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Growing Organic Apples

World class production systems for new Australian apple varieties

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Growing Organic Apples

World class production systems for new Australian apple varieties

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Abbreviations

ACO	Australian Certified Organic Pty Ltd
APAL	Apple and Pear Australia Limited
ARS	Applethorpe Research Station, Stanthorpe, Queensland
BFA	Biological Farmers of Australia
DPI&F	Department of Primary Industries and Fisheries, Queensland
HAL	Horticulture Australia Limited
IFP	Integrated Fruit Production
LAI	Leaf Area Index
LBAM	Light Brown Apple Moth (*Epiphyas posvittana*)
LSD	Least Significant Difference
PAR	Photosynthetically Active Radiation
PBR	Plant Breeders Rights
RIRDC	Rural Industries Research and Development Corporation
TCA	Trunk Cross-sectional Area
USDA	United States Department of Agriculture
WFT	Western flower thrip (*Frankliniella occidentalis*)

mm	millimetre
cm	centimetre
m	metre
g	gram
kg	kilogram
t	tonne
ha	hectare

apple scab	apple black spot caused by *Venturia inaequalis*

Foreword

Organic apple production is an increasing, though difficult to quantify segment of the Australian apple industry. A small number of apple growers, for reasons ranging from a philosophical opposition to the use of synthetic agricultural chemicals, to wanting to farm for continued sustainability of Australia's agricultural land, have already chosen to produce their crop using organic production systems. Reported price premiums for organic apples have piqued the interest of conventional apple growers to consider conversion to organics. Pests, diseases and weeds that are usually controlled in conventional production systems by the use of agricultural chemicals can, however, prove difficult to manage once these chemicals are eliminated from the farming system.

Australian apple growers considering organic production need to be aware they will face similar, and often more arduous challenges to those faced by non-organic apple orchardists. Managing the orchard to produce quality fruit for market requires careful attention to tree nutrition, tree phenology (annual growth cycle), pest, disease and weed management, and can be a significant cost for the organic apple producer. The commercial apple varieties currently grown by the Australian industry are susceptible to a range of pests and diseases, in particular apple scab (black spot), a major fungal disease of apples world-wide caused by the fungus *Venturia inaequalis*. To address this deficiency in current varieties, the Department of Primary Industries and Fisheries, Queensland (DPI&F) initiated a conventional breeding program to develop new apple varieties resistant to apple scab. Several of these selections have potential for organic production.

While conventional orchard systems rely heavily on applied synthetic fertilisers and pesticides, organic apple producers have relatively few organically certified products available for crop protection and nutrition. Instead, organic management aims to achieve a 'balanced' system using cultural practices which recycle nutrients and resources on-farm, with limited use of allowable inputs.

The importance of this report is that it provides the information required for successful organic production of a new scab-resistant Australian apple variety. The un-named variety is currently protected by provisional Plant Breeders Rights and is referred to by its breeding code of 'RS103-130'. Evidence that this variety can be grown organically is of value to apple growers intending to convert to organic production, but who may have some concerns that apple scab would be a significant impediment to successful production.

The study was funded by the Rural Industries Research and Development Corporation, Horticulture Australia Limited, Apple and Pear Australia Limited and the Department of Primary Industries and Fisheries, Queensland. It is an addition to RIRDC's diverse range of over 1800 research publications and forms part of our Organics R&D Program, that aims to facilitate the development of a viable organic industry through increasing adoption of sustainable organic farming systems.

Most of our publications are available for viewing, downloading or purchasing online through our website www.rirdc.gov.au.

Peter O'Brien
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Executive summary

What the report is about

The increasing demand for organically produced agricultural and horticultural commodities has attracted attention from conventional producers who see the organic market segment as a potential outlet for their product. This interest in organics is also occurring in the apple industry, but to grow conventional apple varieties using organic systems is difficult, due in part to pressures from some pests and diseases. One of these, apple scab (black spot), is a major fungal disease occurring in most regions where apples are grown. The cost of apple scab to the Australian apple industry has been estimated at upwards of $10 million annually in lost production and chemical control.

New apple varieties with resistance to apple scab are being developed by the Department of Primary Industries and Fisheries, Queensland (DPI&F). This report identifies strategies to grow scab-resistant apples organically in Australia, as demonstrated in a commercial planting on a Queensland orchard.

Who is the report is targeted at?

The report is targeted at industry and government interests in organic apple production, and conventional apple growers considering a shift into organic production systems.

Background

The Australian apple industry has reduced its reliance on synthetic agricultural chemicals in the past decade, and with the adoption of integrated fruit production (IFP) principles is poised to be recognised as one of the world's more eco-friendly apple producers. To help facilitate this industry direction, DPI&F has supported an apple breeding program to develop new varieties with resistance to apple scab.

One of these varieties is 'RS103-130', which will soon be available to Australian apple growers and help them meet consumer demands for healthier agricultural food products grown using reduced agricultural chemicals. It has a broken red stripe to almost full block red overcolour on a yellow-green to yellow background, matures mid-season (six to eight weeks after 'Royal Gala'), has exceptional shelf-life and is juicy with a sweet, low-acid and mild flavour. As part of this project, 'RS103-130' was selected for a new commercial planting to determine strategies appropriate to the organic production of new Australian scab-resistant apples.

Aims

This project was designed to show Australian apple growers that 'RS103-130', a new scab-resistant apple variety bred and developed for Australian conditions, can be successfully grown using organic production methods. The variety was grown organically for four seasons in the Stanthorpe district of southern Queensland, where up to 12 primary infection periods for apple scab can occur during the spring and early summer. The Stanthorpe district is one of the more marginal apple growing regions of Australia, and if appropriate strategies can be developed to organically produce scab-resistant apples in Queensland, it is highly likely that this can also be achieved in other apple growing regions of Australia which contend with fewer environmental, pest and disease pressures.

The project also determined a range of strategies for successful organic apple production, and included trials to develop 'Tree management packages' for 'RS103-130' and an additional three scab-resistant apple selections.

Methods used

The project consisted of two major components. The first of these was the establishment of a block of organically grown scab-resistant apple trees in the orchard of a large commercial grower in the Stanthorpe district of southern Queensland. The orchardist was a non-organic grower with an influential standing in the industry, and an interest in organic production

that had not yet translated into the adoption of organic farming practices.

In January 2001, one hectare of existing stone fruit orchard was removed on the property, and the organic certification process for the site initiated with Australian Certified Organic (ACO), the certification arm of the Biological Farmers of Australia (BFA). From 2001 onwards, only organically approved inputs were applied.

The initial planting in winter 2001 was of 120 trees of the scab-resistant apple 'RS103-130', and 80 trees of the commercial variety 'Galaxy' planted as a comparator. With subsequent plantings the site now consists of 1000 trees of 'RS103-130', 51 trees of a second scab-resistant apple variety, and the 80 'Galaxy' comparator trees.

The site was used to determine organic farming practices appropriate for the production of scab-resistant apples, to identify problems (and their solutions) encountered in organic apple production, and to provide a demonstration block of trees for apple growers considering a shift into organic production.

The second component of the project consisted of high density planting system trials for four scab-resistant apple selections, including 'RS103-130'. These were planted as replicated trials at Applethorpe Research Station (ARS), and included evaluation of a range of rootstocks and tree densities to develop 'Tree management packages' appropriate for the new apple selections.

Key findings

The project identified a range of strategies for successful organic apple production in Australia, and demonstrated that the scab-resistant apple variety 'RS103-130' can be successfully grown in Queensland using organic production methods. The robustness of the scab resistance of 'RS103-130' has been demonstrated in the field, with no apple scab occurring on trees or fruit of 'RS103-130' despite the presence of apple scab on 'Galaxy' trees planted as a commercial standard within the organic block.

While 'RS103-130' is resistant to apple scab, and control sprays for this disease are not needed, the apple scab resistance is conferred by a single major gene complex (V_f derived from *Malus floribunda*) that appears to be simply inherited when varieties with this gene are used in a conventional cross-breeding program.

Caution is therefore warranted to avoid exposure of resistant varieties to excessive pressure from apple scab in field situations. For this reason, a management strategy for apple scab recommended as part of the tree management package for 'RS103-130' is to use a single, green-tip copper spray in early spring, when there is greatest disease pressure from the apple scab fungus.

The comparator cultivar 'Galaxy' is susceptible to apple scab, and a seasonal apple scab control program for this variety is essential. A green-tip copper application followed by lime sulphur in late dormancy, with wettable sulphur applied fortnightly—just prior to predicted rain events throughout the season, has provided effective management of both apple scab and powdery mildew.

Weed management is a significant issue in Australian apple orchards, in particular for organic producers. Standard practice in conventional apple orchards is to control weeds with herbicide. This reduces soil microbial diversity, and in the sandy soils of the Stanthorpe district creates a bare soil surface which crusts and is impenetrable to rainfall, leading to excessive runoff.

Weed mat was used at the organic apple trial site for the first two years (the critical tree establishment phase), but supplementary hand hoeing was still required to provide adequate weed control. A seed bank of weeds progressively established on the surface of the mat, with the roots of weeds penetrating down through it and into the soil. Due to concerns about the effect of weed competition on soil moisture and tree productivity, a 20 cm layer of sugar cane mulch was also tested as a weed control strategy, in combination with supplementary organic compost (equivalent rate 10 tonnes/ha).

Sugar cane mulch effectively controlled weeds, and in 2005 (third leaf) the largest 'RS103-130' apples were produced from trees treated with organic compost and sugar cane mulch. The long-term effects of these weed management and tree nutrition treatments on tree growth and productivity are yet to be determined.

In a preliminary comparison of soil quality beneath the sugar cane mulch in the organic orchard and in the herbicide strip beneath conventionally-managed trees in an adjacent block of apples, biological activity was greater, soil temperature was reduced, and water infiltration increased 40-fold beneath the sugar cane mulch. The improved infiltration is particularly important, as much of the rainfall received in many apple growing regions of Australia occurs as high intensity storms. Soil biological activity, as indicated by soil respiration, was increased under the sugar cane mulch, but was still at a low level. This needs to be measured over several years to confirm if sustained use of sugar cane mulch can improve the biological activity of 'poor quality' soils. Excessively high soil temperatures of 30°C can reduce tree productivity in orchards, especially with the Malling rootstocks (MM.106, MM.109, M.26) commonly used in Australia. The 10°C reduction in soil temperature under sugar cane mulch provides trees with an improved soil environment in which to grow.

An organic apple production guide has been produced which details strategies for successful organic production of scab-resistant apples in Australia. It was developed using the results of trials conducted in this project, information obtained from a review of literature at the commencement of the project (and subsequently tested and amended in trial work), and incorporation of the principles outlined in the National Standard for Organic and Bio-Dynamic Produce.

Implications

The project has conclusively demonstrated that a Queensland-bred apple variety with resistance to apple scab can be grown organically in the Stanthorpe district of southern Queensland. The spring and summer rainfall experienced in this locality makes it a high risk environment for apple scab infection. The total absence of apple scab on leaves or fruit of 'RS103-130' during the term of this project suggests this variety is ideally suited to organic production systems in other apple producing regions of Australia.

The availability of a new, high quality scab-resistant apple variety at the organic retail level not only offers more choice to the organic apple consumer, but provides orchardists with the opportunity to produce organic apples a little more easily than if growing the standard varieties currently available. 'RS103-130' apple is crisp, sweet, juicy and mild-flavoured with low acid, and has good shelf life when harvested fresh off the tree. It has scored favourably in consumer evaluations, and offers organic consumers a pleasant eating experience while providing a healthy snack product produced without harmful chemicals.

Recommendations

Specific recommendations for organic apple production in Australia are included in an organic apple production guide written as part of this project.

Apple growers wishing to develop their varietal mix of organically produced apples are encouraged to plant and test 'RS103-130' when it becomes commercially available. The recommendations in this report are targeted in the first instance to current Australian organic apple growers, and secondly to non-organic growers who are contemplating the switch to organic production, but have to date been hesitant to do so. 'RS103-130' is also recommended for testing on conventional apple orchards yet to undergo the conversion process to organic production.

Although pests and diseases present particular challenges in organic apple production, drought and soil quality are factors that affect the productivity of all organic and non-organic apple orchards in Australia. Indeed, as Australian apple orchardists adopt more efficient production systems to meet market demands for high quality, 'clean, green' fruit, it is the potential effect of soil management strategies on soil quality, water use efficiency and managing drought that may ultimately see more orchardists adopt organic systems for apple production.

Plate 1. Scab-resistant apple variety 'RS103-130'

1. Introduction

There is currently an increasing level of attention directed by the media and popular press to the rising levels of obesity, diabetes and general health issues in Australian society (e.g. Redfearn 2006). Coupled with an awareness of the potential for the foods that we eat to do us harm (e.g. toxicity of peanuts to susceptible individuals), an increased consumer interest in healthy food has helped drive the demand for organically produced foodstuffs.

Recent research commissioned by the Australian apple industry shows that domestic consumption of fresh apples is static. When combined with reduced Australian apple exports and increased imports of apple juice concentrate, there is likely to be a continued oversupply of apples in the immediate future. Consequently, there is fiscal pressure on Australian apple growers to explore alternative markets for their product and to ensure the apples they produce are of the high quality required by consumers. A perceived price premium for organically grown apples is an enticement for apple growers to consider organic production, regardless of their philosophical leanings or any consideration of environmental sustainability.

Appropriate varietal selection and high fruit quality are critical for Australian apple orchards to remain viable. The increased need for environmentally sustainable horticultural production systems that place minimal demands on natural resources, especially water, is also a driving force for orchardists to adopt more efficient production systems.

Organically produced apples offer one option for growers seeking higher returns, and practical production systems need to be developed to help satisfy consumer demand for organic produce. Neither the seven organic certifying bodies in Australia nor Apple and Pear Australia Ltd (APAL) keep statistics of organic apple production, however organic apple production in Australia is relatively small, and estimated to currently total no more than 8000 tonnes per annum.

The Australian environment is a challenging one for agricultural and horticultural producers, whether conventional or organic. The introduction of European farming practices from the late eighteenth century onwards has led to soil degradation through erosion, salinity, acidification and structural breakdown (Alenson, 2001), and with few exceptions soils are shallow and of low fertility and low organic matter content. In addition, climatic variability characterised by cycles of drought and floods makes average annual rainfall an unreliable indicator of the suitability of a region for horticultural production.

Apple production in Queensland is confined to the Granite Belt region around Stanthorpe, at an elevation of 800–1000 metres. The soils are derived from decomposed granite and are typically shallow and sandy, overlying a semi-pervious to impervious clay layer. They are generally of poor fertility, low water holding capacity and low organic matter content. The climate is characterised by cool to mild winters (average maximum 14°C, average minimum 1°C) and warm summers (average maximum 28°C, average minimum 16°C). The 750 mm average annual rainfall is concentrated in spring and summer, and predominantly occurs as high intensity storms. Extreme weather events (drought, hail, heatwaves) are frequent, and present apple growers with considerable challenges in producing consistent yields of high quality fruit. The warm growing conditions provide an ideal environment for pests, diseases and weeds.

Apple scab (caused by the fungus *Venturia inaequalis*) is a major disease of apples in Australia, and costs the Australian apple industry up to $10 million per annum in control measures and lost production. Apple varieties resistant to the apple scab fungus have been bred and developed in the Department of Primary Industries and Fisheries, Queensland (DPI&F) apple breeding program (Zeppa et al. 2002). Several selections show promise as high quality apples with the potential to be grown in both organic and conventional systems.

There has been little research in Australia specific to organic apple production, although much of the research into pest, disease and soil management in conventional apple orchards is also applicable to organic apple systems. Europe has led the way in the research and adoption of organic systems for apple production, followed by North America.

Studies in Italy (Boscheri & Mantinger 1994), Switzerland (Meli & Schmid 1994), the Netherlands (Groot 2000) and Germany (Brzozowski 2004) have included details of the yields, costs and labour inputs required in organically managed apple orchards, and the problems encountered during periods of transition from conventional to organic apple production. In the Swiss study (Meli & Schmid 1994), the highest annual yield in the eight years from planting was 33 t/ha, with over 80% of apples sold as grade I or II.

In California, insect and disease problems resulted in significantly reduced yields and market value of organically-produced apples, compared to conventionally-produced apples (Vossen et al. 1994). The organic production system was more expensive to manage and was considered a greater risk to the grower. Swezey et al. (1998) in the USA also reported organically managed orchards required higher material and labour inputs than conventional orchards. However, using farm-gate premiums of 33–38% received by the grower for unsorted, certified organic apples, comparative cost accounting showed greater net returns per hectare for the organically managed orchards.

It should be noted that in many of the earlier European and North American studies, organic production systems were based on traditional apple varieties, characterised by low yields due to reliance on old systems and management technologies.

In establishing an organic orchard, Kellerhals et al. (1997) stress that the choice of site is critical, due to the effect of frost, hail, wind, sunshine and soil conditions on potential disease incidence and orchard productivity. In preparing replant soil for organic apple production, Shalimov (1991) compared the use of various crop rotations used for two to three years prior to planting. Five years after planting, the yields and profitability were highest from apple trees planted into plots previously sown to several crops of rye + sorghum.

Soil testing prior to planting and at regular intervals thereafter is essential to monitor and meet the nutrient requirements of organic apple orchards (Heller & Weibel 1997). Nutrients are frequently supplied to organic orchards by side-dressing of composted manure, however inadequate nitrogen can be a major limitation to tree growth in organic orchards ((Neilsen et al. 2007). The rate of release of nitrogen, mineralisation potential and nutrient composition of composts vary, and can be difficult to quantify (Neilsen et al. 2007).

Calcium is another critical nutrient in organic apple production. Bitter pit is a physiological disorder in apple fruits induced by calcium deficiency, and can be common in organic orchards (Weibel et al. 2000). The incidence of bitter pit is related to the K:Ca ratio in the top soil layer (Weibel 1997), however organic calcium complexes are available that can be used as supplementary foliar sprays (e.g. Wooldridge et al. 1997).

In Queensland, root lesion nematodes (*Pratylenchus jordanensis*) are a primary contributing factor to tree decline in replanted orchards. Organic control and management of root lesion nematode is possible through a combination of thorough removal of root material from the previous orchard, spelling the ground for one to two years, incorporation of green manure crops and animal manure during this period, appropriate rootstock selection and maintenance of a layer of organic mulch around the trees (Stirling et al. 1995).

Weed management is a major issue facing organic apple producers, as excessive competition from weeds can significantly reduce the growth and yield of apple trees (Hogue & Neilsen 1987). Weibel (2002) and Neilsen et al. (2007) have considered the advantages and disadvantages of organic methods of weed control, which include mulches, mechanical tillage, flame weeders and brush cutters.

Mulches (eg. straw, bark, sugar cane) are commonly used in organic apple orchards, however cost and availability vary and can be prohibitive to their use. Straw mulch was shown by Hartley & Rahman (1997) to be more effective than pine sawdust or wooldust in controlling weeds in apple orchards. The straw mulch had negligible effect on tree growth, yield, leaf and fruit nutrient levels when compared to trees in plots treated with conventional herbicide. After one year, the straw also harboured higher numbers of earthworms (532/m^2) than the sawdust (196/m^2), wooldust (152/m^2) or herbicide (296/ m^2) treatments.

In Washington State, organic soil management practices that included additions of bark mulch and composted poultry manure resulted in lower soil bulk densities and improved biological soil properties compared to conventional soil management using synthetic fertiliser and herbicides (Glover et al. 2000). An additional advantage of mulch is the reduction in soil temperature (Himmelsbach et al. 1995; Hartley & Rahman 1997).

One of the more challenging management issues in organic apple production is crop load regulation. Strimmer et al. (1997) tested a mechanical thinning machine, as well as chemical thinning agents (waterglass, soap, mineral oils and oil-seed-rape oil) approved for organic apple production in Italy. The thinning machine consisted of high speed rotating cords to physically knock off flowers and fruit buds on the periphery of trees, but also damaged the bark. Although trees treated with oils or soap had 20-40% fewer fruitlets, the thinning agents caused fruit russet and leaf necrosis. Lime sulphur sprays have been successfully used as a blossom thinner (Stopar 2004; Kelderer 2004), but can also induce leaf phytotoxicity symptoms (leaf scorch and small leaves).

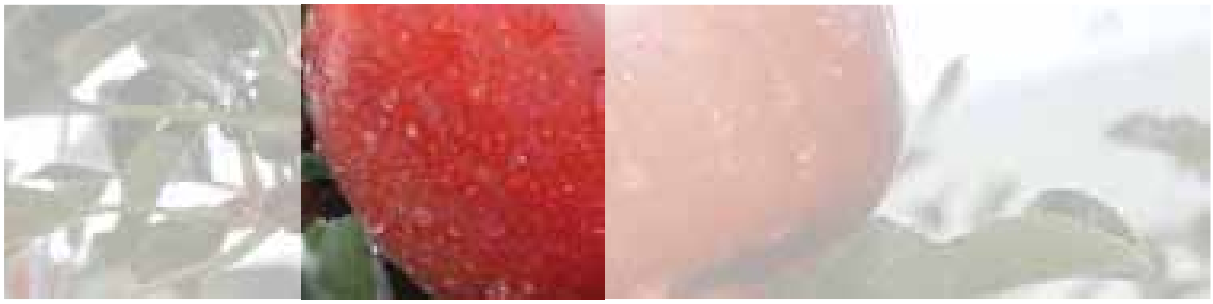
There remains a heavy reliance on hand thinning to reduce crop load in organic apple orchards. Swezey et al. (1998)

reported that due to differences in crop load on trees that are hand-thinned compared to chemically-thinned trees, yield is often higher, but fruit size smaller, on organically managed trees that are hand-thinned. Hail netting, through its effect on tree shading and orchard microclimate, can also reduce fruit set and the level of thinning required, especially on more vigorous trees (Middleton & McWaters 2002).

Pest and disease management options for organic apple orchards in European and North American locations have been studied and summarised by several authors, including Berrie & Cross (2000), Swezey et al. (2000), Kelderer (2004) and Neilsen et al. (2007). The most likely significant diseases and pests to occur in organic orchards in Australia are apple scab (caused by the fungus *Venturia inaequalis*), powdery mildew (caused by the fungus *Podosphaera leucotricha*), codling moth (*Cydia pomonella*), light brown apple moth (*Epiphyas posvittana*), woolly apple aphid (*Eriosoma lanigerum*), apple dimpling bug (*Campylomma liebknechti*), native budworm (*Heliocoverpa punctigera*) and Queensland fruit fly (*Bactrocera tryoni*).

Strategies tested in this project to manage these pests and diseases include mating disruption, mite predators, parasitoids and *Bacillus thuringienses*, in addition to regular monitoring, trapping (codling moth, Queensland fruit fly), and attention to orchard hygiene, tree health and soil management. The use of high quality, scab-resistant varieties from the DPI&F apple breeding program should assist in the successful development of organic strategies appropriate to Australian apple orchardists.

2. Objectives and methodology



Objectives

The four primary objectives of the project were to:

- Review the techniques used in organic apple production around the globe, including approved methods and inputs, identification of national and international 'experts', costs, problems and possible solutions.
- Develop world class organic apple production systems with associated 'Tree management packages' aimed specifically at producing organic apples from new scab-resistant apple varieties derived from the DPI&F breeding program. Most fungicide applications in apple orchards are used to control apple scab, caused by the fungus *Venturia inaequalis*. The use of apple varieties resistant to scab will help overcome one of the greatest hurdles to successful organic apple production in Australia.
- Determine organic 'best management' strategies which integrate the most effective organic (and where appropriate, IFP) methods for pest and disease management, weed control, plant nutrition and crop load regulation. The aim is to produce fruit that will comply with and obtain organic accreditation in Australia, as well as comply with the organic standards of European Union countries.
- Encourage non-organic apple growers to adopt organic farming techniques, through the demonstration of appropriate orchard and tree management strategies, and identification of the benefits, costs and practical problems (including solutions) likely to be encountered in Australia. Queensland is one of the more marginal apple growing regions of Australia, and if appropriate strategies can be developed to organically produce scab-resistant apples in Queensland, it is highly likely that this can be achieved in other apple growing regions of Australia which contend with fewer environmental, pest and disease pressures.

Methodology

The project consisted of several key components. Some aspects of the project were conducted as research trials and experiments, some as demonstration trials, and some as part of a communication strategy for growers.

For ease of reporting and comprehension by the reader, the methodology used in each component of the project is included as appropriate in the following three chapters.

Similarly, a discussion of results and a brief summary is included with each of these chapters, and an overall summary of the project and recommendations is provided as Conclusions.

3. Establishment of organic apple trees on a commercial orchard

The organic apple trial site discussed in this chapter was primarily used as a demonstration planting to establish and manage a block of trees of a scab-resistant apple variety on a large commercial orchard. The objectives of this site were to (i) show non-organic apple growers that successful organic production of a scab-resistant variety is achievable, (ii) identify major and minor problems in organic apple production and the solutions to these problems, and (iii) to undergo the process of organic certification in a newly-planted commercial block of trees.

Methodology

One-year-old nursery trees of 'RS103-130' apple (*Malus x domestica* Borkh.) and 'Galaxy' (comparator variety) were planted on a commercial orchard in August 2002 in the Stanthorpe district of southern Queensland (280 37'S). All trees were on MM.106 rootstock at a spacing of 5 metres x 1.8 metres (1111 trees/ha), and trained to a free-standing central leader system. The initial planting consisted of 120 trees of 'RS103-130' and a row of 80 trees of 'Galaxy'.With subsequent plantings, the one hectare site in 2005 consisted of 1000 trees of 'RS103-130' and a row of 51 trees of a second black spot resistant apple selection, in addition to the row of 80 'Galaxy' trees in the centre of the block and 15 crab apple polleniser trees ('Golden Hornet' and 'Manchurian') planted randomly throughout.

The area was covered by a permanent hail netting structure, and bordered by native Eucalypt forest and a *Pinus radiata* plantation. The outside row of a block of conventionally grown apples was 100 metres to the east of the site.

Soil type was gritty, siliceous sands amongst rock outcrops (Wills 1976), and typical of the Stanthorpe apple growing region. Pre-plant soil analysis showed pH 5.5–5.9, organic matter 1.9%–2.3%, organic carbon 1.1%–1.3%, and low nitrogen, phosphorus, potassium and magnesium. Nutrient status has been monitored annually with soil and leaf analysis.

The site was previously planted to peach trees. These were uprooted, and the above-ground parts of the trees cut up *in situ* and incorporated back into the soil as wood chip. All tree roots were removed from the site. Pre-plant soil preparation included 3 tonnes/ha dolomite, 1.5 tonnes/ha soft rock phosphate, and 10 m^3 of organic compost (Enviroganics Pty Ltd) incorporating 250 kg/ha sulphate of potash. A crop of forage sorghum (*Sorghum bicolor*) was grown in the summer preceding the planting of the orchard. The sorghum was slashed and incorporated into the soil to add vegetative bulk and organic matter, and to augment soil structure.

After planting of the trees, the alleyways were sown to a mixture of white clover (*Trifolium repens*), perennial rye grass (*Lolium perenne*), oats (*Avena sativa*) and lucerne (*Medicago sativa*) to create a permanent sod. A T-tape drip irrigation system (40 cm outlet spacing, 2 litre/hour capacity) was used to irrigate the trees, with irrigation rate and frequency scheduled on the basis of EnviroScan soil moisture readings.

The general management of trees is summarised in Table 1. Monitoring for pests and diseases occurred once a week, and all orchard operations and treatments conformed strictly to organic production guidelines. Yields were collected from all trees in 2005 and 2006 (the first two cropping seasons), and fruit quality, fruit blemishes, pest and disease damage assessed for all apples harvested.

The organic certification of the site was conducted annually by ACO (Australian Certified Organic Pty Ltd), the certification arm of the Biological Farmers of Australia (BFA). Full organic certification was granted in 2005. All inputs continue to be monitored, recorded and annually audited to ensure ongoing compliance with BFA organic standards and continuance of organic certification.

Table 1. General management practices used in the organic production of 'RS103-130' and Galaxy' apples during the first four years from planting

Operation	Management practices
Pre-plant	Removal of all roots from previous peach trees Green manure crops – sorghum, oats, lucerne Dolomite, Soft rock phosphate, Organic compost
Weed control	Weed mat, Sugar cane mulch, Hand hoeing
Alleyways	Perennial rye grass, White clover, Oats, Lucerne
Nutrition	Organic compost, Biodynamic fish emulsion, CaB™
Disease management	Lime sulphur (late dormancy for apple scab and powdery mildew management) Wettable sulphur just prior to predicted rain, or Lime sulphur within 3 days after rain finished (early season for apple scab management) Symptomatic shoot removal (powdery mildew) Symptomatic leaf removal (*Alternaria*)
Pest management	Winter oil (San José Scale) Hand removal (Painted Apple Moth, Loopers) Mating disruption – Isomate Plus (Codling moth/LBAM) *Bacillus thuringienses* (Loopers, LBAM, Native budworm) Spinosad (Native budworm, LBAM, WFT)

Results and discussion

Despite ongoing drought, tree growth was satisfactory and a small crop of fruit was harvested in 2005 (third leaf). In 2006 (fourth leaf) the trees produced significant quantities of Australia's first crop of organically grown Australian-bred scab resistant apples. The scab-resistant selection 'RS103-130' was derived from a population of 'Royal Gala' seedlings produced using pollen from 'CPR7T90', a scab-resistant selection (from the Purdue-Rutgers-Illinois program) that has the V_f resistance gene complex.

'RS103-130' matures mid-season (six to eight weeks after 'Royal Gala') and has a broken red stripe to almost full block red overcolour on a yellow-green to yellow background. Fruit is round-conic in shape with a medium length stalk. Flesh is off-white, medium textured, crisp and breaking. It is juicy with a sweet, low-acid and mild flavour. 'RS103-130' has exceptional shelf life, and when picked fresh off the tree retains firmness after seven to 14 days at room temperature. Fruit colour up very late on the tree (within two to three weeks of harvest), which helps ensure the apples are harvested close to optimum maturity for both storage and fresh market consumption.

Diseases and pests

To date, the scab resistance of 'RS103-130' has proved durable under Queensland growing conditions. No scab lesions have been observed on fruit or leaves of 'RS103-130' since planting, whereas 4.6% and 1.1% of harvested 'Galaxy' apples at the organic site were infected in the first two cropping seasons (Table 2). This demonstrated that the 'RS103-130' trees were being exposed to *V. inaequalis*, and that the resistance was holding up in the field. Powdery mildew (caused by *Podosphaera leucotricha*) was minimal, and effectively controlled by wettable sulphur sprays supplemented with hand removal of infected shoots from the orchard.

An observation trial comparing the ability of preventative wettable sulphur sprays and curative (after rain) lime sulphur sprays to manage foliar fungal diseases was also conducted in this block. Sprays were applied as described in Table 1. Apple fruit were rated for *Alternaria*, apple scab and *Glomerella* symptoms at harvest. Although a randomised, replicated trial was not conducted, this work provided anecdotal evidence that both forms of sulphur may provide similar levels of foliar fungal disease control for 'RS103-130' and 'Galaxy'.

Table 2. Pest and disease incidence (% of fruit numbers damaged) in the first two crops of organically produced 'RS103-130' and 'Galaxy'

	2005		2006	
Pest/disease	Galaxy	RS103-130	Galaxy	RS103-130
LBAM	27.2	49.6	6.4	1.9
Native Budworm	25.5	18.4	59.5	32.7
Qld Fruit Fly	5.9	4.9	7.8	3.2
Apple Scab	4.6	0.0	1.1	0.0
Glomerella	0.7	0.6	1.0	0.5
Alternaria	0.5	2.3	1.3	0.0
Codling Moth	0.4	0.8	0.2	0.3
No Damage	na	na	14.9	49.2

na: not assessed

The most significant causes of insect damage to fruit (Table 2) have been native budworms (*Heliocoverpa punctigera*) and Light Brown Apple Moth (LBAM) (*Epiphyas posvittana*). LBAM damage was high in 2005, when no control measures were used. Pheromone disruption and spinosad provided effective control of this pest in 2006, and this has continued. Similarly, *Bacillus thuringienses* and spinosad are providing adequate management of native budworms. Although a high proportion of fruit are affected by native budworms (Table 2), most damage is minor and the fruit is of acceptable appearance to consumers of organic apples. Spinosad-based bait spraying is maintaining populations of Queensland Fruit Fly (*Bactorcera tryoni*) at an acceptable level.

White clover (*Trifolium repens*) planted in the alleyways grew prolifically and appeared to attract damaging insects, including western flower thrip (WFT) (*Frankliniella occidentalis*) away from the trees. There have been no "pansy spot" symptoms on fruit produced at the organic site. Indeed, in screening trials 'RS103-130' has shown tolerance to this pest, with no fruit damage occurring despite high numbers of WFT present in the flowers.

Painted Apple Moth (*Teia anartoides*) is a significant pest in organic apple orchards in Queensland. The larvae of this moth feed on and skeletonise leaves, and can rapidly strip the foliage of a young apple tree. Two outbreaks of this pest emphasised the importance of close and continuous monitoring in organic apple production. Due to early intervention, Painted Apple Moth has been confined to a few trees and effectively controlled by hand removal.

Two spotted mite (*Tetranychus urticae*) has not been found in the organic orchard, yet it is a significant problem in conventional orchards where care is required when using standard spray programs to avoid killing mite predators such as *Typhlodromus pyri*. Similarly, there has been no evidence of woolly apple aphid (*Eriosoma langerum*) at the organic apple trial site. Insect biodiversity in the organic block was monitored, and the increased biodiversity appears to be impacting on insect pest levels. Very high populations of Ladybirds (*Hippodamia* spp., *Coelophora inaequalis*) have been recorded compared with the adjacent conventionally-managed block of apples.

Kangaroos (*Macropus* spp.) have been a major problem due to the ongoing drought and the close proximity of the trial site to forest. The kangaroos nibble on shoot tips and leaves, as well as break shoots and branches whilst feeding on green crops in the alleyways and fallow ground. An electric fence only partially solved the problem.

Hail netting

Hailstorms are an annual occurrence on the Granite Belt, and hail netting of apple orchards is essential. Additional benefits of hail netting include reduced fruit sunburn and the elimination of birds, which can cause considerable losses as fruit approach maturity. Exclusion netting is also an organic option for Queensland Fruit Fly control, but is very expensive.

Hail netting reduces sunlight (PAR) levels by 12–25% (Middleton and McWaters 2002). Incident sunlight levels in the apple producing regions of Australia are high, and under Queensland conditions, the more moderate environment beneath hail netting improves fruit quality and tree productivity. In addition, tree water use efficiency is improved through reduced evapotranspiration (Middleton and McWaters 2002).

Fruit set at the organic apple site was satisfactory, with only moderate hand thinning required. Hail netting can reduce fruit set (Middleton and McWaters 2002) and is beneficial in reducing the need for thinning, provided tree vigour is kept under control. It should be cautioned that excessive fruitlet shedding may occur on over-vigorous trees due to shading effects on bud strength. Hail netting combined with the presence of flowering white clover during the apple blossoming period has helped to regulate crop load at the organic apple site, where all trees are of moderate to low vigour.

Honeybees (*Apis mellifera*) were attracted to the white clover and hence did not solely work the apple blossom. It is important, however, to ensure that sufficient hives are introduced for adequate pollination, and that the white clover doesn't attract all bees away from the apple trees. If white clover is simultaneously in flower with the apple trees, mowing alternate alleyways during the apple blossoming period can help prevent this occurring. To mow all the alleyways in this situation will only encourage thrip populations to move from the orchard floor into the apple trees.

Summary

Based on results from the first four years of this planting, a summary schedule of recommended orchard operations is reproduced in Appendix A as an annual calendar of activities for organic apple production.

Australia's first commercial crop of organically grown and organically certified, Australian-bred scab-resistant apples ('RS103-130') was harvested from this site in March 2006. Some of these apples were marketed and sold through an organic wholesaler in Sydney, receiving an average price of $37 for first grade and $32 for second grade fruit per 12 kg two-layer carton. The wholesaler also undertook in-store promotional activities for the organic 'RS103-130' apples, including tastings and distribution of leaflets. Customer feedback was excellent, and the apples sold quickly at the retail level.

An economic analysis spreadsheet for organic apple production has been developed (Appendix B). This has been based on the actual costs of recommended orchard operations undertaken at the commercial organic apple trial site, and returns of $32 per 12 kg two-layer carton as obtained for the second grade fruit sold through the organic wholesaler in Sydney. The analysis showed that organic apple production was profitable, provided annual yields of 17.4 tonnes per hectare were obtained from year four onwards, with year seven as the 'breakeven' year. It should be cautioned, however, that this analysis is based on many assumptions, as outlined in Appendix B. Flexibility is included in the model, and the effect of changes in yield, costs and returns can be determined for individual circumstances.

Plate 2. Tree of 'RS103-130' at the commercial organic apple trial site

Plate 3. Grading Australia's first commercial crop of organic 'RS103-130' apples

4. Organic weed management and soil health

Introduction

Weeds are a significant problem facing all Australian orchardists, and the availability of strategies to effectively manage weeds is a major consideration influencing the decision of non-organic growers to move into organic apple production. Non-organic apple growers rely almost entirely upon herbicides to control weeds. This practice, although a quick and cost-effective measure, can have deleterious impacts on soil physical, chemical and biological properties. Apple growers need practical, organically-approved strategies for weed and soil management if the organic apple industry is to further expand.

Methodology

Two field trials were established to evaluate organic weed management strategies for apple production.

'Galaxy' weed management trial

A field trial was planted at the DPI&F Applethorpe Research Station (ARS) in Queensland to compare a range of organic weed management strategies, and the effect of these on apple tree growth and productivity. The experiment also included a conventional herbicide treatment for comparison.

'Galaxy' trees on MM.106 rootstock were planted in October 2003 at a spacing of 3.6 m x 1.0 m (2777 trees/ha) and trained to a vertical trellis. During the first growing season (2003/2004), all plots at the site were hand hoed to remove weeds. The weed management treatments described below were then applied in the 2004/2005 and 2005/2006 growing seasons, when the trees were in their second and third leaf. The first apples from the experiment were harvested in 2006.

The experiment was designed as a randomized complete block, with ten weed management treatments each replicated three times using plots of four or five trees.

The weed management treatments were:

- no weed control
- conventional herbicide
- weed mat (polypropylene non-woven matting)
- mowing of alleyway, and clippings placed along the row beneath trees
- sugar cane mulch
- sugar cane mulch + spot spraying with pine oil as required
- living mulch (Japanese millet sown beneath the trees and burnt off with pine oil as necessary)
- hand hoeing every week to keep weed-free all season
- hand hoeing between January and April only (second half of the season); no weed control in the first half of the season (September to December)
- 'sandwich' system.

The 'sandwich' system for weed control was developed in Switzerland (Weibel 2002). The 'sandwich' consists of two cultivated strips approximately 50 cm wide and parallel to the tree row at a distance of 15–20 cm on either side of the apple tree trunk, with a low-growing 'living' mulch directly beneath the trees. In this experiment, white clover (*Trifolium repens*) cv Haifa was sown beneath the trees and allowed to establish as a living mulch, and hand hoeing used to form and maintain the cultivated strips on either side of the tree row.

Weed management in the commercial organic apple trial

Weed mat (polypropylene non-woven matting) buried under a layer of pine chip mulch was used successfully at the commercial organic apple trial site (Chapter 3) for the first two seasons, but necessitated supplementary hand hoeing to provide adequate weed control beneath the young trees. A seed bank of weeds progressively established on the surface of the mat, with the roots of weeds penetrating down through the mat and into the soil. Due to concerns about the effect of weed competition on soil moisture and tree productivity,

organically-certified sugar cane mulch was tested as an alternative weed control strategy.

In 2004/05, an experiment commenced at this site to compare the effectiveness of weed mat with sugar cane mulch (20 cm depth) for weed control, in addition to the effect of a supplementary organic compost application (equivalent rate 10 tonnes/ha) on tree growth and productivity. A two x two split plot randomised block design was used, with weed mat and sugar cane mulch as the main treatments (10 trees/plot), and compost/nil compost as the subplot treatments. There were four replicates (five trees/plot) of each treatment for 'Galaxy' and eight replicates of each treatment for 'RS103-130'. Crop load was standardised, and tree growth, yield and fruit quality data collected from individual trees and analysed using Genstat v8.

Soil parameters beneath the sugar cane mulch in the organic orchard were compared with those in the bare soil herbicide strip beneath apple trees in an immediately adjacent block of 'Galaxy' apple trees grown conventionally. Soil respiration and water infiltration were measured according to the procedures described in the USDA Soil Quality Test Kit Guide (USDA 1999), in addition to soil temperature at 10 cm depth.

Results and discussion

After two seasons there was little difference in the productivity of trees in the 'Galaxy' weed management trial at ARS, and no effect of weed management treatments on tree size and growth, as indicated by trunk cross-sectional area (Table 3). The 2006 harvest was a light first crop as the three-year-old trees were relatively small and grown under drought conditions with minimal irrigation. Yield and fruit size were significantly lower on trees with no weed control (Table 3), where high populations of weeds competed for the limited soil moisture. By contrast, highest yields were harvested from trees growing in soil treated with herbicide and kept weed-free all season.

It made no difference to tree growth, yield and fruit size whether trees were hand hoed all season or for only the second half of the season, from January to April (Table 3). The presence of weeds beneath trees from October to December hence had no effect on productivity. Under less stressful conditions with adequate supply of water, differences between these and other weed management treatments will likely become evident, especially in subsequent years as the trees become larger and reach full fruit bearing capacity. The experiment will therefore be continued, and with the recent availability of a ready supply of treated effluent water, can now be irrigated at optimal frequency.

At the commercial organic apple trial site (Chapter 3), 31 weed species have been identified to date. Cobblers Pegs (*Bidens pilosa*), Fat Hen (*Chenopodium album*), Green Couch (*Cynodon dactylon*) and Purple Top (*Verbena bonariensis*) were among several weed species that have particularly been a problem. For effective management in an organic orchard it is imperative that these species are not allowed to flower and seed.

Table 3. The effect of weed management strategies on the yield, average fruit weight and trunk cross-sectional area (TCA) of 'Galaxy' trees in their third leaf (2006)

Weed management	Yield (kg/tree)	Average fruit weight (g)	TCA (cm^2)
No weed control	1.9	137	5.4
Conventional herbicide	4.6	162	7.6
Weed mat	3.3	168	7.2
Mowed clippings as mulch	3.2	161	7.5
Sugar cane (SC) mulch	2.7	154	6.4
SC mulch + Pine oil	3.7	154	8.2
Living mulch + Pine oil	2.6	147	7.4
Hand hoeing (all season)	3.8	159	7.2
Hand hoeing (Jan - Apr)	3.3	157	6.8
'Sandwich' system	3.1	150	6.4
LSD (p<0.05)	*1.0*	*15*	*NS*

NS: not significant

LSD: Least Significant Difference

In 2005, the largest 'RS103-130' apples were produced from trees treated with sugar cane mulch and organic compost (Table 4). There was no difference in 'Galaxy' fruit size on trees growing in weed mat or sugar cane mulch. As an early season apple with a six to eight week shorter growing season than 'RS103-130', 'Galaxy' is a smaller apple. There was sufficient soil moisture during the early part of the season to adequately size 'Galaxy' apples. Dry conditions between the harvest of 'Galaxy' and the harvest of 'RS103-130' saw weed competition have an effect on the fruit size of 'RS103-130'. Sugar cane mulch effectively controlled the weeds, however by contrast, there was prolific growth of weeds through the weed mat, leading to competition for soil moisture with the 'RS103-130' trees.

Compost application increased the size of 'Galaxy' and 'RS103-130' apples, regardless of the weed management system used (Table 4).

Standard practise in conventional apple orchards is to control weeds with herbicide. In the Stanthorpe district, this creates a bare soil surface which crusts and is impenetrable to rainfall, leading to excessive runoff. In a preliminary comparison of soil qualities beneath the sugar cane mulch in the organic orchard (Chapter 3) and in the herbicide strip beneath conventionally-managed trees in an adjacent block, soil temperature was reduced and water infiltration and biological activity increased with the sugar cane mulch (Table 5).

The 40-fold increase in water infiltration beneath the sugar cane mulch is particularly significant. Most rainfall in

southern Queensland occurs as high intensity storms, and the soil beneath the sugar cane mulch is able to absorb much of this precipitation. Conversely, most rain runs off the bare soil herbicide strip. The second infiltration rate reading for saturated soil is less significant, as soils generally dry out considerably between rainfall events. Soil biological activity, as indicated by soil respiration, is increased under the sugar cane mulch, but is still at a low level (USDA 1999). It will be of particular interest to monitor this over time in the organic block. Excessively high soil temperatures of 30°C can reduce tree productivity, especially with the Malling rootstocks commonly used (MM.106, MM.109, M.26). The 10°C reduction in soil temperature under sugar cane mulch provides the trees with an improved soil environment in which to grow.

Measurements of soil parameters in September 2006 (Table 6) confirmed the results from December 2004. With the trees just coming out of dormancy and soil temperatures only just starting to rise after winter, a soil temperature difference of 4°C was already evident between sugar cane mulch and herbicide. The addition of supplementary compost further increased water infiltration beneath the sugar cane mulch (Table 6).

Summary

The beneficial effects of sugar cane mulch and compost on soil properties requires further study, and may necessitate apple orchardists, whether organic or non-organic, to re-consider their weed and soil management strategies in the future. As pressure on Australia's limited water resources increases and the cost of irrigation water rises, it is crucial that agricultural industries adopt sustainable soil management strategies that maximise crop water use efficiency.

Table 4. The effect of sugar cane mulch, weed mat and supplementary compost on the average fruit weight (g) of organically-produced 'Galaxy' and 'RS103-130' apples in 2005

Compost rate	Weed management	Average fruit weight (g) 'Galaxy'	'RS103-130'
10 t/ha	Sugar cane mulch	163.9a*	230.0a
10 t/ha	Weed mat	165.3a	191.9b
0 t/ha	Sugar cane mulch	147.7b	191.2b
0 t/ha	Weed mat	142.8b	170.0c

**Means in the same column followed by the same letter are not significantly different (p <0.05)*

Table 5. Preliminary comparison of soil qualities (December 2004) in the organic apple orchard (sugar cane mulch) and in an adjacent conventional apple orchard (bare soil herbicide)

Soil parameter	Organic (Sugar cane mulch)	Conventional (Herbicide – bare soil)
Soil Temp (°C) 10 cm depth	20.3	30.2
Soil Respiration (kg CO_2/ha/day)	12.3	5.6
Infiltration rate (cm/min)		
dry	49.8	1.2
wet	1.8	0.6

Table 6. Soil qualities (September 2006) in the organic apple orchard (sugar cane mulch) and in an adjacent conventional apple orchard (bare soil herbicide)

Treatment	Temp (10 cm) (°C)	Soil Respiration (kg CO_2/ha/day)	Infiltration (cm/min)		pH
			Dry	Wet	
Herbicide	17	0.5	2.8	1.2	6.9
Sugar cane mulch	13	1.5	11.5	2.2	7.9
Sugar cane mulch + compost	13	1.3	30.6	2.0	7.6

5. Tree management packages for new Australian scab-resistant apple varieties

Introduction

The DPI&F apple scab resistance breeding program based at ARS commenced in 1985, with the objective of developing scab-resistant apple varieties that are adapted to Australian growing conditions, and that satisfy the fruit quality requirements of consumers.

Several apple selections from this program show considerable promise, and have the potential to be grown organically. One of these, 'RS103-130', is currently protected by provisional Plant Breeders Rights (PBR) in Australia and is being tested and evaluated for agronomic and fruit quality traits. It should be noted that for the purposes of Plant Breeders Rights, until the selections in these trials are secured by PBR here in Australia, the 'intellectual property' (IP) of these potential varietal releases is at risk. This is particularly so in relation to securing United States Plant Patents in the event of future commercialisation overseas. Consequently, the selections cannot be named or fully described in publications that will ultimately reach the public domain.

With the exception of 'RS103-130', the scab-resistant selections are therefore referred to as 'Selection 2', 'Selection 3' and 'Selection 4' and only broad, generic descriptions are given. An application for United States Plant Patent for 'RS103-130' will be made by the end of 2006, so description of this variety must also, by necessity, be scant. 'RS103-130' is a sweet, low-acid, midseason apple (matures six to eight weeks after 'Galaxy') with a mild flavour, and has performed well in consumer evaluations to date.

Before releasing a new variety to industry it is necessary to have a good understanding of the productivity and growth habit of trees in the field. Tree management is a critical component in the development of organic and low input apple production systems appropriate to new disease resistant apple selections. This requires experimental trials to evaluate a range of rootstocks and planting densities, and to develop a 'Tree management package' for each variety so that growers are able to produce high quality fruit. Such experiments take many years to complete. Apple trees don't start producing commercial quantities of fruit until at least their third year (third leaf) after planting in the orchard, and do not reach full bearing maturity until their fifth or sixth year.

As part of this project, six high density trials for a range of rootstocks and tree densities were planted at ARS to evaluate the growth and productivity of four superior scab-resistant selections from the DPI&F apple breeding program. The experiments were planted sequentially as progressively increasing tree numbers were propagated for experimental purposes. It should be noted that it takes one year to propagate a basic 'whip' (unbranched), maiden tree for orchard planting, provided sufficient virus-tested scion wood is available for grafting and budding.

Methodology

In winter, dormant scion wood was taken from virus-tested mother trees, bench-grafted onto the appropriate rootstock and planted in a designated nursery area. The trees were grown for one year in the nursery, then planted in the orchard as unbranched one-year-old 'whip' trees the following winter. Some trees were retained in the nursery for a second year, then planted in the orchard as two-year-old feathered (branched) trees. This was done to demonstrate to orchardists the advantage of planting well-feathered trees that produce crops of apples within two years of planting.

The trials described below were planted sequentially as discrete replicated experiments within a Fruit Production/ Tree Management Block at ARS, and will continue for several more years. The Fruit Production Block is also designed to provide fruit for storage and market evaluation. All six experiments were planted into unfumigated apple replant ground. Roots from the previous apple trees were removed,

and the land spelled for two years prior to replanting. During this period, two green manure crops of 'Jumbo' sorghum were planted, and incorporated into the soil just prior to seed head development. Following the second sorghum crop, bull manure (20 t/ha) was also incorporated into the soil. The experimental sites at ARS experience known high levels of apple scab infection. In all experiments, no sprays for apple scab were applied, with the exception of a low rate copper spray at green tip (late September) each year.

Experiments

1. Planting systems for 'RS103-130'

The first experiment was planted in winter 2002, with trees of 'RS103-130' trained to a vertical trellis. The trial was a randomised incomplete block design consisting of six treatments x four replicates, with six trees in each replicate. The six rootstock x spacing treatments for 'RS103-130' were MM.106 rootstock at 4.0 m x1.75 m (1428 trees/ha) and 4.0 m x 1.5 m (1666 trees/ha); and M.26 rootstock at 4.0 m x 1.5 m (1666 trees/ha), 4.0 m x 1.25 m (2000 trees/ha), 4.0 m x 1.0 m (2500 trees/ha) and 4.0 m x 0.5 m (5000 trees/ha). The trees were in their fourth leaf in 2006, and have cropped for the past two seasons. The crop in 2005 was light, with the first significant quantities of apples produced in 2006. 'RS103-130' has been described previously.

2. Planting systems for 'Selection 2'

Planted in October 2003 as a randomised incomplete block design, the trial includes the following rootstock x spacing treatments (six trees per replicate): MM.106 rootstock at 4.0 m x 1.5 m (1666 trees/ha), 4.0 m x 1.25 m (2000 trees/ha) and 4.0 m x 1.0 m (2500 trees/ha); M.26 rootstock at 4.0 m x 1.25 m (2000 trees/ha), 4.0 m x 1.0 m (2500 trees/ha), 4.0 m x 0.75 m (3333 trees/ha) and 4.0 m x 0.5 m (5000 trees/ha); and Ottawa 3 rootstock at 4.0 m x 1.0 m (2500 trees/ha). Trees cropped heavily in 2006, in their third leaf.

'Selection 2' has 'Royal Gala' in its parentage and was crossed with a scab resistant breeding line from a USA program. It is ready for harvest in early April, but tends to retain high levels of starch, suggesting it could have long-term storage potential. The apple colour is similar to 'Red Delicious', with a broken dark red stripe and small, prominent lenticels on yellow/green ground colour. The red over-colour darkens as fruit remain longer on the tree. Fruit is medium to very large and flat-round to round in shape, with a thick skin. Flesh is white to off-white, has a medium-coarse texture and a sweet, low acid flavour.

3. Rootstock trial for 'RS103-130'

A rootstock trial for 'RS103-130' was planted in September 2004. The experiment is a randomised complete block design with five rootstocks (MM.106, MM.102, M.26, Ottawa 3 and M.9) x four replicates x five trees per replicate. All trees are planted at 4.0 m x 1.0 m spacing (2500 trees/ha) and trained to a vertical trellis. The five rootstocks used are in the semi-vigorous (MM.106), semi-dwarf (M.26, MM.102, Ottawa 3) and dwarf (M.9) vigour range. In 2006 the trees were in their second leaf, and produced a light crop.

4. Training systems for 'RS103-130'

In a separate experiment also planted in September 2004, 'RS103-130' trees on MM.106 and M.26 rootstocks have been trained to a double-row 'V' trellis and to a single-row vertical trellis. The experiment is designed as a randomised incomplete block to compare the two training systems, the two rootstocks and a range of tree densities from 2500 – 5925 trees/ha. Each replicate consists of up to 12 trees, depending on the planting system used. All trees were planted as well-feathered two-year-old trees, and produced significant crops in 2006 (second leaf).

5. Rootstock trial for 'Selection 3'

A rootstock trial was planted in August 2005 to compare MM.106, MM.102, M.26, Ottawa 3 and M.9 rootstocks for a new scab resistant apple selection which has excellent potential as an organic apple. Trees of this selection have also been planted at the commercial organic apple trial site. The trees were planted at 3.8 m x 1.0 m (2630 trees/ha) and trained to a vertical trellis. Trial design is a randomised complete block with five rootstocks x four replicates x five trees per replicate. The trees completed their first leaf in 2006, and will set a very light first crop in 2007.

'Selection 3' is a sibling to 'Selection 2', having 'Royal Gala' as one of its parents. It is medium red colour with a dark red over-stripe on yellow-green ground. Flesh is crisp and juicy with fine texture, and a sweet, low acid, clean, fresh and mild flavour. Fruit shape is flat round to round.

6. Rootstock trial for 'Selection 4'

In September 2004 a rootstock trial for a fourth scab resistant apple selection was planted. Trial design is a randomised complete block with five rootstocks (MM.106, MM.102, M.26, Ottawa 3, M.9) x four replicates x five trees per replicate. The trees were planted at 4.0 m x 1.0 m (2500 trees/ha), trained to a vertical trellis and produced a light crop of apples in 2006 (second leaf). Unfortunately, 'Selection 4' is extremely susceptible to *Alternaria* leaf blotch, with severe defoliation of trees occurring as early as February (six to eight weeks prior to harvest). It is therefore unlikely to be suitable as an organic apple, despite its visual appeal and excellent eating quality.

Results and discussion

The six experiments described are designed to measure the growth and productivity of new Australian-bred scab resistant apple selections, and thereby provide the information required for the development of 'Tree management packages'. The first significant crops of fruit were produced from four of these experiments in 2005/06.

Apples harvested from these experiments in 2005/06 were large (Tables 7–10), and average fruit weight for most management systems was greater than 200 g. All trees were hand thinned, and with heavier crop loads the average fruit weight would be lower. This suggests that more apples could have been left on the trees, particularly for 'Selection 2', where apples were excessively large and averaged close to 300 g each (Table 8).

Heavier crop loads will be retained on the trees in 2006/07. This will also provide a measure of the biennial bearing habit (annual fluctuations in yield) of the scab resistant selections, which can only be determined once the trees are mature and approach full cropping potential. A fundamental question to be answered is how heavy a crop can trees of 'RS103-130' carry without becoming biennial and/or significantly reducing tree volume and hence subsequent productivity? This is particularly important for trees in their second and third leaf, where the temptation for growers is to crop them heavily for early returns. If cropped too heavily, however, trees can become stunted and/or biennial bearing, with heavy crops in one year followed by little return bloom (and hence crop) the next. 'RS103-130' is a semi-spur variety and fruit bud development for 2006/07 is high, so it is possible that 'RS103-130' trees have little tendency to biennial bearing.

The yields of trees in their second leaf (Tables 9 and 10) are quite high, and any crop produced in the second year is important to generate early returns on investment. Normally few, if any, apples are produced on young two-year-old trees. As indicated previously, it is important to avoid over-cropping trees in their second leaf as it can retard shoot growth and delay the achievement of full cropping potential.

For trees in only their second, third and fourth leaf, all systems are producing reasonable crops of large, well-coloured fruit. To date there are relatively few differences in the productivity of the tree management systems, however rootstock and planting density effects as a consequence of increasing tree vigour will occur as the trees mature. For example, a shading effect is becoming evident on four-year-old 'RS103-130' trees on M.26 rootstock planted at 5000 trees/ha (Table 7 – respective packouts of 93% and 62% for acceptable and premium fruit). The packout figures (Tables 7-10) are generally high, but can be expected to decline as the trees become larger. Potential internal shading will be managed with supplementary summer pruning, which will need to be quantified for the different management systems.

It is noteworthy that with only one exception, 'Selection 2' trees in their third leaf had a 100% packout (Table 8). This selection is a very highly coloured, large apple that is visually stunning. It will be of particular interest to measure by how much the packout declines in subsequent years as the trees become older and larger, but it is likely the packout for this selection will remain above 90%.

The desirable objectives in apple tree management are to obtain annual yields of at least 50 tonnes per hectare and a packout of >80 per cent within five to six years of planting, and to maintain this level of productivity for the lifetime of the orchard. The use of high density planting systems with trees grown on semi-dwarf and dwarf rootstocks such as M.26 and M.9 is an effective means to attain high yields early in the lifetime of the orchard. In Experiment 2, trees of 'Selection 2' on M.26 rootstock planted at 5000 trees/ha have already yielded 45 tonnes/ha in their third leaf (Table 8). At such a high tree density, however, the cost of trees for orchard establishment is expensive, and unless individual trees can be confined to their small allotted space, yield and fruit quality will decline in subsequent years through the effect of shading on fruit bud development, colour and size.

The effect of higher planting densities on increasing early yields is evident in Tables 7, 8 and 10. The 'V' trellis system in Experiment 4 (Table 10) is an efficient means of growing trees at a high density to minimise potential shading within and between trees. The trees are planted as a zig-zag double-row system, and with the aid of the trellis are inclined at an angle of 75^0 above the horizontal. This maximises light interception, and permits light penetration to lower regions of the canopy. With such a system, yields of up to 22 tonnes/ha have already been attained in the second year (Table 10), albeit at a very high planting density.

Apple orchard light interception and distribution are the keys to high orchard productivity (Middleton et al. 2002), and rootstocks are the single most important factor that orchardists can use to influence apple tree vigour and cropping potential. The growth and productivity of two-year-old trees of 'RS103-130' planted at 2500 trees/ha (Table 9) shows that yields from trees on MM.106 rootstock are significantly higher than from the other rootstocks in the experiment. This is likely due to the larger tree size and hence fruiting canopy volume of these trees. As the experiment progresses and the trees reach full size and maturity, the other more dwarfing rootstocks may become more productive than MM.106, especially if the MM.106 trees become too large and shade reduces fruit yield and quality.

Trunk cross-sectional area (TCA) is commonly used as an indicator of tree size, as it is quick and easy to measure. Reductions in TCA occur with increasing tree density (Tables 7 & 8), as individual trees occupy less orchard floor area and experience root competition from closely adjacent trees. This effect is greater as the trees age, and along with the influence of rootstock helps to control vigour and encourage fruit bud development. The effect of tree density on reducing TCA is not yet fully evident for the 'RS103-130' trees in their second leaf (Table 10), although MM.106 trees at densities of 3555-5925 trees/ha already have significantly smaller TCA than MM.106 trees at 2500 trees/ha.

Leaf Area Index (LAI) is a far more accurate measure of tree vigour, but is time-consuming to measure. LAI is calculated as m^2 leaf per m^2 orchard floor surface area allocated to the tree. Calculation of LAI required counts of all leaves on the trees (subdivided into spur leaves and shoot leaves), and measurement of the individual leaf areas of a sub-sample of 100 spur and 100 shoot leaves taken from each tree.

Based on measurements of the light interception, LAI, yield and fruit quality of a wide range of apple orchard systems throughout Australia, an LAI of close to 2.0 is considered optimal for high productivity of mature, bearing trees in 'standard' apple tree planting systems (Middleton et al. 2002), and an LAI of 2.5 - 3.0 for 'V' trellis systems. The objective in tree management should be to achieve these LAI levels as early as possible in the lifetime of the orchard.

To date, none of the trees in these experiments has reached an LAI of 2.0 or above (Tables 7–11). This is to be expected, as the trees are still young and have only just commenced cropping. For the first three to five years after planting, tree size dramatically increases each year, dependent on the pruning strategies used. However, in the first growing season much of the growth occurs in root development below the ground, so trees remain relatively small. Indeed, there is little difference in TCA and LAI between rootstocks for trees of 'Selection 3' in their first leaf (Table 11), with all trees of low vigour. Rootstock effects on tree size will start to emerge in years two and three.

In the first planted experiment (Table 7) the highest LAI for trees in their fourth leaf is 1.3. The trees in this experiment are upright, and branches have now been spread to increase light interception and LAI. The benefits of the 'V' trellis system are already evident, and trees in only their second leaf are yielding 17–22 tonnes/ha with an LAI of 1.0–1.5 (Table 10).

Summary

Until the trees in Experiments 1–6 have been cropped for several successive seasons at full bearing maturity, it is difficult to adequately compare the performance of the different management systems and make conclusive recommendations. At this early stage, trees on M.9 and MM.102 rootstocks are of lower, more manageable vigour than the other rootstocks.

Trees on Ottawa 3, M.26 and MM.106 rootstocks planted at 2500 trees/ha are performing well. One future issue will be whether trees on the more vigorous MM.106 rootstock (an industry standard) at high densities start to out-grow their allocated space as they become older, and if required, whether supplementary vigour control measures such as summer pruning will adequately address this and prevent yield and packout declines as trees approach 10 years of age.

The 'V' trellis is to date proving its suitability as a system for growing trees of scab-resistant apples at densities of 3555 trees/ha and above. Again, it is impossible to conclusively recommend this system until the trees are older and have reached full bearing size and productivity potential.

The growth and productivity of trees in these experiments is demonstrating the suitability of the scab-resistant apples to be grown at high densities in replant situations under known high levels of scab infection. It remains to be seen whether these promising results continue in the future.

Table 7. The yield, packout and vigour (2005/06) of tree management systems for 'RS103-130' trees in their fourth leaf (Experiment 1)

Rootstock	Density (trees/ha)	Yield (t/ha)	Av. fruit wt (g)	Packout* (%)	Packout** (%)	TCA (cm^2)	LAI
MM.106	1428	18.4	203	97	78	14.7	1.3
MM.106	1666	23.6	208	97	80	12.6	1.1
M.26	1666	20.5	216	97	72	11.1	0.8
M.26	2000	18.6	227	98	84	8.9	0.9
M.26	2500	21.0	215	97	79	9.1	0.9
M.26	5000	31.5	217	93	62	6.9	1.3
LSD (p<0.05)		*7.4*	*14*	*NS*	*14*	*0.5*	*0.3*

TCA: trunk cross-sectional area LAI: Leaf Area Index NS: not significant

** Packout percentage based on fruit weight > 120 g and colour rating ≥ 2 on a 1-4 scale. ie. includes fruit of 'acceptable' colour (rating 2)*

***Packout percentage based on fruit weight > 120 g and colour rating ≥ 3 on a 1-4 scale. ie. only includes fruit of superior colour (ratings 3, 4)*

Table 8. The yield, packout and vigour (2005/06) of tree management systems for 'Selection 2' trees in their third leaf (Experiment 2)

Rootstock	Density (trees/ha)	Yield (t/ha)	Av. fruit wt (g)	Packout* (%)	Packout** (%)	TCA (cm^2)
MM.106	1666	14.3	281	100	100	10.3
MM.106	2500	20.3	290	100	100	9.0
Ottawa 3	2500	38.6	308	100	100	7.8
M.26	2000	24.8	299	100	100	9.3
M.26	2500	31.1	312	100	100	8.5
M.26	3333	26.5	304	100	97	6.4
M.26	5000	45.0	290	100	100	6.5
LSD (p<0.05)		*12.1*	*NS*	*NS*	*1*	*1.2*

TCA: trunk cross-sectional areaLAI: Leaf Area IndexNS: not significant

** Packout percentage based on fruit weight > 120 g and colour rating ≥ 2 on a 1-4 scale. ie. includes fruit of 'acceptable' colour (rating 2)*

***Packout percentage based on fruit weight > 120 g and colour rating ≥ 3 on a 1-4 scale. ie. only includes fruit of superior colour (ratings 3, 4)*

Table 9. The effect of rootstock on the yield, packout and vigour (2005/06) of 'RS103-130' trees (second leaf) planted at 2500 trees/ha (Experiment 3)

Rootstock	Yield (t/ha)	Av. fruit wt (g)	Packout* (%)	Packout** (%)	TCA (cm^2)	LA (m^2)	LAI
M.9	6.6	234	78	67	6.2	1.9	0.5
Ottawa 3	8.1	225	82	68	6.8	2.8	0.7
MM.102	8.0	216	87	84	8.8	2.0	0.5
M.26	7.3	209	80	66	9.7	2.6	0.7
MM.106	11.8	218	85	78	11.4	3.1	0.8
LSD (p<0.05)	*2.4*	*11*	*NS*	*13*	*1.3*	*0.7*	*0.2*

TCA: trunk cross-sectional areaLA: Leaf area/treeLAI: Leaf Area IndexNS: not significant

** Packout percentage based on fruit weight > 120 g and colour rating ≥ 2 on a 1-4 scale. ie. includes fruit of 'acceptable' colour (rating 2)*

***Packout percentage based on fruit weight > 120 g and colour rating ≥ 3 on a 1-4 scale. ie. only includes fruit of superior colour (ratings 3, 4)*

Table 10. The yield, packout and vigour (2005/06) of tree management systems for 'RS103-130' trees in their second leaf (Experiment 4)

Rootstock	Density (trees/ha)	Yield (t/ha)	Av. Fruit wt (g)	Packout* (%)	Packout** (%)	TCA (cm^2)	LAI
M.26	2500	6.2	193	96	87	6.8	0.5
M.26 V trellis	4444	12.1	197	97	83	7.1	0.9
MM.106	2500	8.9	203	99	96	14.2	0.9
MM.106 'V'	3555	16.8	196	99	95	11.5	1.0
MM.106 'V'	4444	19.7	197	99	87	11.5	1.2
MM.106 'V'	5925	22.1	179	99	94	11.5	1.5
LSD (p<0.05)		3.8	*NS*	*NS*	*NS*	*2.4*	*0.4*

TCA: trunk cross-sectional areaLAI: Leaf Area IndexNS: not significant

** Packout percentage based on fruit weight > 120 g and colour rating ≥ 2 on a 1-4 scale. ie. includes fruit of 'acceptable' colour (rating 2)*

***Packout percentage based on fruit weight > 120 g and colour rating ≥ 3 on a 1-4 scale. ie. only includes fruit of superior colour (ratings 3, 4)*

Table 11. The effect of rootstock on trunk cross-sectional area (TCA), leaf area and leaf area index (LAI) of trees of 'Selection 3' in their first leaf (Experiment 5)

Rootstock	Density (trees/ha)	TCA (cm^2)	Leaf Area/tree (m^2)	LAI
M.9	2500	2.3	0.7	0.2
Ottawa 3	2500	2.0	0.7	0.2
MM.102	2500	2.3	0.5	0.1
M.26	2500	2.6	0.7	0.2
MM.106	2500	2.1	0.6	0.2
LSD (p<0.05)		*0.3*	*NS*	*NS*

TCA: trunk cross-sectional areaLAI: Leaf Area IndexNS: not significant

Plate 4. Harvesting scab-resistant 'RS103-130' apples from a V-trellis system (Experiment 4)

6. Conclusions

This project demonstrated that the new Australian-bred scab-resistant apple 'RS103-130' can be successfully grown using organic production methods. To date, the scab resistance of 'RS103-130' has been robust in the field.No apple scab has occurred on trees or fruit of 'RS103-130' despite the presence of the disease on 'Galaxy' trees planted in the commercial organic apple trial (Chapter 3), and the planting of trees in replant ground at a site of known high scab infection (Chapter 5). 'RS103-130' should also be ideally suited to organic production in other apple producing regions of Australia, particularly those areas which do not have spring and summer rainfall, as in Queensland.

Australia's first commercial crop of organically grown 'RS103-130' apples was produced in March 2006, as part of this project. Some of these apples were marketed through an organic wholesaler in Sydney. Customer feedback was excellent and the apples sold quickly, receiving an average price of $37 for first grade and $32 for second grade fruit per 12kg two-layer carton. The availability of a new, high quality scab-resistant apple variety at the organic retail level not only offers more choice to the organic apple consumer, but provides orchardists with the opportunity to produce organic apples a little more easily than if growing the standard varieties currently available. 'RS103-130' scored favourably in consumer evaluations, and offers organic consumers a pleasant eating experience whilst providing a healthy snack product produced without harmful chemicals.

Apple growers wishing to develop their varietal mix of organically produced apples are encouraged to plant and test 'RS103-130' when it becomes commercially available. The recommendations in this report are targeted in the first instance to current Australian organic apple growers, and secondly to conventional growers who are contemplating the switch to organic production, but as yet have been hesitant to do so. 'RS103-130' can be particularly recommended for testing on conventional apple orchards still to undergo the conversion process to organic production.

The project identified a range of strategies for successful organic apple production in Australia, and specific recommendations are included in a manual written by the project team, *Organic Apple Production in Australia – A Practical Guide*. A schedule of recommended orchard operations is included as an annual calendar of activities for organic apple production, and is reproduced in Appendix A of this report.

A cost-benefit economic analysis spreadsheet for organic apple production has been developed (Appendix B), based on the actual costs of recommended orchard operations undertaken at the commercial organic apple trial site. The analysis showed that organic apple production was profitable, provided annual yields averaged 17.4 tonnes/ha from year four onwards. The analysis is based on many assumptions (Appendix B), and is designed as a working model so that the effect of changes in yields, costs and returns can be determined for individual circumstances.

Weed management is a significant issue in Australian apple orchards, in particular for organic producers. The beneficial effects of sugar cane mulch and compost on soil properties requires further study. The use of compost as a potential option to alter the soil ecological balance and perhaps help control soil borne plant pathogens is also worth investigation, since soil-borne diseases are often difficult to manage and thereby pose a high risk of economic loss. For example, White root rot, caused by the fungus *Rosellinia necatrix*, is the most significant soil-borne disease affecting apple production in Queensland, and costs the industry $1 million per annum in lost productivity and tree death.

Although pests and diseases present particular challenges in organic apple production, drought and soil quality are factors that affect the productivity of all organic and conventional apple orchards in Australia. Indeed, as Australian apple orchardists adopt more efficient production systems to meet market demands for high quality, 'clean, green' fruit, it is the potential effect of soil management strategies on soil quality, water use efficiency and managing drought that may ultimately see more orchardists adopt organic systems for apple production.

7. Technology transfer

The following publications were prepared for growers and scientists from this project:

McWaters, AD, Horlock, CM, Nimmo, PR, Zeppa, AG, McGrath, C, Middleton, SG & Boucher, WD 2008, *Organic Apple Production in Australia – a Practical Guide,* Department of Primary Industries & Fisheries, Brisbane, Queensland, prepared for publication.

Middleton, SG, Zeppa, AG, Nimmo, PR & Horlock, CM 2007, 'Organic production of a new Australian-bred scab resistant apple in Queensland, Australia', *Acta Horticulturae*, vol. 737, pp. 139-145.

McWaters, A, Zeppa, A & Middleton, S 2006, 'Producing apples free of black spot', *Australian Organic Journal*, vol. 66, pp. 46-47.

McWaters, A, Zeppa, A & Middleton, S 2006, 'Organic production of black spot-resistant apples', *Australian Organic Journal*, vol. 65, pp. 46-47.

McWaters, A, Zeppa, A & Middleton, S 2005, 'Organic production of new black spot resistant apples', *Tree Fruit*, November 2005, pp. 4-6.

Middleton, S & Zeppa, A 2004, 'Production systems for Australian-bred scab resistant apples', *Tree Fruit,* December 2004/January 2005, pp. 12-13.

McWaters, A, Zeppa, A, Middleton, S, Rickard, D, Nimmo, P, Cameron, D et al. 2004, 'Developing systems for low input and organic apple production based on new black spot resistant selections', Poster presented at the Apple & Pear Australia Ltd., 2nd National Conference, Adelaide, SA.

Zeppa, A, Middleton, S & McWaters, A 2004, 'Top tasting spot-resistant apples', *Tree Fruit*, November 2004, p. 15.

Middleton, S 2003, 'Organic apple trial underway', *Tree Fruit*, June-July 2003, p. 16.

Middleton, S, Nimmo, P & Zeppa, A 2003, 'Systems for organic production', *Tree Fruit,* September 2003, pp. 20-21.

Middleton, S 2003, 'Organic apple trial gets underway', *Good Fruit and Vegetables*, vol. 14, p. 49.

Stephens, P & Middleton, S 2002, 'Organic apple project', *Tree Fruit*, September 2002, pp. 20-23.

Stephens, P 2002, 'Organic apple project', Paper presented to the Snack Fruit 2002 conference, Brisbane, Qld, 8-12 July.

Rickard, D, Stephens, P, Boekholt, K & McWaters, A 2002, 'Initial glasshouse trials to identify compounds for weed control in organic apple and stone fruit orchards', Poster presented at the Snack Fruit 2002 conference, Brisbane, Qld, 8-12 July.

Rickard, D, Stephens, P, Page, F & Nimmo, P 2002, 'Ability of organic compounds to control Queensland fruit fly', Poster presented at the Snack Fruit 2002 conference, Brisbane, Qld, 8-12 July.

Rickard, D, Stephens, P, Page, F & Nimmo, P 2002, 'Keeping European brown snails out of apple trees', Poster presented at the Snack Fruit 2002 conference, Brisbane, Qld,

8. Appendices

Appendix A: Schedule of operations for organic apple production based on the first four years of planting of scab-resistant apples in the Stanthorpe district, Queensland 20

Appendix B: Economic analysis of organic apple production 24

Appendix A: Schedule of operations for organic apple production based on the first four years of planting of scab-resistant apples in the Stanthorpe district, Queensland

This appendix provides an overview of seasonal activities in a mature, bearing organic apple orchard, based on tree management and experimental results from the commercial organic apple block of 'RS103-130' and 'Galaxy' trees (Chapter 3), and from trees of scab-resistant apple selections planted into replant ground (Chapter 5). The calendar is a quick reference guide to major operations, with the following text covering selected areas in more detail.

Pre-plant preparation

Where possible, select a site that is isolated and distant from adjacent orchards. An outbreak of a pest or disease on a neighbouring orchard may spread and be difficult to control in an organic system. A buffer zone of at least 15 metres and the presence of windbreaks are also desirable to eliminate spray drift from nearby blocks of trees.

Soil depth and drainage are two key factors when selecting an orchard site. Where soils are shallow it is good practice to mound the soil along the tree rows to provide sufficient depth for root development and tree anchorage. Mounding rows in combination with surface drains and subsurface drains of slotted drainage pipe are essential for maintaining healthy soil aeration and preventing erosion.

Pre-plant strategies to prepare a new site for planting will depend on the previous cropping history of the site. Ideally, apple trees should be planted into soil which has not previously been planted to apples, or into ground which has grown stonefruit as a long term rotation for many years. This avoids planting young trees into soil which has a build-up of parasitic nematodes and soil pathogens from a previous apple planting, thereby minimising potential problems from Apple Replant Disease.

The basic requirements for successful orchard establishment include:

- Removal of existing crop residues such as tree roots and tree stumps. This is an important step which will help remove potential sources of disease inoculum from the root zone of trees in the new orchard.
- Deep ploughing to open up the soil and break up hard pans.
- Providing adequate drainage and appropriate placement of irrigation mains.
- Liming acidic soils to adjust soil pH to 6.0–6.5.
- Growing green manure crops to suppress weeds and build up the soil.
- Addition of phosphate and trace elements.
- Applying organically certified compost. Manures should not be applied directly to the orchard and must first be composted.
- Spell the ground (for two years or more if possible) after removal of any previous trees. Use this period to sow and incorporate a series of green manure crops to build up soil organic matter.
- Cultivating the orchard and then ploughing to form the tree rows for the desired row spacing and tree planting density.

To replant an orchard is a considerable investment of time and money. In replant situations sufficient time should be allowed for 'reconditioning' the soil. At least twelve months (preferably longer) should elapse between apple tree removal and the planting of a new orchard, in which to grow legume and forage sorghum crops to fix nitrogen and add organic matter to the soil. Soil health can be improved with these cultural practices and by correcting the soil pH to 6.0–6.5. Mulching of crop residues and minimum tillage practices benefit both the soil structure and organic carbon levels. Maintenance of beneficial soil cover plants also helps to suppress weeds and improve soil structure, aeration and water infiltration.

Diseases and pests

Crop monitoring:

- Involves frequent (weekly) observation of apple tree foliage, branches and fruit.
- Ideally walk up every third alleyway, closely examining trees in both rows at regular intervals.
- Take a pen, paper, pruning shears and flagging tape with you, so you can immediately remove any symptomatic material, write down what was found, and label trees for future observation or further remedial measures.

Application of sprays:

- Spraying should be the last resort in an organic system, and the use of physical and cultural methods should be attempted first – except in severe cases where all three methods should be used together.
- Spot spraying (applying products to a small area of the orchard) after infected plant tissue is removed, can be an effective way of reducing the recurrence of disease. However, if more than 20% of a block is affected by disease, spraying the entire block may be more efficient.
- **Copper** can currently be applied to manage apple scab and powdery mildew prior to blossoming. Keep in mind that the Australian standard allows up to a total of 8 kg/ha of copper, whereas European standards allow only 3 kg/ha (lower in some countries), and are constantly under review.
- **Sulphur** can be applied either as lime sulphur or wettable sulphur. Lime sulphur can be used preventatively or curatively, while wettable sulphur is only effective preventatively. Sulphur can have a short term, negative effect on photosynthesis, so should be used thoughtfully, especially on young trees.

Organic Apple Production Quick Reference.

An Annual Calendar of Organic Apple Production Activities.

	June	July	August	September	October	November	December	January	February	March	April	May
Apple tree growth stages.	Dormancy			Green tip (bud movement)								
				Blossoming								
					Petal fall and fruit development				Fruit Ripening and Harvest			
						Shoot growth and bud initiation .						

Diseases	June	July	August	September	October	November	December	January	February	March	April	May
Cultural Management	Monitor frequently during the season, cut off infected tissues (leaves, buds, fruit and shoots) and remove from the orchard. Maintain good general farm hygiene.											

	June	July	August	September	October	November	December	January	February	March	April	May
Apple Scab	Over-wintering spores on fallen leaves.			Release of primary spores triggered by rain. Primary infections occur on unprotected foliage. (Time, Temperature, Leaf Wetness are main factors)			Secondary infections on leaves and fruit.					
Management	Either remove leaf litter from orchard floor and destroy, or ensure leaf litter is completely broken down before spring.			All Varieties: Green tip copper spray (usually combined with winter oil for mites and San Jose scale). Susceptible varieties: Apply Lime Sulphur and /or Wettable Sulphur sprays, as indicated by your local Apple Scab Warning Service. Resistant Varieties: Apply Lime Sulphur and/or Wettable Sulphur sprays after severe Apple Scab warnings.								

	June	July	August	September	October	November	December	January	February	March	April	May
Powdery Mildew	The fungus over-winters in dormant flower and leaf buds.			Infection is favoured by high humidity and moderate temperatures (19-25°C) typically in spring and autumn.								
Management	Refer to cultural management.			Apply 2 Lime Sulphur sprays prior to blossoming		Refer to cultural management.						

	June	July	August	September	October	November	December	January	February	March	April	May
Alternaria	Over-wintering spores on infected fallen leaves, buds and rough bark.			Release of primary spores triggered by rain. Primary infections occur on unprotected foliage. (Time, Temperature, Leaf Wetness are main factors)			Secondary infections on leaves and fruit.					
Management	Either remove leaf litter from orchard floor and destroy, or ensure leaf litter is completely broken down before spring.			Monitor the trees and remove infected leaves and fruit.								

	June	July	August	September	October	November	December	January	February	March	April	May
Glomerella	The fungus over-winters in infected fruit mummies and cankers on spurs.					New fruit and leaf infections appear from November onwards.			Fruit symptoms become most obvious close to maturity.			
	Refer to cultural management (no organically certified products are currently available).											

Insect Pests:	June	July	August	September	October	November	December	January	February	March	April	May
Codling Moth	Mature Codling Moth Larvae overwinter in cocoons in sheltered sites near the fruit they emerged from under loose bark or nearby debris. Pupation occurs with the onset of warmer weather in late August.			Codling Moths emerge late September or early October and fly in search of a mate.		Up to three generations of moths may develop during the apple growing season in warmer areas. Colder environments such as Tasmania may have only one generation of Codling Moth for the season.					Mature Codling Moth larvae enter a resting stage (diapause) inside silken cocoons at the end of the growing season.	
Management				Apply Pheromone dispensers to trees prior to flight of Codling Moths as determined by trap catches.		Remove affected fruit from the orchard and bury or destroy it using a flail mower. Open fruit dumps should not be used because the Codling Moth will emerge from the discarded fruit and become a source of infestation.						

Organic Apple Production Quick Reference.

An Annual Calendar of Organic Apple Production Activities.

	June	July	August	September	October	November	December	January	February	March	April	May
Apple tree growth stages.	Dormancy			Green tip (bud movement)								
				Blossoming								
					Petal fall and fruit development				Fruit Ripening and Harvest			
						Shoot growth and bud initiation						

Insect Pests:	June	July	August	September	October	November	December	January	February	March	April	May
Western Flower Thrip	Western flower thrips are present in the orchard throughout winter on flowering weeds and clovers.			During apple blossoming WFT will move from alternate hosts into apple flowers where they lay eggs in the developing fruit (at the flower base).		WFT present on flowering host plants throughout the year.						
Management			Mow clover in permanent sod to minimise blossom and infestation with thrips. As apple blossoming commences, cease mowing to avoid displacing thrips from the clover to apple blossoms. Check flowers and spray Entrust® if WFT are present in apple blossoms.									

	June	July	August	September	October	November	December	January	February	March	April	May
Queensland Fruit Fly						Active in orchards and infest most smooth skin fruit as it ripens.						
Management						Place traps in the orchard and monitor weekly.	Weekly bait sprays of Naturalure ® up to harvest.					

	June	July	August	September	October	November	December	January	February	March	April	May
Native Budworm or commonly known as Heliothis (*Heliocover punctigera)*				Monitor and Apply BT sprays when caterpillars are small. Alternatively, Entrust ® sprays for LBAM will also kill developing caterpillars.								
Light Brown Apple Moth					Entrust® sprays as indicated by monitoring .							
Woolly Apple Aphid	Use resistant rootstocks (e.g. MM106). Encourage predatory wasps.											
Mites	Green tip winter oil spray (usually combined with copper spray for Apple Scab). Encourage natural predators.											
Painted Apple Moth	Monitor regularly and apply BT spray to affected trees if necessary.											

Nutrition:	June	July	August	September	October	November	December	January	February	March	April	May
Zinc Spray		When trees are fully dormant										
Foliar Calcium						Approved Calcium spray for fruit nutrition. Timing will depend on product used.						
Apply Compost				Apply along tree row under mulch								
Fish Emulsion												Foliar application for Autumn

Organic Apple Production Quick Reference.

An Annual Calendar of Organic Apple Production Activities.

	June	July	August	September	October	November	December	January	February	March	April	May
Apple tree growth stages.	Dormancy			Green Tip (bud movement)								
				Blossoming								
					Petal fall and fruit development				Fruit Ripening and Harvest			
						Shoot growth and bud initiation						

Weed Control:	June	July	August	September	October	November	December	January	February	March	April	May
Mulching				Annual application of sugar cane mulch to a depth of 20cms along tree rows.								
Mowing and Brush-cutter			Mow the inter-row sod on a regular basis to prevent clover and weeds from flowering (see WFT comments).			Regular mowing of the inter-row sod throughout the season to prevent establishment of tall woody weeds and seeding. Some brush-cutter slashing of tall weeds growing through the mulch may also be necessary						
Hand Hoeing					Strategic removal of problem weeds while the problem is limited to a small area or a few plants.							

Harvesting:	June	July	August	September	October	November	December	January	February	March	April	May
									Pick varieties at optimum ripeness for fresh market and storage.			

Pruning:	June	July	August	September	October	November	December	January	February	March	April	May
	Prune after Zinc spray. Remove unwanted shoots and branches. Avoid heading cuts.						Summer pruning may be necessary on some vigorous varieties.					

Appendix B: Economic analysis of organic apple production

The aims of the economic analysis were to:

- Estimate the costs of an organic apple production system
- Project the cash flow and estimate the profitability of an organic production system
- Provide enough information to help growers make more educated decisions about organic apple production.

Information and figures used in the analysis were derived from the commercial organic apple trial site (Chapter 3).

The method used for financial assessment of the organic apple orchard involved a discounted cash flow analysis (DCF) and calculation of net present value (NPV), as is commonly used in assessing agricultural investment options. The NPV method was chosen as it is relatively simple, widely practiced, widely taught and relatively easy to explain.

The analysis involved discounting the cash flows of the project to their present value at an appropriate discount rate (9%). It compared the present day value of the amount invested at the time of planting, with the present value of the amount returned on the investment from selling the fruit in future years. This method is based on the principle that the value of a dollar received in the future is less than the value of a dollar received today. The approach calculates a figure which may be either positive or negative. Generally, a positive NPV suggests that an enterprise would be profitable.

A breakeven year for investment in an organic orchard was also calculated. This was determined by calculating the accumulated cash flows of the orchard enterprise, and is important for apple growers who may need to acquire loans to cover the period in which the enterprise operates in a deficit cash position. Only during the breakeven year will enough cash flow be generated to cover start up expenses.

The analysis assumes:

- Part of an existing orchard is converted to organic production and that existing machinery and infrastructure would be utilised. Our model is based on an area of five hectares of organic apple production.
- Projected average annual marketable yields of 25 tonnes/ha from year four to year 20. These figures are based on estimates and research from the best practice model. Projected yields are conservative to allow for the wide variability of soil types and fertility.
- The price received for organic apples is $2666/tonne ($32/12 kg two-layer carton). This price is what was received from an organic wholesaler in Sydney for second grade fruit of 'RS103-130' produced from the commercial organic apple orchard (Chapter 3) in 2006. Prices received are difficult to predict, and will vary from variety to variety and with prevailing market conditions at the time of supply.
- A useful orchard life of 20 years.
- Establishment costs of $299 000, which were assumed to be the same as those of establishing a conventional orchard block. Table B1 shows a breakdown of the establishment costs used. These included land and water, plant and equipment, ground preparation, purchase of trees and planting costs. This expenditure is assumed to occur in year zero.
- Growing and marketing expenses were based on actual costs incurred at the commercial organic apple trial site in the 2005/2006 season.
- Certification costs and royalties were not included in these calculations.
- Fixed costs were typical of a similar sized orchard enterprise.
- A discount rate of 9% was used (6% cash rate + 3% inflation).
- Hail netting is either already established on the block, or is not present.

Results

- Table B1 shows a screenshot of the discounted cash flow and net present value (NPV) analysis for the organic apple production system.
- Table B2 presents a financial comparison of pest and disease control measures for conventional and organic apple production systems. Organic pest and disease control was more expensive than conventional control methods.
- Using our assumptions, a NPV of $406 847 was calculated at a discount rate of 9%. Based on this model, investment in a five hectare organic apple orchard would therefore be considered as profitable.
- The breakeven year was calculated as year seven.
- Further analysis showed that a return of $2233 per tonne of organic apples is necessary for the enterprise to be profitable, assuming other variables remain constant.
- An average annual yield of 17.4 tonnes/ha after year four is necessary for the enterprise to be profitable, assuming other variables remain constant.

Conclusion

A working version of the economic analysis model is provided on compact disc with the organic apple production guide. This will allow users to modify the spreadsheet calculations to fit their individual circumstances, and to compare the potential profitability of a range of different scenarios for changes in costs, returns, yields, discount rates etc.

The figures and assumptions presented in this model (Table B1) are only a guide to possible outcomes.

Potential organic growers should do their own research and seek advice from their financial adviser.

Table B1. Screenshot of the financial model for economic analysis of organic apple production

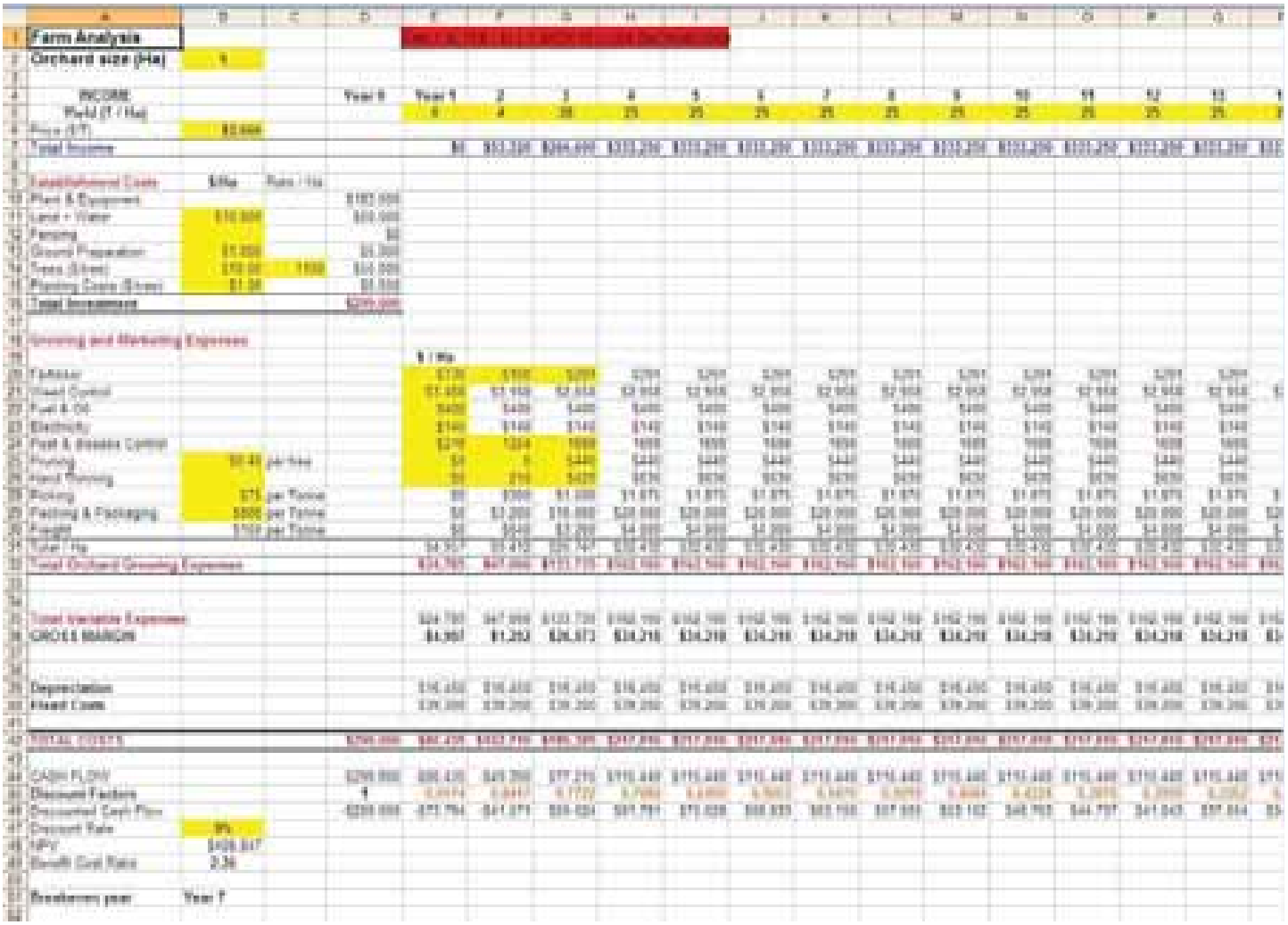


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Table B2. Financial comparison of conventional and organic apple spray programs

Conventional Spray Programme					Organic Spray Programme			
Product	rate/ 100L	price/ unit L/Kg	Cost/Ha 1200L	Timing	Product	rate/ 100L	price/ unit L/Kg	Cost/Ha 1200L
Zinc Sulphate	2.5	$1.04	$31.20	Mid July	Zinc Sulphate	2.5	$1.04	$31.20
				Mid Sept				
Kocide	0.15	$12.50	$22.50	Green Tip	Kocide	0.15	12.50	$22.50
Winter Oil	3	$1.80	$64.80		Winter Oil	3	1.80	$64.80
				September	Lime Sulphur	4	3.85	$184.80
Topas	0.025	$121.20	$36.36		Lime Sulphur	4	3.85	$184.80
Ziram	0.15	$8.50	$15.30		Codling Ties	500	0.77	$386.50
					LBAM Ties	500	0.73	$0.00
				October Blossoming				
Success	0.04	$172.73	$82.91		Entrust	0.006	1,127.27	$81.16
Endosulfan	0.2	$16.36	$39.26		Lime Sulphur	0.8	3.85	$36.96
Saprol	0.012	$54.55	$7.86		Wettable Sulphur	0.35	2.64	$11.09
Ziram	0.15	$8.50	$15.30		Dipel	0.1	47.76	$57.31
Azinphos-methyl	0.245	$16.50	$48.51					
				15- 20 Days	Entrust	0.006	1,127.27	$81.16
Carbaryl (Thinning)	0.125	$16.36	$24.54	After Full Bloom	Lime Sulphur	0.8	3.85	$36.96
					Wettable Sulphur	0.35	2.64	$11.09
					Wettable Sulphur	0.35	2.64	$11.09
Azinphos-methyl	0.245	$16.50	$48.51	Early November				
Topas	0.025	$121.20	$36.36		Lime Sulphur	0.8	3.85	$36.96
Ziram	0.15	$8.50	$15.30		Wettable Sulphur	0.35	2.64	$11.09
Solubor	0.275	$3.20	$10.56					
Azinphos-methyl	0.245	$16.50	$48.51	Late November	Biomin Calcium	2Kg/Ha	29.70	$59.40
Nustar	0.01	$265.00	$31.80		Wettable Sulphur	0.35	2.64	$11.09
Mancozeb	0.2	$7.50	$18.00					
Calcium Chloride	0.5	$0.80	$4.80	Mid December	Biomin Calcium	2kg/Ha	29.70	$59.40
Azinphos-methyl	0.245	$16.50	$48.51					

Table B2. Financial comparison of conventional and organic apple spray programs (continued)

Conventional Spray Programme					Organic Spray Programme			
Product	**rate/ 100L**	**price/ unit**	**Cost/Ha**	**Timing**	**Product**	**rate/ 100L**	**price/ unit**	**Cost/Ha**
		L/Kg	**1200L**				**L/Kg**	**1200L**
Mancozeb	0.2	$7.50	$18.00					
				Late December				
Mancozeb	0.2	$7.50	$18.00	Early January	Naturalure Bait Spray	1L/Ha	17.09	17.09
Azinphos-methyl	0.245	$16.50	$48.51		Naturalure Bait Spray	1L/Ha	17.09	17.09
Acramite	0.065	$220.00	$171.60	Mid January	Biomin Calcium	2kg/Ha	32.67	$65.34
Azinphos-methyl	0.245	$16.50	$48.51		Naturalure Bait Spray	1L/Ha	17.09	17.09
Calcium Chloride	0.5	$0.80	$4.80					
Ziram	0.15	$8.50	$15.30					
				Late January	Naturalure Bait Spray	1L/Ha	17.09	17.09
Calcium Chloride	0.5	$0.80	$4.80	Early Feb	Naturalure Bait Spray	1L/Ha	17.09	17.09
Calcium Chloride	0.5	$0.80	$4.80	Mid February	Biomin Calcium	2kg/Ha	32.67	$65.34
Azinphos-methyl	0.245	$16.50	$48.51		Naturalure Bait Spray	1L/Ha	17.09	17.09
Ziram	0.15	$8.50	$15.30		Naturalure Bait Spray	1L/Ha	17.09	17.09
Calcium Chloride	0.5	$0.80	$4.80	Late February	Naturalure Bait Spray	1L/Ha	17.09	17.09
Azinphos-methyl	0.245	$16.50	$48.51		Naturalure Bait Spray	1L/Ha	17.09	17.09
Ziram	0.15	$8.50	$15.30	Mid March	Naturalure Bait Spray	1L/Ha	17.09	17.09
					Naturalure Bait Spray	1L/Ha	17.09	17.09
		Total	**$1,117.63**				**Total**	**$1,698.03**

a. All figures are exclusive of GST and represent the cost of pest and disease control for one hectare of orchard.

b. The Organic spray program includes Codling Moth pheromone dispensers. Add $363.50 if LBAM pheromone dispensers are required.

c. This spray schedule is a guide to comparative costs only. Management decisions and local circumstances will affect costs.

d. This schedule omits LBAM pheromone ties to reduce the cost per hectare. Combined Codling Moth /LBAM are no longer available.

9. References

Alenson, C 2001, 'Restoring fertility to a degraded soil using strategies consistent with organic farming', *Proceedings of the Inaugural OFA National Organics Conference*, Publication no. 01/121, Rural Industries Research and Development Corporation, Canberra. pp. 234-243.

Berrie, A M & Cross, J V 2000, 'Evaluation of integrated pest and disease management strategies for apple using disease resistant versus susceptible cultivars', *Acta Horticulturae*, vol. 525, pp. 331-336.

Boscheri, S & Mantinger, H 1994, 'Ten years of experience with organic farming of apples at the Laimburg agricultural research station', *Erwerbsobstbau*, vol. 36, pp. 127-129.

Brzozowski, P 2004, 'Comparison of apple production costs between conventional, integrated and organic farming', *Journal of Fruit and Ornamental Plant Research*, vol. 12, pp. 63-68.

Glover, J D, Reganold, J P & Andrews, P K 2000, 'Systematic method for rating soil quality of conventional, organic, and integrated apple orchards in Washington state', *Agriculture, Ecosystems and Environment*, vol. 80, pp. 29-45.

Groot, M J 2000, 'Economics of apple production systems with minimal input of chemicals', *Acta Horticulturae*, vol. 536, pp. 47-52.

Halpin, D 2004, *The Australian Organic Industry – A Profile,* Dept of Agriculture, Fisheries and Forestry, Canberra.

Hartley, M J & Rahman, A 1997, 'Organic mulches for weed control in apple orchards', *Orchardist*, vol. 70, pp. 28-30.

Heller, W & Weibel, F 1997, 'Integrated production and organic apple cultivation: a comparison. 4. Objectives of plant nutrition and fertilisation in IPM and organic fruit growing', *Obst und Weinbau*, vol. 133, pp. 185-186.

Himmelsbach, J, Kleisinger, S & Link, H 1995, 'Organic soil management: II. Effect on soil parameters', *Erwerbsobstbau*, vol. 37, pp. 108-112.

Hogue, E J & Neilsen, G H 1987, 'Orchard floor vegetation management', *Horticultural Reviews*, vol. 9, pp. 377-430.

Kelderer, M 2004, 'Organic apple growing: Legal roles, production statistics, special feature about the cultivation', *Compact Fruit Tree*, vol. 37, pp. 82-85.

Kellerhals, M, Riesen, W & Weibel, F 1997, 'IPM and organic apple cultivation. 2. Choice of sites and cultivars', *Obst und Weinbau*, vol. 133, pp. 80-81.

Meli, T & Schmid, O 1994, 'Yield and cost conditions from the example of a biological organic fruit enterprise', *Obst und Weinbau*, vol. 130, pp. 420-423.

Middleton, S & McWaters, A 2002, 'Hail netting of apple orchards – Australian experience', *Compact Fruit Tree*, vol. 35, pp. 51-55.

Middleton, S, McWaters, A, James, P, Jotic, P, Sutton, J & Campbell, J 2002, 'The productivity and performance of apple orchard systems in Australia', *Compact Fruit Tree*, vol. 35, pp. 43-47.

Neilsen, G, Cossentine, J, Forge, T, Hampson, C, Hogue, E, Judd, G et al. 2007, 'Organic apple production in British Columbia: Discovery to application', *Acta Horticulturae*, vol. 737, pp. 129-138.

Organic Industry Export Consultative Committee 2005, *National Standard for Organic and Bio-dynamic Produce,* Edition 3.2, October 2005, Canberra.

Readfearn, G 2006, 'Junior whoppers', *Brisbane Courier Mail,* 6 June, p. 53.
Shalimov, S I 1991, 'Soil preparation after grubbing old orchards', *Sadovodstvo i Vinogradarstvo*, vol. 2, pp. 11-13.

Stirling, G R, Dullahide, S R & Nikulin, A 1995, 'Management of lesion nematode (*P.penetrans*) on replanted apple trees', *Australian Journal of Experimental Agriculture*, vol. 35, pp. 247-258.

Stopar, M 2004, 'Thinning of flowers/fruitlets in organic apple production', *Journal of Fruit and Ornamental Plant Research*, vol. 12, pp. 77-83.

Strimmer, M, Kelderer, M & Pieber, K 1997, 'New thinning methods in organic apple growing', *Erwerbsobstbau*, vol. 39, pp. 130-136.

Swezey, S L, Vossen, P, Caprile, J & Bentley, W 2000, *Organic apple production manual*, United States Department of Agriculture, California, USA.

Swezey, S L, Werner, M R, Buchanan, M & Allison, J 1998, 'Comparison of conventional and organic apple production systems during three years of conversion to organic management in coastal California', *American Journal of Alternative Agriculture*, vol. 13, pp. 162-180.

United States Department of Agriculture 1999, *Soil Quality Test Kit Guide*. Natural Resources Conservation Service, Soil Quality Institute, USA.

Vossen, P, Jolly, D, Meyer, R, Varela, L & Blodgett, S 1994, 'Disease, insect pressures make organic production risky in Sonoma county', *California Agriculture*, vol. 48, pp. 29-36.

Weibel, F 2002, 'Soil management and in-row weed control in organic apple production', *Compact Fruit Tree*, vol. 35, pp. 118-121.

Weibel, F 1997, 'Enhancing calcium uptake in organic apple growing', *Acta Horticulturae*, vol. 448, pp. 337-343.

Weibel, F P, Beyeler, C & Hauert, C 2000, 'A strategy to prevent bitter pit incidence in organic apple growing by combining early risk prediction on the basis of fruitlets analysis and specifically adapted soil management', *Acta Horticulturae*, vol. 512, pp. 181-188.

Wills, A K 1976, *The granite and traprock area of south east Queensland. A land inventory and land utilisation study,* Technical Bulletin no.13, Division of Land Utilisation, Queensland Department of Primary Industries, Brisbane.

Wooldridge, J, Joubert, M E & Kotze, W A G 1997, 'Control of bitter pit in apple and internal breakdown in plum using an organically complexed calcium carrier (Calcimax)', *Acta Horticulturae*, vol. 448, pp. 351-357.
Zeppa, A, Dullahide, S, McWaters, A & Middleton, S 2002, 'Status of breeding for apple scab resistance in Australia', *Acta Horiculturae*, vol. 595, pp. 33-41.

Growing Organic Apples

World class production systems for new Australian apple varieties

by Simon Middleton, Aldo Zeppa, Allan McWaters, Christine Horlock,
Peter Nimmo and David Rickard

RIRDC publication number 08/123

Organic apple production is an increasing segment of the Australian apple industry, however, Australian apple growers considering organic production need to be aware they will face similar and often more arduous challenges to those faced by non-organic apple orchardists.

This report provides information needed for successful organic production of a new scab-resistant Australian apple variety that has been developed by the Department of Primary Industries and Fisheries, Queensland. The un-named variety is currently protected by provisional Plant Breeders Rights and is referred to by its breeding code of 'RS103-130'. Evidence that this variety can be grown organically is of value to apple growers intending to convert to organic production, but who may have some concerns that apple scab would be a significant impediment to successful production.

The study was funded by the Rural Industries Research and Development Corporation, Horticulture Australia Limited, Apple and Pear Australia Limited and the Department of Primary Industries and Fisheries, Queensland. It is an addition to RIRDC's diverse range of over 1800 research publications and forms part of our Organics R&D Program, that aims to facilitate the development of a viable organic industry through increasing adoption of sustainable organic farming systems.

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