be subjected to international peer review and kept abreast of the latest international developments.

## **Conclusions**

Research conducted by the New Zealand avocado industry concentrates on offering solutions to avocado growers within a reasonable timeframe as opposed to the goal of producing a scientific paper. There is an advantage of using 'in-house' research capability where problems have to be clearly defined and framed within an industry context so that the research can answer a specific question. Having an implicit knowledge of the industry systems has allowed the Avocado Industry Council to better direct external research providers into research considered to be of most importance to the New Zealand avocado industry. The internalised research capability has the advantage of possessing an overview, in both a tactical and strategic sense, leading to the development of more effective and pragmatic solutions than would be possible without an overarching perspective. This has resulted in a strong ability to influence and change industry systems. By shifting the emphasis away from producing scientific papers research has been allowed to deliver solutions more quickly. The challenge for the researchers is to achieve the right balance between obtaining solutions and robustness of the research and effective technology transfer to impart knowledge in orchard operations.

Implementing research findings in a commercial framework is best achieved through small incremental changes. This contrasts with a 'silver bullet' solution that involves considerable change to many systems. In solving the quality problems for avocados exported to the USA it was the combination of many small improvements by all industry stakeholders that gave a large improvement in quality. By using 'in-house' research, industry systems can be changed as the need arises making the New Zealand avocado industry research effort very responsive to challenges.

The New Zealand avocado industry has a strong commitment to R&D as an important method to overcome industry issues when they arise and to meet long term industry strategic goals. This research is industry led and directly addresses the industry business plan rather

than being researcher led. Systems have been developed that allow continual feedback on the performance of the system. This approach creates the expectation of continual improvement to industry systems. The benefit to New Zealand avocado growers has been more robust postharvest management of exported avocados and improved knowledge of avocado horticultural management under New Zealand conditions. The New Zealand avocado industry has benefited considerably in overcoming phytosanitary challenges rapidly to maintain market access. Such achievements would have been more difficult and costly without an 'in house' capability.