FINAL REPORT

PROJECT AP01006 (May 2007)

DEVELOPING SYSTEMS FOR ORGANIC AND LOW INPUT APPLE PRODUCTION

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Department of Primary Industries and Fisheries, Queensland

AP01006

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This document is the final report for the project "Developing systems for organic and low input apple production", and as such contains the details and results of work carried out in this project.

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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
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*

Media Summary

The Australian apple industry has worked hard in recent decades to reduce its reliance on synthetic agricultural chemicals to control pests and diseases. Apple scab, caused by *Venturia inaequalis*, is the major fungal disease of apples in Australia, and new apple varieties resistant to scab have been developed by the Department of Primary Industries and Fisheries, Queensland (DPI&F).

One of these varieties is 'RS103-130', which will soon be available to Australian apple growers and help meet consumer demands for healthy food products grown using reduced agricultural chemicals. 'RS103-130' is a red apple that has exceptional shelf-life, and is juicy with a sweet, low-acid and mild flavour.

This project identified strategies to successfully grow 'RS103-130' apples in the Stanthorpe district of southern Queensland, in both organic and conventional production systems. The spring and summer rainfall 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' over four years suggests this variety is ideally suited to other apple producing regions of Australia, which contend with fewer environmental, pest and disease problems.

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, receiving an average price of $37 for first grade and $32 for second grade fruit per 12 kg two-layer carton. Returns in 2007 were even higher, and up to $60 per 12 kg two-layer carton.

The scab-resistant apples, including 'RS103-130', are well-adapted to modern high density planting systems (upwards of 2000 trees per hectare). To date, the yield and quality of apples from young trees in such intensive systems has been excellent, with 'RS103-130' apples averaging 200 g or higher.

The availability of a new, high quality scab-resistant apple variety at the organic retail level will not only offer more choice to the organic apple consumer, but provide orchardists with the opportunity to produce organic apples more easily than if growing the standard varieties currently available. In addition, 'RS103-130' has shown it is a suitable apple for conventional production, rating highly in consumer evaluations.

The potential effects of soil management strategies and mulches on soil health, water use efficiency and managing drought requires further investigation, and is applicable to both organic and conventional systems of apple production.

A practical manual has been written which provides detailed strategies for successful organic production of scab-resistant apples in Australia.

Technical Summary

Apple scab (colloquially known in Australia as apple black spot) caused by the fungus *Venturia inaequalis*, is a major disease of apples in Australia and throughout the world. Apple varieties resistant to apple scab have been bred and developed in the Department of Primary Industries and Fisheries, Queensland (DPI&F) apple breeding program, and several show promise as high quality apples with the potential to be grown in both organic and non-organic systems.

One of these varieties is 'RS103-130', which 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 commercial planting to determine strategies for successful organic production of new Australian scab-resistant apples. Organically produced apples offer one option for growers seeking higher returns, and practical production systems need to be developed to help satisfy increasing consumer demand for organic produce.

'RS103-130' was successfully 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. This region is one of the more marginal apple growing areas of Australia, characterised by sandy soils and a warm, summer rainfall climate. With appropriate strategies now developed to organically produce 'RS103-130' 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.

Australia's first crop of organically grown 'RS103-130' scab resistant apples was produced in March 2006, as part of this project. Some of these apples were marketed 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. Customer feedback was excellent and the apples sold quickly. Returns in 2007 were even higher, and up to $60 per 12 kg two-layer carton.

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.

A second, ongoing component of the project consists of replicated high density planting system trials for four scab-resistant apple selections, including 'RS103-130'. These are planted at Applethorpe Research Station (ARS), and include evaluation of a range of rootstocks (M.9, Ottawa 3, M.26, MM.102, MM.106) and tree densities (1666 - 5925 trees/hectare). The oldest trees were in their 5th leaf in 2006/07. Early yields and packouts have been excellent, and yields are expected to further improve significantly as the trees reach their full bearing potential. Of particular promise is that fruit size of 'RS103-130' averages 200 g or higher in most systems, despite heavy crop loads.

In a comparison of soil characteristics beneath 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 apple growing regions of Australia occurs as high intensity storms. The potential effects of soil management strategies on soil health, water use efficiency and managing drought requires further investigation, and is applicable to both organic and conventional systems of apple production.

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, and incorporation of the principles outlined in the National Standard for Organic and Bio-Dynamic Produce.

1. Introduction

In Australia, over-production of apples together with low per capita consumption, in part as a result of competition from other fruit and foods, has contributed to low market prices. Premium fruit quality and the planting of 'high value' varieties in demand by the market are critical for apple orchards to remain viable. In addition, the increased need for environmentally sustainable horticultural production systems that place minimal demands on natural resources, especially water, is forcing 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 steadily increasing consumer demand for organic apples. 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 6000 - 8000 tonnes per annum (Middleton *et al.*, 2007).

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.

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, and a perceived price premium for organically grown apples is an enticement for apple growers to consider organic production, regardless of their philosophical leanings. Globally, organic apple production is steadily increasing, and is set to continue rising as large food retailers in the USA and Europe sell more organic apples to meet consumer demand (Granatstein and Kirby, 2007).

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 (colloquially known in Australia as apple black spot), is caused by the fungus *Venturia inaequalis*, and is a major disease of apples in Australia and throughout the world. 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 production systems. One of these, 'RS103-130', is currently protected by provisional Plant Breeders Rights (PBR) in Australia.

The Australian environment is a challenging one for 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, of low fertility and low organic matter content. In addition, the climate is variable and characterised by cycles of drought and floods. Average annual rainfall is an unreliable indicator of the viability 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, sandy and of poor fertility, low water holding capacity and low organic matter content. The climate is characterised by cool to mild winters (average maximum 14^0C, average minimum 1^0C) and warm summers (average maximum 28^0C, average minimum 16^0C). The 750 mm average annual rainfall is concentrated in spring and summer, and predominantly occurs as high intensity storms. Extreme weather events (drought, hail) 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.

Weed management is a significant issue in all Australian apple orchards, in particular for potential and current organic producers. Standard practice in conventional apple orchards is to control weeds with herbicide. This option is unavailable to organic producers, so alternative strategies need to be found. Weeds can significantly reduce apple tree growth and yields (Hogue and Neilsen, 1987), and research into the weed management of organic apple orchards continues to be a priority throughout the world (Weibel *et al.*, 2007; Neilsen *et al.*, 2007).

Continued herbicide applications in conventional orchards are also likely to alter and reduce soil biological activity, however there is a lack of information on the impacts of soil management on the biological component of the soil (Yao *et al.*, 2005). Soil health can be defined as "the capacity of the soil to function" (Karlen *et al.*, 1997), and important soil functions include water use efficiency, sustained crop production, physical stability, retention and recycling of nutrients and the suppression of soil-borne pathogens. Soil management within organic systems must necessarily aim to maintain and improve soil health in the context of these parameters.

Stirling *et al.* (1995) suggested that maintenance of an organic mulch around apple trees is able to suppress plant-parasitic nematodes. However, the mulch may also be affecting additional soil properties, and its impact on other soil-borne diseases is unclear. Glover *et al.* (2000) measured 14 indicators of soil quality in organic, conventional and integrated (IFP) apple orchard systems in Washington State, USA, and developed a soil health index that validated the soil management of organic and integrated cropping systems over the use of herbicide in the conventional system.

Over the past several decades, low density apple orchards of poor productivity have been steadily replaced by more intensive systems planted on precocious dwarfing and semi-dwarfing rootstocks that reduce tree size and permit closer planting. Ongoing intensification of apple orchards has occurred widely throughout the world (Barritt, 1992; Mantinger, 2000; Palmer and Warrington, 2000; Robinson and Hoying, 2002), as an efficient means to attain high yields early in the lifetime of the orchard, maximise light interception and optimise light distribution within the tree canopy for high fruit quality.

High density planting systems require appropriate trellis designs to provide tree support and help maintain tree structure. In recent years, the presumed and real benefits of 'V' trellis systems that intercept high levels of sunlight (angled arms of the tree canopy are trained upwards and out over the alleyways), has seen this type of system adopted in some intensive plantings (Robinson, 2000).

The trend to intensification of apple orchards has also occurred in Australia (Middleton *et al.*, 2002), albeit at a much slower rate and generally at less intensive planting densities than in Europe, North America and elsewhere. The advantages of high density planting systems for apple have been demonstrated in several research trials in Australia (James, 1997; Campbell, 1997; Middleton and McWaters, 2001; Jotic and Oakford, 2003), and specific rootstock, planting density and tree training recommendations developed as appropriate for each local environment.

Although the recommendations from these trials vary due to differences in the performance of rootstocks and varieties in the distinctive soil and climatic conditions of each region of Australia, light interception provides an excellent comparative guide to the productivity of apple orchard systems. In all of these trials, the systems of highest productivity had midseason diurnal light interception of close to 60% (Middleton *et al.*, 2002).

The sunlight intensities of Australia's apple growing regions are high relative to most other apple producing countries (Jackson, 1997). Despite this, the use of over-vigorous rootstocks and inappropriate training systems and planting densities can create levels of shading within intensive orchards in Australia that severely reduce their yield and fruit quality (Middleton and McWaters, 1997; James and Middleton, 2001).

Apple yields increase with light interception, until a point is reached where the leaf canopy is too dense and/or excessive tree height and spread lead to severe shading effects (Jackson, 1980). Declines in fruit set, yield and fruit quality through overcrowded leaf canopies on mature apple trees at higher planting densities have been reported by many authors, including Parry (1978), Christensen (1979) and Mika and Piatkowski (1986). Reduced fruit size (Palmer and Wertheim, 1980; Parry, 1981; Wertheim, 1985) and colour (Sansavini *et al.*, 1980; Parry, 1981; Barritt *et al.*, 1987) are the most commonly reported effects of excessive shading within intensive orchards.

To achieve maximum orchard productivity, the objective of high density planting systems for apples in Australia should therefore be the rapid development of a leaf canopy that intercepts 60% of incident sunlight levels, ideally within three to four years of planting, and the subsequent maintenance of a tree form and structure that allows adequate sunlight to reach all parts of the canopy (Middleton *et al.*, 2002).

The new Australian-bred scab-resistant apple varieties developed at Applethorpe Research Station (Zeppa *et al.*, 2002) are untested on semi-dwarfing and dwarfing rootstocks grown in high density planting systems. It is therefore unknown what the vigour, growth habit, biennial bearing habit, fruit colour sensitivity to sunlight, potential yield and fruit quality of these varieties is, and how best to grow and manage trees of these new selections in modern intensive orchard systems. Without this information it is impossible to further develop the varieties and evaluate their true potential for commercial release.

The overall objective of this project was to develop orchard and tree management strategies for the successful production of new Australian-bred scab-resistant apples. Recommendations specific to both organic and conventional systems of production are presented in this report, with particular focus on organic production of 'RS103-130'.

If appropriate strategies can be developed to successfully produce scab-resistant apples organically in the warm summer rainfall environment of the Granite Belt, Queensland, it should be feasible to do so in other apple growing regions of Australia which contend with fewer environmental, pest and disease pressures.

2. Materials and methods

The project consisted of two key 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.

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' (Plate 1). These were planted as replicated trials at Applethorpe Research Station (ARS), and included evaluation of a range of rootstocks and tree densities.

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

Similarly, the results, discussion and a brief summary of outcomes are included with each of these chapters.

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

3. Organic production of scab-resistant apples on a commercial orchard

3.1 Introduction

The organic apple trial site discussed in this chapter was primarily used as a demonstration planting to establish and organically 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) undergo the process of organic certification for a newly-planted commercial block of trees.

3.2 Materials and methods

One-year-old nursery trees of 'RS103-130' apple (*Malus x domestica* Borkh.) and 'Galaxy' (comparator apple variety) were planted on a commercial orchard in August 2002 in the Stanthorpe district of southern Queensland (28^0 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 80 trees of 'Galaxy', however with subsequent plantings the one hectare site in 2005 consisted of 1000 trees of 'RS103-130' and 51 trees of a second black spot resistant apple selection, in addition to the 80 'Galaxy' trees and 15 crab apple polleniser trees ('Golden Hornet' and 'Manchurian'). 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 was 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 (Envirogànics 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, and further details are provided in Appendices A and C. 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 on all apples harvested. The organic certification of the site was conducted by ACO (Australian Certified Organic Pty Ltd), the certification arm of the Biological Farmers of Australia (BFA). All inputs continue to be monitored and recorded to ensure compliance with BFA organic standards (Organic Industry Export Consultative Committee, 2005).

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)

3.3 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 ('RS103-130').

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.

3.3.1 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 can provide similar levels of foliar fungal disease control for 'RS103-130' and 'Galaxy'.

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*). *Bacillus thuringienses*, spinosad and pheromone disruption are now providing effective management of these pests. Spinosad-based bait spraying is maintaining populations of Queensland Fruit Fly (*Bactorcera tryoni*) at an acceptable level. Although a high proportion of fruit were affected by native budworms (Table 2), most damage was minor and the fruit was of acceptable appearance to consumers of organic apples.

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 (Appendix C). 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 an 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.

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

3.3.2 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.

3.4 Outcomes

Based on results from the first four years of this planting, a summary schedule of recommended orchard operations for organic apple production is reproduced in Appendix A as an annual calendar of activities. Further specific recommendations and practical information derived from this trial site are included in an organic apple production manual (Appendix C of this report).

Australia's first commercial crop of organically grown, 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. A larger consignment of organic 'RS103-130' apples was sold through this wholesaler in April 2007, with returns of up to $60 per 12 kg two-layer carton.

An economic analysis spreadsheet for organic apple production has been developed (Appendix B), based on the actual costs of recommended orchard operations at the commercial organic apple trial site, and returns of $32 per 12 kg two-layer carton. This was the lowest price received for organically produced 'RS103-130' apples in 2006 and 2007, and is therefore a conservative estimate of the returns for organic 'RS103-130'. 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

4.1 Introduction

Weeds are a significant problem facing all Australian orchardists. The limited range of organic strategies to effectively manage weeds is one issue hindering a more significant shift 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.

4.2 Materials and methods

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

4.2.1 '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.

4.2.2 Weed management in the commercial organic apple trial

Weed mat (polypropylene non-woven matting) covered with a layer of pine chip mulch was used 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 to the row) 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 was 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.

4.3 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, as measured 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 that was treated with herbicide and kept weed-free all season.

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
Herbicide (conventional)	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

Hand hoeing of weeds beneath trees all season had no significant effect on tree size (TCA), yield and fruit size when compared to hand hoeing beneath trees for only the second half of the season, between January and April (Table 3). The presence of weeds beneath trees from October to December hence had little effect on productivity. Under less stressful conditions with adequate supply of water, differences between these and other weed management treatments will likely become more 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.

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 than 'RS103-130'. There was sufficient soil moisture during the early part of the season, up until February, 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 above 28^0C can limit apple tree growth, and apple trees on many rootstocks perform poorly at soil temperatures above 25^0C (Ferree and Carlson, 1987). The 10^0C reduction in soil temperature under sugar cane mulch provides 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 4^0C 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).

4.4 Outcomes

The beneficial effects of sugar cane mulch and compost on soil properties requires further detailed study, including longer-term monitoring of the effects of these soil management strategies on soil biological activity, potential soil-borne disease suppression, apple tree growth, yield and fruit quality. The results from such work may ultimately see apple orchardists, whether organic or non-organic, re-considering 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 sustainable soil management strategies are adopted, which 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 Temperature (10 cm depth)	20.3 °C	30.2 °C
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

All figures in Table 5 are the mean of four separate measurements within each orchard

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) Dry	Wet	pH
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

All figures in Table 6 are the mean of four separate measurements within each orchard

5. Intensive orchard systems for new Australian scab-resistant apple varieties

5.1 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 also 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', 'Selection 4', and only broad, generic descriptions are given. An application for United States Plant Patent for 'RS103-130' has been made, 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 (Zeppa *et al.*, 2006).

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 scab-resistant apple selections. This requires experimental trials that evaluate a range of rootstocks and planting densities to develop recommendations for each variety, so that growers are able to produce high quality fruit. Such experiments take many years to complete. Apple trees don't produce 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 tree 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.

5.2 Materials and methods

In winter, dormant scion wood was taken from virus-tested mother trees of the scab-resistant apple selections, 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 the advantage of planting well-feathered trees that produce crops of apples within two years.

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 scab-resistant apples for storage, consumer and market evaluation.

In all experiments, no sprays for apple scab have been applied, with the exception of a low rate copper spray at green tip (mid-late September) each year.

A standard program was used in all experiments to control other major diseases (powdery mildew) and pests (codling moth, light brown apple moth, native budworms, Queensland fruit fly). Weeds beneath trees were controlled with herbicide, and a mown grass sward maintained in the alleyways. All trees were irrigated and fertilised as required. In particular, calcium nitrate was applied to bearing trees through the trickle irrigation system at fortnightly intervals between September and early December, and again on three occasions in March – April, after harvest. Non-bearing trees received fortnightly calcium nitrate from September to April. Supplementary calcium sprays were also used.

Tree training and pruning was based on maintaining a dominant upright leader, using a minimum of pruning cuts, and tying down limbs to control growth and encourage fruiting.

All six experiments described below are protected by a permanent hail netting structure, and are continuing as part of project AP05008.

5.2.1 Experiment 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 complete 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 x 1.75 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, and the first significant quantities of apples were produced in 2006. 'RS103-130' has been described previously.

5.2.2 Experiment 2 – Planting systems for 'Selection 2'

Planted in October 2003 as a randomised complete block design, the trial includes the following rootstock x spacing treatments (four replicates x 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 their third leaf, in 2006.

'Selection 2' has 'Royal Gala' in its parentage and was derived from a 'Royal Gala' cross with a scab-resistant breeding line from a USA program. It is ready for harvest in 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 large 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.

5.2.3 Experiment 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 were 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.

5.2.4 Experiment 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 (Plate 5) and to a single-row vertical trellis. The experiment is designed as a randomised complete block to compare the two training systems, the two rootstocks and tree densities of 2500, 3555, 4444 and 5925 trees/ha. Each system is replicated five times, and 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).

5.2.5 Experiment 5 – Rootstock trial for 'Selection 3'

In September 2004 a rootstock trial for a third 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 3.6 m x 1.0 m (2777 trees/ha), trained to a vertical trellis and produced a light crop of apples in 2006 (second leaf). Unfortunately, 'Selection 3' 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.

5.2.6 Experiment 6 – Rootstock trial for 'Selection 4'

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 selection which has excellent potential as either a conventionally or an organically produced apple. The trees were planted at 3.7 m x 1.0 m (2702 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 produce a light first crop in 2007.

'Selection 4' is a sibling to 'Selection 2', having 'Royal Gala' as one of its parents. It is medium red with a dark red over-stripe on yellow-green ground, and matures two to three weeks after 'Royal Gala'. 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.

5.2.7 Tree vigour and orchard productivity

The procedures used to measure tree vigour, yield and fruit quality were common across all experiments, and will continue to be used in subsequent seasons.

Tree vigour

The vigour of trees in each experiment was measured annually. The parameters used include tree height, annual shoot growth, total leaf area per tree, and trunk cross-sectional area (TCA) as calculated from measurements of trunk circumference 15cm above the graft union.

The leaf area index (LAI) of each orchard system was calculated from leaf counts and average individual leaf areas (cm^2). All of the leaves on at least two trees per plot were counted. To date, due to the smaller size of the trees, the leaves on all datum trees in Experiments 3, 4 and 6 have been counted. In all experiments, spur leaves and shoot leaves were counted separately. Individual leaf areas were measured non-destructively in the field with a perspex grid as described by Freeman and Bolas (1956), using a random sample of up to thirty spurs per tree for spur leaves, and fifteen extension shoots per tree for shoot leaves.

The individual leaf areas estimated from the grid were highly correlated ($r^2 > 0.90$) with measures of leaf areas made in the laboratory with a Licor LI-3000 leaf area meter (Licor Instrument Co., Lincoln, Nebraska, USA).

LAI was calculated as m^2 leaf per tree / m^2 orchard floor surface area per tree. For example, an orchard system planted at a density of 1000 trees/hectare ($10m^2$ orchard floor/tree) and consisting of trees with an average leaf area of 16.6 m^2 /tree, has an LAI of 1.66 (16.6/10).

Orchard Productivity
Starch:iodine measurements (1.5% aqueous iodine solution) were used to determine the optimum harvest maturity for each variety.

At harvest, all fruit on each tree was counted and weighed. In experiments 1 and 2, fruit size, colour and sunburn were measured on all apples harvested from two datum trees in each replicate of each orchard system.

In experiments 3, 4 and 5, all apples from all datum trees were individually weighed and assessed for colour and sunburn. Trees in Experiment 6 had not yet cropped as they were only in their first leaf in 2005/06.

Apple fruit colour was assessed visually on a scale of 1 to 3, as illustrated in Plate 4 for 'RS103-130'. A colour rating of 1 was used for fruit of unacceptable, sub-standard colour; 2 for adequately coloured fruit; and 3 for apples with premium colour.

Sunburn was visually assessed using a scale of 0 (nil), 1 (slight) or 2 (severe). Due to protection of the trees with hail netting, there was insignificant sunburn damage to apples in any of the experiments.

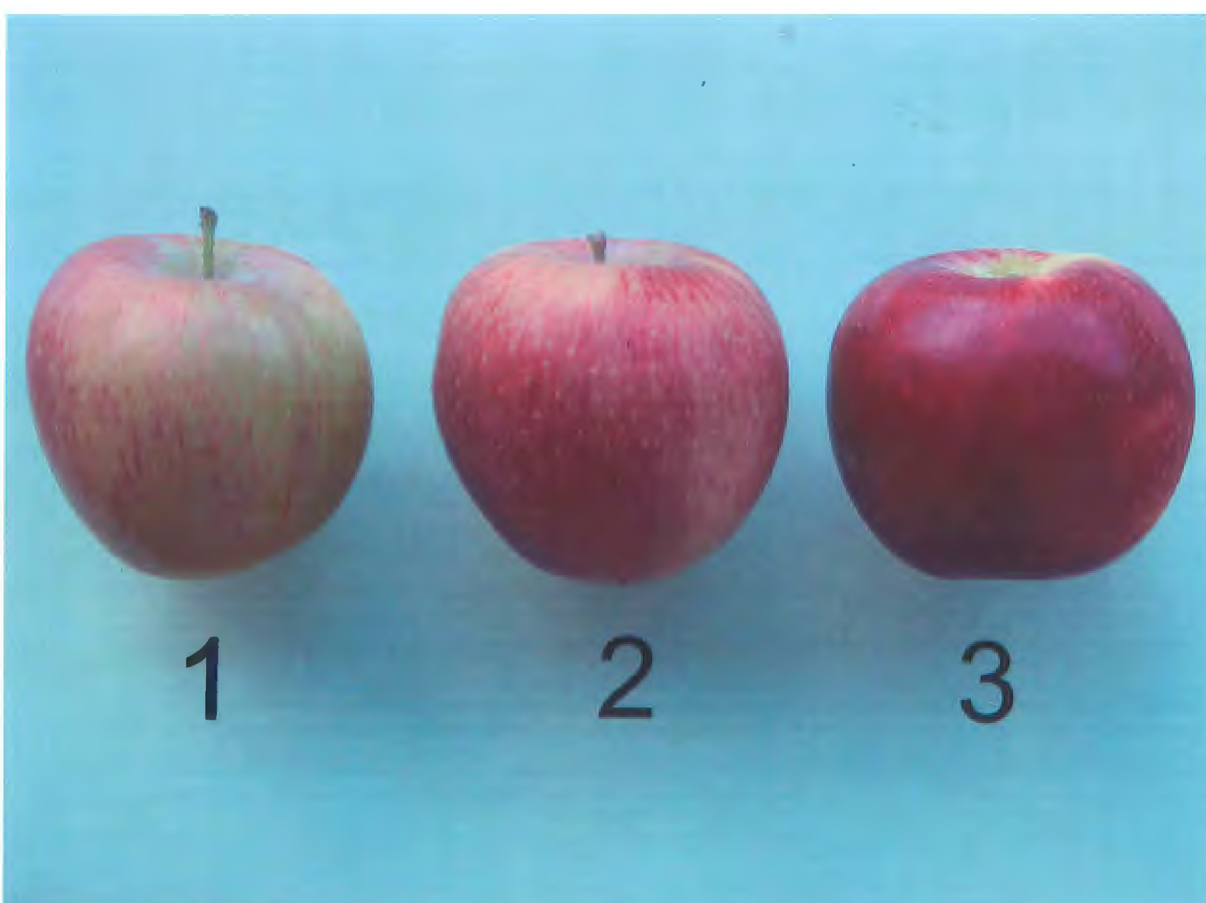

Plate 4. Rating classes (1-3) used to visually assess the colour of 'RS103-130' apples

5.3 Results and discussion

The six experiments described in this chapter are designed to measure the tree growth, yield and fruit quality of new Australian-bred scab-resistant apple selections grown on semi-dwarf and dwarf rootstocks in a wide range of high density planting systems. These experiments are necessary to develop appropriate intensive orchard system designs and tree management strategies that maximise the potential productivity and profitability of the new scab-resistant apples.

The first significant crops of fruit were produced from four of these experiments (experiments 1-4) in 2005/06. Apples harvested in 2005/06 were large (Tables 7-10), and average fruit weight in most 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 were therefore retained in 2006/07 on trees in experiment 1 (fifth leaf) and experiment 2 (fourth leaf). This will also help provide some measure of the biennial bearing habit (annual fluctuations in yield) of 'RS103-130' and 'Selection 2', which can only be fully determined once the trees are mature and approach full cropping potential.

Similarly, it is unknown how heavy a crop younger trees of 'RS103-130' can carry without significantly reducing tree volume, and hence potential 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.

Overcropping an apple tree reduces shoot growth (Maggs, 1963; Jackson, 1984; Forshey and Marmo, 1985), and can, depending on rootstock and tree habit, set up a biennial bearing pattern in the tree (Jonkers, 1979), with heavy crops in one year followed by little return bloom (and hence crop) the next. 'RS103-130' is a semi-spur variety and trees carried a high number of fruit buds in 2006/07, so it is possible that 'RS103-130' trees have little tendency to biennial bearing. These issues are being investigated in 2006/07 in crop load experiments on young (third leaf) and more mature (fifth leaf) trees of 'RS103-130'.

The yields of trees in their second leaf (Tables 9 and 10) are moderate to high. An important objective of intensive planting systems is to be able to harvest apples from the second year onwards, and any fruit produced in the second year is important to generate early returns on investment. It is critical, however, to avoid over-cropping trees in their second leaf as this can retard tree growth and hence delay the achievement of full canopy volume and cropping potential.

For trees in only their second, third and fourth leaf, all systems are producing reasonable crops of large, well-coloured fruit. Nevertheless, some significant differences in the yields of the tree management systems are emerging (Tables 7-10). In experiments 2, 3 and 4, this is largely due to differences in the size, volume and LAI of the young trees ie. trees with higher canopy volumes and LAI (Tables 9 and 10) are producing the higher yields. It should be stressed, however, that the trees are still young, have not yet reached their full size, and have only cropped for one or two seasons.

In experiment 1 there has been little difference in the yield and packout of the six systems to date, with the exception of 'RS103-130' trees on M.26 rootstock planted at 5000 trees/ha. In 2005/06, trees in this system yielded significantly higher than other trees, however already, in their fourth leaf, the packout of premium quality apples in this system was down to 62% (Table 7), due to internal shading effects on fruit colour.

Rootstock and planting density effects on yield and fruit quality as a consequence of increasing tree size and vigour will occur as the trees become older. The most productive tree management systems will become evident as the trees reach full maturity, and once potential shading effects on the yields and fruit quality of mature bearing trees in the different systems are known. The true gauge of orchard system performance will come in the next three to four years, when appropriate high density planting systems can be identified that consistently produce at least 50-60 tonnes/ha/annum of apples from the fifth or sixth leaf onwards, with packouts of 80 - 90% and above.

The packout figures (Tables 7-10) are generally high, but can be expected to decline as the trees become larger. The key to success with all systems will be to manage tree vigour for maximum productivity, through the development of a "well-illuminated" canopy and tree structure that ensures adequate sunlight can penetrate to leaves and fruit in all parts of the tree.

Bending of limbs and shoots to well below horizontal is an effective technique to develop good tree structure, control shoot growth and encourage the development of fruiting spurs (Österreicher, 2004). This strategy, combined with minimal pruning, will be continued in all experiments in 2006/07, to help develop the optimal tree form and structure required for the highest productivity in each system. Potential internal shading will also 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, trees of 'Selection 2' in their third leaf had a 100% packout (Table 8). 'Selection 2' 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%. Strategies to reduce the fruit size of 'Selection 2' in future years will include reduced thinning, irrigation and nitrogen, as 300 g apples are too large for wide consumer appeal.

The use of intensive planting systems with trees grown on semi-dwarfing and dwarfing rootstocks is an effective means to attain high yields early in the lifetime of the orchard (Palmer, 1988; Barritt, 2000; Wertheim *et al.*, 2000). 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, it is expected that fruit quality relative to the other systems 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 (second, third and fourth leaf trees) is evident in experiments 1, 2 and 4 (Tables 7, 8 and 10). The 'V' trellis system in Experiment 4 (Plate 5) 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, 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 this experiment. This can be attributed to the larger size and hence fruiting canopy volume of these trees. As the experiment progresses and all trees reach their full size and maturity, the other more dwarfing rootstocks will likely 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 apple tree size (eg. James, 1997; Perry, 1997; Marini, 2002), as it is quick and easy to measure. Reductions in TCA occur with increasing tree density (Tables 7 and 8), as individual trees occupy less orchard floor area at higher densities, and experience root competition from closely adjacent trees. This effect is greater as the trees age, and along with the influence of dwarfing rootstocks 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, 4444 and 5925 trees/ha already have significantly lower TCA than MM.106 trees at 2500 trees/ha.

Leaf Area Index (LAI) is more accurate than TCA as a measure of tree size and vigour, especially on young trees (Palmer, 1987). Unfortunately, the total leaf area of trees can be very time-consuming and tedious to measure. Nevertheless, LAI has been measured on trees in these experiments to accurately quantify the interaction of rootstock and planting density on tree size. Although individual trees are smaller, the LAI for trees on a given rootstock tends to increase at higher planting densities (Tables 7 and 10), due to the higher number of trees per unit area.

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' single-row apple orchard systems (Middleton *et al.*, 2002), and an LAI of 2.5 - 3.0 ideal for 'V' trellis systems. Compared to single-row systems, the angle of trees positioned on the 'V' trellis system (Plate 5) permits a broader spread of tree canopy, and hence leaf area, across a greater orchard floor surface area. This in turn means that the 'V' trellis can accommodate a higher LAI before declines in yield and fruit quality occur.

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 rootstock and the pruning strategies used. In the first growing season, much of the growth occurs in root development below the ground, so trees may remain relatively small, especially if water stressed. Indeed, there is little difference in TCA and LAI between rootstocks for trees of 'Selection 3' in their first leaf (Table 11). Rootstock effects on TCA and tree size will start to emerge in years two and three of this experiment.

In the first experiment planted (experiment 1), the highest LAI for trees in their fourth leaf is 1.3 (Table 7). The trees in this experiment are upright, and a strategy of minimal pruning and spreading of branches has been initiated to increase light interception and LAI.

The advantage of planting trees at high densities in a 'V' trellis system to rapidly attain a high canopy volume is 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). It is not yet possible to recommend this system for scab-resistant apples until the trees have reached full size, and any potential medium and long-term problems of shading on yield and fruit quality at such high tree densities are identified. This will also require an economic analysis based on the costs of establishment of this system, and returns over a number of years.

Due to severe susceptibility of the trees to *Alternaria* leaf blotch, no results are presented for 'Selection 3' (experiment 5). Trees of 'Selection 3' were almost completely defoliated by *Alternaria* leaf blotch in February 2006. Although 'Selection 3' has potential as an attractive scab-resistant apple, it will not be a commercially viable proposition until suitable control measures for *Alternaria* leaf blotch and *Alternaria* fruit spot are found.

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 1-3 scale. ie. includes fruit of 'acceptable' colour (rating 2)

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

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 area LAI: Leaf Area Index *NS*: not significant

* Packout percentage based on fruit weight > 120 g and colour rating ≥2 on a 1-3 scale. ie. includes fruit of 'acceptable' colour (rating 2)

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

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 area LA: Leaf area/tree LAI: Leaf Area Index *NS*: not significant

* Packout percentage based on fruit weight > 120 g and colour rating ≥2 on a 1-3 scale. ie. includes fruit of 'acceptable' colour (rating 2)

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

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 area LAI: Leaf Area Index *NS*: not significant

* Packout percentage based on fruit weight > 120 g and colour rating ≥2 on a 1-3 scale. ie. includes fruit of 'acceptable' colour (rating 2)

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

Table 11. The effect of rootstock on trunk cross-sectional area (TCA), leaf area and leaf area index (LAI) of trees of 'Selection 4' in their first leaf (Experiment 6)

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 area LAI: Leaf Area Index *NS*: not significant

5.4 Outcomes

Until the trees in Experiments 1-6 have reached full bearing maturity and been cropped for several successive seasons, it is impossible to fully evaluate and compare the performance and potential productivity of the different tree management systems. Nevertheless, it is already clear that the scab-resistant apples, including 'RS103-130', are well-adapted to modern high density systems using semi-dwarfing and dwarfing rootstocks planted at upwards of 2000 trees per hectare.

The future issue will be whether trees at these densities out-grow their allocated spaces, and, if required, whether supplementary vigour control measures such as summer pruning prevent possible fruit quality and packout declines as the trees become older. It is envisaged, however, that the vigour of trees of 'RS103-130' and the other scab-resistant selections planted in the intensive systems trials can be adequately controlled to ensure continued high productivity.

The excellent quality of 'RS103-130' apples produced in experiments 1, 3 and 4 has been borne out in consumer evaluation trials conducted in Brisbane. Consumers rated the appearance and eating quality of 'RS103-130' apples as either comparable to, or better than, currently available commercial apple varieties (Zeppa *et al.*, 2006).

The experiments in this chapter are continuing as part of project AP05008 "Breeding for resistance to apple black spot beyond 2000". Results from these experiments in 2006/07 will be included in the final report for project AP05008. Within the next two years, and certainly by the time of commercial release of 'RS103-130', it will be possible to recommend a full tree management package for growers to produce 50-60 tonnes/hectare/annum of quality apples from mature bearing trees of 'RS103-130'.

Plate 5. Harvesting scab-resistant 'RS103-130' apples from a V-trellis system (Experiment 4)

6. Technology transfer

Grower field days and seminars

Three field days were held at the commercial organic apple trial site on 15 April 2003, 30 April 2004 and 22 March 2006. The 2006 field day was timed for growers to see fruit of 'RS103-130' on the trees, just prior to harvest. On all occasions, growers were invited to inspect trees at the trial site, and members of the project team gave talks in the orchard. Presentations were given on pests, diseases, tree management, 'RS103-130' and other scab-resistant apple selections, soil management and orchard biodiversity. A booklet of talks and notes was prepared as a handout for each field day.

Farmwalks were also held in the high density systems trials at Applethorpe Research Station on 22 March 2006 and 29 March 2007. These farmwalks will be continued at least annually. As the trees in these trials approach full maturity, it is important that growers are able to view the yield and quality of apples on the trees, to assist in their decisions on what systems and tree management strategies are best for intensive production of the new scab-resistant apple varieties.

Members of the INN group (International Nursery Network) from North America, South America, Europe, South Africa and Australia also viewed the intensive systems trials for scab-resistant apples at Applethorpe on 16 March 2007.

Additional seminars were presented by Dr Simon Middleton at Lenswood, South Australia on 8 April 2005 (attended by apple growers from SA, WA, Qld and Victoria), and at Batlow, NSW on 12 September 2005.

Grower seminars on the principles of orchard design and intensive systems for apple production were also presented by Dr Middleton as part of the "Future Orchards 2012" project. These seminars were given as a component of orchard walks held in Donnybrook, WA (29 January 2007), Lenswood, SA (31 January 2007), Yarra Valley, Vic (1 February 2007) and the Huon Valley, Tas (2 February 2007).

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7. Recommendations

7.1 Industry

Apple growers, whether considering organic or conventional systems of production, are encouraged to plant and test the scab-resistant apple variety 'RS103-130' when it becomes commercially available. 'RS103-130' has proven to be an attractive apple that has scored highly in consumer evaluations in Brisbane, and been purchased at premium prices by organic consumers in Sydney.

For conventional or organic production of 'RS103-130', the recommended management strategy for apple scab (apple black spot) is to use a single, green-tip copper spray in early spring, when there is greatest disease pressure from the apple scab fungus. No other sprays for apple scab control have been applied in five seasons of conventional production of 'RS103-130', and no apple scab has been found on leaves or fruit in that period.

A seasonal apple scab control program for organic production of 'Galaxy' and other susceptible varieties 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.

Australian apple growers considering organic production need to be aware they will face similar, and often more arduous challenges to those faced by orchardists using conventional systems. Managing the orchard to produce quality fruit 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.

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

Weed management is a particularly difficult issue facing organic apple growers. A 20 cm deep layer of organically-certified sugar cane mulch provided a satisfactory level of weed control, whilst also beneficially reducing soil temperature and improving water infiltration. The mulch requires "topping up" annually. Non-organic apple growers are also encouraged to test such soil management strategies as an alternative to herbicide for weed control, for their potential benefits in soil health and water use efficiency.

Growers considering organic apple production are advised to refer to the cost-benefit economic analysis in Appendix B. This is based on the actual costs of recommended orchard operations at the commercial organic apple trial site in Queensland, and returns of $32 per 12 kg two-layer carton as obtained for second grade fruit sold through the organic wholesaler in Sydney in 2006. This was the lowest price received for organically produced 'RS103-130' apples in 2006 and 2007, and is potentially therefore a conservative estimate of the returns for organic 'RS103-130'.

The economic analysis uses many assumptions, as listed in 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. Based on these assumptions, the analysis shows that organic apple production is profitable, provided average annual marketable yields of 17.4 tonnes per hectare are obtained from year four onwards, with year seven as the 'breakeven' year. The potential profitability of organic apple production improves as yield increases beyond this level, and as prices improve beyond $32 per 12 kg two-layer carton.

A summary schedule of recommended orchard operations for successful organic production of scab-resistant apples is presented in Appendix A as an annual calendar of activities. Growers are encouraged to use this schedule as a guide in developing orchard management practices suitable for their own particular individual circumstances.

Further specific recommendations developed in this project, and practical information for organic apple production are included in an organic apple production manual, "Organic Apple Production in Australia – A Practical Guide" written as part of this project (Appendix C).

The scab-resistant apples, including 'RS103-130', are well-adapted to modern high density planting systems (upwards of 2000 trees per hectare). To date, the yield and quality of apples from young trees in intensive systems (2000 - 5000 trees per hectare) has been excellent, with 'RS103-130' apples averaging 200 g or higher.

It is suggested that growers wishing to grow 'RS103-130' as a conventional variety, plant trees on semi-dwarfing or dwarfing rootstocks (M.26, M.9) at densities of 2500 trees per hectare or higher, with a view to annually produce 50 - 60 tonnes per hectare of apples by the fifth leaf. 'RS103-130' trees have a semi-spur growth habit and respond well to limb tying, producing a lot of fruitful spurs and a good, easily-managed balance of fruiting wood and annual growth.

For organic production of 'RS103-130', MM.106 rootstock (resistant to woolly apple aphid) is suggested, at planting densities of 1500 - 2000 trees per hectare. The potentially high vigour of trees on MM.106 rootstock can be readily controlled by branch tying and judicious minimal pruning.

7.2 Scientific

This project has demonstrated that the new Australian-bred scab-resistant apple 'RS103-130' can be successfully grown on the Granite Belt, Queensland, using organic production methods. The scab resistance of 'RS103-130' has been robust in the field, and no apple scab has occurred on trees or fruit of 'RS103-130' despite the presence of the disease on adjacent 'Galaxy' trees planted within the commercial organic apple block. 'RS103-130' should also be ideally suited to both organic and conventional production systems in other apple producing regions of Australia, particularly those areas which do not have spring and summer rainfall, as occurs in Queensland.

Whilst '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, the management strategy for apple scab recommended in conventional production of '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. This could be followed by a further application of an apple scab eradicant spray at a time of heavy infestation risk and significant scab ascospore maturity.

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. 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.

Indeed, as Australian apple orchardists continue to 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 consider organic systems for apple production.

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 investigation. The use of compost as a potential option to alter the soil ecological balance and control soil-borne plant pathogens is of particular interest, 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.

With ongoing drought throughout much of Australia and increasing pressure on dwindling water supples for agricultural use, the potential drought tolerance of 'RS103-130' and 'Selection 2' warrants investigation. Both selections are large apples, and may require less water and fewer management inputs than other apple varieties. This is especially the case for 'Selection 2', which to date has produced excessively large apples averaging 300 g. It may be possible to reduce the size of this apple to a more desirable 200 g, by cropping the trees more heavily (less or no thinning), and reducing irrigation and nitrogen.

'Selection 3' has potential as an attractive scab-resistant apple for conventional production systems, however it will not become a commercially viable variety unless suitable control measures for *Alternaria* leaf blotch and *Alternaria* fruit spot are found.

Until trees in the high density planting systems trials (Chapter 5) have been cropped for several successive seasons at full bearing maturity, it is difficult to fully and conclusively compare the performance of the different management systems for the new scab-resistant apple varieties.

Young trees on semi-dwarfing and dwarfing rootstocks planted at 2500 trees per hectare and higher are performing well, and are likely to continue to do so. The future issue will be whether trees at these densities start to out-grow their allocated spaces as they become older, and, if required, whether supplementary vigour control measures such as summer pruning will prevent possible fruit quality and packout declines as trees approach ten years of age.

The 'V' trellis is showing promise as a suitable system for growing young trees of scab-resistant apples at densities of 3555 trees per hectare and higher. The oldest trees in the 'V' trellis systems were in their third leaf in 2006/2007, and again, it is impossible to conclusively recommend this system until the trees are older and have reached full potential canopy volume. Yield, fruit quality, tree vigour and tree management data is required for several seasons from fully mature bearing trees (fifth to eighth leaf and older) on the 'V' trellis before firm recommendations can be made, and the effects of tree density on yield and packouts of the new apple varieties known.

It is envisaged, however, that the vigour of trees of 'RS103-130' and the other scab-resistant selections planted in the intensive systems trials can be adequately controlled to ensure continued high productivity. What is conclusively known from this project, is that all of the scab-resistant apple selections being tested on semi-dwarfing and dwarfing rootstocks in high density systems perform very well in their first two to three years from planting, with high yields, fruit quality and packouts produced from young trees.

Heavier crop loads were retained on trees in the high density planting system trials in 2006/07. A fundamental question to be answered is how heavy a crop can trees of 'RS103-130' and the other scab-resistant varieties carry without becoming biennial bearing, 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. It is possible that 'RS103-130' trees have little tendency to biennial bearing, however this needs to be confirmed.

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9. 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

Appendix B: Economic analysis of organic apple production

Appendix C: Organic apple production in Australia – a practical guide

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). The calendar is a quick reference guide to major operations, with the following text covering selected areas in more detail.

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 to 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.

Schedule of operations for organic apple production

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.	[illegible]			[illegible] bud mov[illegible]								
				Blossoming								
					Petal fall and fruit development				[illegible]			
						[illegible]						
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 José 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.								

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.	[illegible]			Green tip bud movement								
				Blossoming								
					Petal fall and fruit development				[illegible]			
						[illegible]						
Diseases	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.									

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.	[illegible]			Green tip bud movement								
				Blossoming								
					Petal fall and fruit development				[illegible]			
						[illegible]						
Diseases	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).											

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.	[illegible]			Green tip bud movement								
				Blossoming								
					Petal fall and fruit development				[illegible]			
						[illegible]						
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), made silken cocoons at the end of the growing season.	
Management				Apply Pheromone dispensers to trees prior to first 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.	[illegible]			[illegible]								
				Blossoming								
					Petal fall and fruit development				[illegible]			
						[illegible]						
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						Commence monitoring	Weekly bait sprays of Naturalure ® up to harvest depending on trap catch.					

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.	[illegible]			Green tip to bud movement								
				Blossoming								
					Petal fall and fruit development				[illegible]			
						[illegible] and bud initiation						
Insect Pests:	June	July	August	September	October	November	December	January	February	March	April	May
Native Budworm or commonly known as Heliothis (*Helicoverpa 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. MM.106). 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.											

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.	[illegible]			[illegible] ement								
				Blossoming								
					Petal fall and fruit development				[illegible]			
						[illegible]						
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.	[illegible]			Green tip [illegible] movement								
				Blossoming								
					Petal fall and fruit development				[illegible]			
						[illegible]						
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
									[illegible]			

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.	[illegible]			[illegible] bud movement								
				Blossoming								
					Petal fall and fruit development				[illegible]			
						[illegible]						
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 per 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. This was the lowest return received in 2006 and 2007 for organic 'RS103-130' apples produced from this site. Returns in 2007 were up to $60 per 12 kg two-layer carton. 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, hail netting, ground preparation, purchase of trees and planting costs. This expenditure is assumed to occur in year 0.
- 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.
- Inflation was not considered.

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. The figures and assumptions presented in this model 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

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	**Farm Analysis**				[illegible]													
2	**Orchard size (Ha)**	5																
3																		
4	INCOME			Year 0	Year 1	2	3	4	5	6	7	8	9	10	11	12	13	1
5	Yield (T / Ha)				0	4	20	25	25	25	25	25	25	25	25	25	25	2
6	Price ($/T)	$2,666																
7	**Total Income**				$0	$53,320	$266,600	$333,250	$333,250	$333,250	$333,250	$333,250	$333,250	$333,250	$333,250	$333,250	$333,250	$333
8																		
9	**Establishment Costs**	$/Ha	Rate / Ha															
10	Plant & Equipment			$183,500														
11	Land + Water	$10 000		$50,000														
12	Fencing			$0														
13	Ground Preparation	$1 000		$5,000														
14	Trees ($/tree)	$10 00	1100	$55,000														
15	Planting Costs ($/tree)	$1 00		$5,500														
16	**Total Investment**			$299,000														
17																		
18	**Growing and Marketing Expenses**																	
19					**$ / Ha**													
20	Fertiliser				$730	$100	$291	$291	$291	$291	$291	$291	$291	$291	$291	$291	$291	
21	Weed Control				$3 468	$3,168	$2,658	$2,958	$2,958	$2,958	$2,958	$2,958	$2,958	$2,958	$2,958	$2,958	$2,958	$2
22	Fuel & Oil				$400	$400	$400	$400	$400	$400	$400	$400	$400	$400	$400	$400	$400	
23	Electricity				$140	$140	$140	$140	$140	$140	$140	$140	$140	$140	$140	$140	$140	
24	Pest & disease Control				$219	1254	1698	1698	1698	1698	1698	1698	1698	1698	1698	1698	1698	
25	Pruning	$0 40	per tree		$0	0	$440	$440	$440	$440	$440	$440	$440	$440	$440	$440	$440	
26	Hand Thinning				$0	210	$420	$630	$630	$630	$630	$630	$630	$630	$630	$630	$630	
28	Picking	$75	per Tonne		$0	$300	$1,500	$1,875	$1,875	$1,875	$1,875	$1,875	$1,875	$1,875	$1,875	$1,875	$1,875	$1
29	Packing & Packaging	$800	per Tonne		$0	$3,200	$16,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20
30	Freight	$160	per Tonne		$0	$640	$3,200	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4
31	Total / Ha				$4,957	$9,412	$26,747	$32,432	$32,432	$32,432	$32,432	$32,432	$32,432	$32,432	$32,432	$32,432	$32,432	$3
32	**Total Orchard Growing Expenses**				$24,785	$47,060	$133,735	$162,160	$162,160	$162,160	$162,160	$162,160	$162,160	$162,160	$162,160	$162,160	$162,160	$16
33																		
34																		
35	**Total Variable Expenses**				$24,785	$47,060	$133,735	$162,160	$162,160	$162,160	$162,160	$162,160	$162,160	$162,160	$162,160	$162,160	$162,160	$16
36	GROSS MARGIN				-$4,957	$1,252	$26,573	$34,218	$34,218	$34,218	$34,218	$34,218	$34,218	$34,218	$34,218	$34,218	$34,218	$3
37																		
38																		
39	**Depreciation**				$16,450	$16,450	$16,450	$16,450	$16,450	$16,450	$16,450	$16,450	$16,450	$16,450	$16,450	$16,450	$16,450	$1
40	**Fixed Costs**				$39,200	$39,200	$39,200	$39,200	$39,200	$39,200	$39,200	$39,200	$39,200	$39,200	$39,200	$39,200	$39,200	$3
41																		
42	TOTAL COSTS			$299,000	$80,435	$102,710	$189,385	$217,810	$217,810	$217,810	$217,810	$217,810	$217,810	$217,810	$217,810	$217,810	$217,810	$21
43																		
44	CASH FLOW			-$299,000	-$80,435	-$49,390	$77,215	$115,440	$115,440	$115,440	$115,440	$115,440	$115,440	$115,440	$115,440	$115,440	$115,440	$11
45	**Discount Factors**			1	0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224	0.3875	0.3555	0.3262	0.
46	Discounted Cash Flow			-$299,000	-$73,794	-$41,571	$59,624	$81,781	$75,028	$68,833	$63,150	$57,935	$53,152	$48,763	$44,737	$41,043	$37,654	$3
47	Discount Rate	9%																
48	NPV	$406,847																
49	Benefit Cost Ratio	2.36																
50																		
51	**Breakeven year**	Year 7																
52																		

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 After Full Bloom	Entrust	0.006	1,127.27	$81.16
Carbaryl (Thinning)	0.125	$16.36	$24.54		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					
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

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
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.

Appendix C: Organic apple production in Australia – a practical guide

Appendix C is a revised version of the organic apple production manual produced as part of project AP01006. It has been slightly revised to permit compatible inclusion in this final report. Other sections of the organic apple manual have been included separately as Appendices A and B in this report.

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Table of Contents (Appendix C)

1. Introduction

Before making the decision to produce apples organically, growers should ask the question: "Is organic apple production really for me?" This manual will assist with that decision, and provide a resource for managing apple orchards organically. The manual also provides information and options for all apple growers to consider in managing pests, diseases, weeds, soil and tree growth to maximise orchard productivity and profitability.

While the basic agronomy of apple trees is the same for both conventional and organic orchards, there are key differences in the use of agricultural chemicals and the management strategies available to control orchard pests, diseases and weeds.

Conventional orchard systems rely on agricultural chemicals for the control of key pests and diseases. Management options are flexible, and the response time needed to control pest and disease outbreaks is short. Application of sprays for pest and disease control is effective most of the time. Crop nutrition is largely based on the addition of proprietary fertilizers to the soil or through trickle irrigation, and a range of herbicides are registered to control weeds.

In contrast, organic crop production principles and standards specify the use of "holistic" management practices rather than reliance on substances for control of pests and diseases. These management practices include the use of biological controls, disease resistant varieties, pheromones and lures, a few organically acceptable fungicides based on copper and sulphur, and a few organic formulations of insecticides. Weeds are controlled by cultural methods such as cropping, mowing, mulching and mechanical cultivation. Soil management and crop nutrition utilise legumes, green manure crops, composts and minimum tillage practices to maintain and enhance soil fertility. Integration of methods is important and organic growers must be prepared to accept some crop losses in situations of high pest and disease pressure.

Adoption of organic production techniques requires farmers to undergo a paradigm shift from the use of agricultural chemicals towards a holistic farming system. Apple growers wishing to convert to organic production should consider these factors carefully.

2. Organic Apple Growing In Australia

Organic apple production in Australia is small relative to the apple industry as a whole. Gauging the size of the organic apple industry in Australia is difficult because official statistics are not collected for organic apple production. Our best estimate is that annual production of organic apples in Australia is approximately 8000 tonnes, which is two to three percent of the 320,000 plus tonnes per annum (Australian Food Statistics 2004) produced by the Australian apple industry.

The organic industry in Australia adheres to the National Standard for Organic and Bio-dynamic Produce which is known as "the Standard". This was originally published as an export standard for organic produce. It has since become the minimum standard for organic production across all agricultural industries. This one document covers all aspects of plant and animal production, processing of organic food and fibres, distribution of organic produce through supply chains and marketing.

The Australian Quarantine and Inspection Service (AQIS) regulates the export of Organic produce and administers "the Standard". AQIS also licences the Organic Certification organisations. These organisations are non-government private businesses which charge fees and production royalties to their clients for provision of certification services. AQIS currently licences seven accredited organic certifiers (Appendix 1).

Currently, organic produce in Australia does not have to be organically certified to be sold as organic. However, this situation may change in the near future because certification provides a verifiable means of tracing organic products from the farm to the consumer. This ensures that consumers can be confident of the origin and certified status of organic produce. Growers should undertake organic certification to gain full access to the organic market.

Organic apple growers are mostly small scale operators and may list apples as one of the commodities they produce. Some parallel production does take place where larger conventional apple growers have part of their property under organic certification, and the rest under conventional management. There are also a few larger organic apple growers who manage their whole orchard organically.

3. Organic Certification

Organic Certification is a process which involves having the farm and the farmer's methods inspected by their certifying organisation to ensure compliance with the National Standard for Organic and Bio-dynamic Produce. This involves the adoption of an Organic Management Plan and regular auditing by independent auditors appointed by the certifier. Good record keeping is an essential part of the process, and continued certification is dependant on the outcome of these audits. Information packages are available from the certifiers which streamline the application process and detail the processes and requirements of that organisation (Appendix 1).

The majority of Australian organic apple growers are clients of either Australian Certified Organic (ACO) or the National Association for Sustainable Agriculture Australia (NASAA). These are the two largest organisations accredited by AQIS to provide organic certification services. Each organisation publishes an Organic Standard which is based on the National Standard for Organic and Bio-dynamic Produce and may impose additional requirements in some instances. Organic producers should comply with the certification requirements of their chosen certifier at all times to ensure they fulfil all their obligations as growers of certified organic produce.

The certification process involves three major steps:

Pre-certification
This transitional stage commences after acceptance of an application made by the grower to the certification organisation. A statutory declaration is made with respect to the farming and production practices used by the grower in recent years. An initial inspection is made of the farm by the certifying body, and organic management and farming practices adopted. Non-organic inputs are no longer used or permitted. The pre-certification period is a minimum of twelve months, and may be longer under some circumstances. Produce cannot be sold as organic at this stage.

In conversion
Following a successful audit during the first year, in-conversion status may be granted. This is a minimum period of twelve months. Produce can be marketed as "In conversion to organic".

Certified Organic
Certified organic requires a minimum of three years of verified conformance to the National Standard for Organic and Bio-dynamic Produce, with annual auditing. Produce can then be sold as "Certified organic".

Growers who attain "In Conversion" or "Certified Organic" status enter into contractual arrangements with their certifier for the use of that organisation's logo on the labelling of the produce they sell. These trademark logos help to identify organic produce in the market place and give consumers a measure of certainty about the origin and status of the products they are purchasing. It should also be appreciated that certification requirements extend past the farm gate to include wholesalers and retailers. These key players in the distribution chain can implement procedures which allow them to be certified. Their role is to ensure that certified produce is handled properly, not contaminated in any way and that no fraudulent substitution of non-certified produce can take place. Auditing and traceability of produce at every stage in the marketing chain is an essential part of the marketing process for organic produce.

4. Apple Orchard Management

Organic farming is based on production principles which aim to produce high sustainable yields without the use of artificial fertilizers and synthetic chemicals. All organic growers should base their orchard management on these principles and standards, which are detailed in the National Standard for Organic and Bio-dynamic Produce (the Standard). The national Standard should also be read in conjunction with the Organic Standard published by the grower's own certifying organisation. These documents set the framework for all organic management decisions.

In the following chapters a broad range of issues are discussed, including insect pests, diseases, weeds, apple varieties, orchard establishment and tree management. Readers should be aware that organic standards change and evolve over time. Specific recommendations are correct at the time of printing but accepted practice may change. Always refer to the current version of the Standard and the relevant certifier (Appendix 1) for the most up to date information.

4.1 Site Selection and Preparation

For organic apple production, 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 (see Disease Management section).

The basic requirements for successful orchard establishment include:

- Removal of existing crop residues such as tree roots, stumps and trees. This is an important step which will help remove potential sources of disease inoculum (especially White root rot - see Disease Management) 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 to 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 both time and money. In replant situations sufficient time should be allowed for "reconditioning" the soil. At least twelve months should elapse between apple tree removal and the planting of a new orchard. During this time legume and forage sorghum crops should be grown 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 to 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.

There are numerous organic and biodynamic products which are "allowed inputs" or "certified for organic use". These may be used to enhance biological activity in the soil or as soil amendments. The efficacy of some of these products may be open to interpretation. Growers should consider each product on its merits, test on a few trees as appropriate, and make a value judgement for themselves.

4.1.1 Nematodes

Nematodes, or roundworms, are a diverse group of microscopic worms which include beneficial and parasitic species found in both plants and animals (estimated 500,000 to 1,000,000 species). The plant parasitic species that commonly cause damage to apple roots are root lesion nematodes such as *Pratylenchus penetrans* and *Pratylenchus jordanensis*. Moist soil conditions are favourable for nematode activity. The nematode life cycle includes adult and larval stages that move through the soil and invade and kill the young feeder roots of apple trees. Nematodes may move through the roots or through the soil from damaged roots to new roots.

Nematodes contribute to a slow decline of the trees in combination with other factors such as poor soil aeration, low pH (and associated plant nutrition disorders), and soil-borne disease problems caused by fungi and bacteria. Symptoms of nematode damage may not be readily apparent on established apple trees. On young trees, nematode damage may contribute to the death of apple replants in orchards which have high populations carried over from a previous apple planting. (See Apple Replant Disease section).

In addition to plant parasitic nematodes, there are many beneficial nematodes species found in the soil. Some feed on bacteria and fungi, some break down organic matter, whilst others feed on other nematode species or attack and kill insect pests. Nematode feeding contributes to nutrient cycling in the soil by releasing nutrients such as ammonium (NH4+) stored in the bodies of the bacteria and fungi.

The diversity of nematodes found in the soil may be used as a soil health indicator. The ratio of different types of nematodes and what they eat can be used to determine what processes are occurring in the soil in relation to the total soil biota and soil biological activity. These biological indicators also interact with other soil factors such as pH and aeration, and together have a huge impact on apple tree health.

Organic management of nematodes is consistent with other soil management strategies outlined previously. All these strategies aim to improve overall soil health and encourage biological activity and biodiversity of beneficial organisms in the soil. In a balanced system, parasitic nematodes will be kept in check and optimum growing conditions provided for tree health. In replant situations it is suggested to:

- fallow the soil.
- plant green manure crops to build up the soil.
- plough these crops into the soil to provide organic matter and encourage biological activity in the soil.
- adjust soil pH to the optimum range of 6.0 to 6.5.
- ensure adequate drainage.

Mulching of tree rows is important as the decomposition of organic matter involves ammonification of organic forms of nitrogen to ammonium (NH4+). Parasitic nematode numbers are reduced under high ammonium conditions. Some types of mustard plants can be grown as a bio-fumigant, however this effect does not extend to any significant depth in the soil.

4.2 Managing Insect Pests

4.2.1 Codling Moth (*Cydia pomonella*)

Plate 1. Codling moth damage

Codling moth is a key pest in most apple growing areas of Australia and if left uncontrolled may infest upwards of 90% of fruit (Plate 1). Conventional orchard systems use an extensive program of insecticide sprays and mating disruption pheromones for codling moth control. The codling moth life-cycle is temperature dependant, and degree day models can be used to predict the emergence of moths and coordinate control measures. Hot dry conditions favour an increase in codling moth numbers. Codling moth is only of minor importance in Tasmania due to the cooler growing conditions, and is not present in Western Australia due to geographic separation and state quarantine measures.

Life-cycle

Mature codling moth larvae pass the winter in a resting stage (diapause) in rough silken cocoons in sheltered sites near to the fruit from which they emerged. Cocoons may be found under the tree bark, on the bark below the soil level or under nearby debris. Codling moths pupate and emerge from these over-wintering sites when spring temperatures are high enough. In most apple growing districts of Australia this is usually in late September or during October. After mating, codling moth lay eggs on or very near the newly developing apple fruitlets. Newly hatched larvae tunnel into the fruitlets and target the seeds, before the mature larva (2 cm) emerge from the apple to pupate, using a suitable site on the tree or in litter under the tree. Depending on environmental conditions up to three of these generations of moths can occur in Australian apple orchards in a single season. For example, Tasmanian orchards experience only one generation while Queensland orchards can have three generations of moths per season. In growing areas which are warm enough for three generations of moths, a proportion of first generation, some of the second generation and almost all of the third generation enter diapause to complete the life-cycle.

Management Methods
Organic control measures are primarily limited to the use of mating disruption pheromones and attention to orchard hygiene. While there are some organically acceptable sprays which are effective these are either not specifically registered for codling moth (e.g. Spinosad as Entrust®) or are not readily available in Australia (e.g. Codling Moth Granulosis Virus).

A newly planted orchard, some distance from any infested blocks, will provide an ideal situation to deploy mating disruption pheromones to prevent male moths locating and mating with female moths. The dispensers are placed high in the tree canopies and release a continuous invisible plume of sex pheromone which blankets the orchard. To be effective, the treated area needs to be as large as possible (preferably a minimum of 4 hectares) and protected from prevailing winds. Orchards on undulating topography also pose a problem for pheromone disruption. This is because a continuous layer of pheromone cannot be maintained around the trees as it tends to settle out in the lower areas of the orchard. Pheromone dispensers will not provide adequate control of codling moth if the trees are heavily infested, or are near other trees with high codling moth pressure.

Orchard hygiene measures include gathering and burying infested fruit that fall to the orchard floor during the growing season, and removing infested fruit from the trees at regular intervals. Old wooden fruit bins stacked outside packing facilities also provide potential overwintering sites for codling moth larvae. Cocoons can quite often be found between the corner braces and the timber slats that form the walls of the bin (Plate 2). Concentrating infested reject fruit in on-farm fruit dumps is also an undesirable practice.

Plate 2. Codling moth larvae overwintering in a wooden bulk bin

Codling moth granulosis virus (CMGV) has been shown to be effective in providing control of codling moth in low to moderate infestations particularly in conjunction with other control measures such as mating disruption. However, CMGV is not registered or generally available within Australia. Some individual growers have imported CMGV from New Zealand from time to time after obtaining appropriate permits.

Spinosad has significant activity against codling moth but is only registered in apples for control of budworm, light brown apple moth (LBAM) and western flower thrips. It is one of the very few effective and allowed insecticides available to the organic orchardist. Overuse of this compound is therefore not recommended, as there will be a heightened risk of pests developing resistance.

Monitoring
Pheromone traps (Plate 3) can be used to catch male codling moths, providing an indication of population levels. Traps should be placed in the top third of the tree canopy, at a rate of two traps per

orchard. If greater than two moths per trap are recorded, the level of codling moth control in that orchard block may not be adequate.

Plate 3. Codling moth trap

4.2.2 Light Brown Apple Moth (*Epiphyas posvittana*)

Light brown apple moth (LBAM) is a native insect which causes significant fruit damage in organic apple orchards because of the absence of insecticide sprays. The larvae are primarily leaf feeders, and shelter in webbed tunnels in leaf folds and between adjacent leaves. As the larvae grow they tend to cause leaf rolling on adjacent leaves near fruit. Fruit damage occurs when the larvae feed between adjacent fruit or between a fruit and leaf (Plate 4). Twenty percent and upwards of the crop can become unmarketable. The presence of weeds and some sod plants such as clover provide an alternative host for LBAM which can increase the general population of LBAM within the orchard.

Plate 4. LBAM larvae, pupa and damage

Pheromone dispensers are available that disrupt both codling moth and LBAM at the same time. However, as these dispensers possess two distinct pheromones they are more expensive than single purpose dispensers. Spinosad applied for western flower thrips, or native budworms will also provide some control. LBAM may remain present, and a threat to fruit during the entire growing season.

4.2.3 Two-spotted mite (*Tetranychus urticae*)

Plate 5. Two-spotted mite and mite predator

Phytophagus mites (including *Panonychus ulmi*, European red mite) are rarely a problem in organic orchards. In the complete absence of broad spectrum insecticides, predators such as predatory mites (Plate 5), beetle larvae, thrips and lacewings will generally provide adequate natural control and prevent mites from reaching population levels which cause economic damage. When beneficial insects are present it is important to minimise the use of approved insecticides such as naturally derived pyrethrums and rotenone. Even the use of spinosad will have an adverse effect on biodiversity. Using *Bacillus thuringiensis* as an alternative for control of leafrollers and budworms will alleviate this problem. Some patchy mite damage may be observed in the extremely hot and dry conditions which favour mite development, and also result in mortality of beneficial species. In such cases an application of a light summer oil may be warranted. This should not be applied during the heat of the day, but rather in the early morning or cool of the evening.

4.2.4 San José scale (*Diaspidiotus perniciosus*)

San Jose scale feeds on leaves, bark and fruit of apple trees. These insects, which can also be found on a range of other shrubs, are bright yellow beneath their grey coloured outer waxy covering. Their presence on leaves and fruit is often characterised by pink or red rings around the scale covers (Plate 6). Moderate infestations debilitate affected limbs, while prolonged and severe infestations may cause tree death.

Plate 6. Apples infested with San José scale

The use of a three percent winter oil spray at green tip should be sufficient to maintain populations of scale insects at a negligible level. In the absence of broad spectrum insecticides and the presence of predators, significant parasitism and predation will occur in organic orchards.

4.2.5 Woolly apple aphid (*Eriosoma lanigerum*)

Plate 7. Woolly apple aphid (*Eriosoma lanigerum*)

Woolly apple aphid (Plate 7) is present in all apple orchards and feeds on the bark and roots of the trees. In organic orchards this insect is rarely a persistent problem, provided that resistant rootstocks are used (e.g. MM.106, MM.102, Northern Spy). The presence of an introduced wasp parasite *Aphilinus mali* should destroy colonies above ground. Where non-resistant rootstocks are used, the below ground colonies will crawl up the tree in spring, and the parasites may not be able to control them before significant damage occurs. Resistant rootstocks do not support woolly apple aphid colonies.

4.2.6 Plague thrip (*Thrips imaginis*)

Description

Plague thrips are pests of apple flowers, and to a lesser extent, leaves. Eggs are laid at night on an extremely wide range of host plants, including grasses. Both nymphs and adults feed by piercing the plant cells with their mandible and rapidly sucking up the cell contents. In apple the most significant damage occurs to the female structures of the flowers at blossoming time (Plate 8).. Thrips feed on the styles of the flowers before fertilisation occurs resulting in failure of the fruit to set.

Thrips are present on apples during the blossom period from early pink to full bloom. Peak incidence normally occurs as the blossom opens. Pest populations are regulated more by weather than biological factors. Cold winters and cold snaps through the spring greatly reduce the survival of the overwintering forms of plague thrips, as well as newly developing populations. In addition, dry conditions that cause poor growth of blossom on alternate hosts prior to apple flowering means that populations of plague thrips start from a very low base with less potential for economic damage.

Plate 8. Flowers damaged by Plague thrips (left) and undamaged flowers (right)

Plague thrips become invasive when shade temperatures exceed 25°C and the local vegetation around the orchard has been desiccated by the heat.

Monitoring

Examine emerging flowers from budburst to early pink for the presence of adult thrips and damage symptoms. Cultivars with long, delicate styles such as Granny Smith, are more prone to damage than those with more stocky ovarian tissues. Economically significant damage occurs when numbers of thrips reach 3-4 per flower in hot, dry environments and 6-8 per flower in cooler, more humid areas. The effect of plague thrips damage may only be evidenced by a light crop of apples.

Biological control

The predatory mites *Neoseiulus cucumeris* and *Typhlodromips montdorensis* are currently under development for plague thrips control, but it is expected they will be better suited to the cooler, more humid conditions of glasshouse crops than apple orchards.

4.2.7 Western Flower Thrip (*Frankliniella occidentalis*)

Western flower thrip (WFT) is an exotic pest, entering Australia in 1993. It was first recorded as an apple pest in 2000 at Stanthorpe, Queensland.

Like plague thrips, WFT is attracted to blossom, however unlike plague thrips, the main damage is to the developing fruit. Egg masses laid into the very small fruit (Plate 9) ultimately show as discoloured white to cream blotches around the oviposition site. Commonly called "pansy spot", these symptoms become more prominent as the apple matures (Plate 10).

In green coloured apple cultivars like Granny Smith, the blemish stays white; in red varieties the blemish either turns a brighter red, or shows as a dark spot, as occurs on Gala apples.

Plate 9. WFT damage on Granny Smith fruitlet

WFT grow more slowly than plague thrips. The length of the egg to adult cycle takes 18 days for WFT and only nine days for plague thrips. WFT have a wide host range and develop quite readily on flowering white clover, which may be present in the alleyway sod mixture between the rows. The dispersal of WFT populations is more localised than plague thrips. While over-wintering populations of WFT will move from native vegetation into adjacent orchards, they do not move as swarms like plague thrips over long distances. WFT also prefers apple blossoms at or near full bloom, rather than unopened flowers.

Plate 10. WFT damage on mature Granny Smith fruit

Acceptable registered inputs
Spinosad (as Entrust®) and natural pyrethrum can be used.

Adhere as closely as possible to the national strategy for the control of WFT. This includes three sprays of the same compound three to five days apart (when daily temperatures exceed 20°C), or at six to twelve day intervals when daily temperatures are less than 20°C. The use of three spray applications is designed to kill any survivors of earlier applications e.g. eggs and pupae which, due to their life stage, are protected from the potency of earlier sprays.

Spinosad should not be sprayed onto foraging bees, but is safe to bees after the spray has dried. For this reason, Spinosad should be applied very late in the day when bee foraging activity has ceased.
Management techniques

Monitoring
Check blossom in plants growing adjacent to the orchard, as well as white clover and flowering weeds in the sward within the orchard. Mow the sward in the alleyways well in advance of apple blossoming, to bring WFT populations down to their lowest levels. Check for the presence of WFT in the apple blossoms from greentip onwards. If mowing is delayed to coincide with apple blossom, thrips merely move from the flowering sward into the blossom of the adjacent apple trees.

Biological control
As with plague thrips, no commercial biological agents are available, although some are under development.

4.2.8 Apple Dimpling Bug (*Campylomma liebknechti*)

Plate 11. Apple dimpling bug adult

Plate 12. Apple dimpling bug damage

Apple dimpling bug (ADB) is a major pest of apples across Australia. The feeding of the adult bugs (Plate 11) on the receptacles of blossoms results in "dimples" of varying sizes occurring on subsequently formed apples (Plate 12). In plague years, over 90% of apples may have some level of damage. This damage which is entirely superficial results in downgrading of the fruit for market. Even moderate levels of damage (one dimple per fruit) effectively render that piece of fruit suitable only for juicing. Organic markets may tolerate higher levels of ADB damage but severely disfigured fruit is visually unappealing.

The use of pyrethrum has been shown to have significant toxicity to ADB in the laboratory, but no field trials have been conducted to test its efficacy in apple orchards. It is anticipated that several applications of pyrethrum would be required in an average season to obtain significant reduction of ADB populations. Such a spray program would adversely affect bio-diversity. Natural predators are not likely to significantly reduce ADB numbers within an organic orchard. Fruit affected by ADB can be removed by hand thinning during normal crop management activity.

Monitoring

Monitor bug numbers by hitting blossom clusters over a white container such as a 2 L ice-cream bucket. Significant damage to the apple crop is likely if bug numbers of two or more per ten "cluster-hits" are recorded.

4.2.9 Queensland fruit fly (*Bactrocera tryoni*)

Queensland fruit fly (QFF) is a pest restricted to Queensland apple orchards and of lesser significance in Orange NSW. QFF (Plate 13) is potentially a concern in organic orchards, where there is no use of broad-spectrum insecticides. Fortunately, apples are not a preferred host of QFF and the climate of Queensland's apple growing region is not ideal for pest development. Damage caused by QFF on apple fruit (Plate 14) is not as spectacular as that on stonefruit. Apples incur a significant proportion of blind stings, nevertheless in seasons favourable for QFF infestation, or in orchards where nearby neglected fruit trees are prevalent, very significant losses will occur.

Plate 13. Queensland fruit fly

Plate 14. Fruit fly sting

Organically approved, spinosad-based bait spray applications have been shown to be effective in controlling QFF in Queensland apple orchards. Bait spraying of organic orchards on a weekly schedule should commence approximately six weeks prior to harvest, or as indicated by the use of Q-Lure or "Wild May" fruit fly traps. The use of exclusion netting offers virtually total protection from QFF infestation.

4.2.10 Painted Apple Moth (*Teia anartoides*)

Painted apple moth (PAM) infestations may occur at irregular intervals in organic apple orchards. These infestations will tend to be localised and restricted to two to three trees per block. PAM are subject to high levels of parasitism from *Ichneumonid* wasps, and PAM populations are eventually reduced to very low levels. However significant damage can occur to individual trees in the meantime, and spot spraying with *Bacillus thuringiensis* may be necessary.

Plate 15. Painted apple moth feeding on apple tree

Monitoring
Regularly walk the rows of organic orchards in order to detect PAM infestations before defoliation occurs. Young trees are particularly susceptible to defoliation (Plate 15). PAM can easily be removed by hand at this time, provided only a few trees are infested.

4.2.11 Native Budworm (*Heliocoverpa punctigera*)
Budworms (commonly known as Heliothis by apple growers) cause significant damage to apples particularly in organic orchards. From flowering onwards, budworm eggs are laid on or near the flowers or fruit. Young larvae vary considerably in colour from grey-green to brown and tunnel into developing fruit, causing a range of damage symptoms. These symptoms may be anything from a raised round scar (Plate 16) to a characteristically neat and deep hole. Mature larvae emerge from fruit to pupate in the soil. Budworm activity tends to be more prevalent in spring and early summer.

Acceptable registered inputs
Spinosad and *Bacillus thuringiensis* can be used to reduce both the amount and severity of budworm damage in organic apple orchards. Fruit with minor damage can still be successfully marketed.

Plate 16. Native budworm damage on Gala apples

4.3 Disease Management

The main focus of organic disease management is to produce healthy crops through a combination of good farm hygiene, careful variety selection and appropriate nutrition. Few chemical control options are available which comply with the Standards of the certifying organisations for the control of apple diseases. Cultural techniques should be used in conjunction with knowledge of disease life-cycles and the targeted use of allowable inputs to maximise tree productivity and tree health.

This section contains basic information on the diagnosis and management of diseases that commonly infect apples in Australia. However, this information is meant to be used as a guide only, and growers are urged to seek professional advice for disease diagnosis, and to consult with their certifying organisation about allowed chemical inputs prior to application.

4.3.1 Cultural control methods

(i) Plant health

It is important to maintain good general plant health in an organic orchard. Trees suffering from water stress (waterlogging or drought), nutrient disorders or other physical factors (such as plant damage) cannot cope with disease as well as healthy trees.

(ii) Farm hygiene

Good farm hygiene is all about preventing the introduction of pathogens, containing the spread of symptoms, and reducing disease inoculum to limit future problems.

Disease entry

Many foliar diseases of apple can be spread by wind-blown spores (*Alternaria*, apple scab and powdery mildew) so little can be done to prevent their arrival. However, soil-borne diseases are a different story, and unless you already have soil-borne diseases (such as White root rot or *Phytophthora*) there is a great deal you can do to prevent them arriving.

Have a reception area at or near the front gate of your property, and make this the only point of entry for visitors. Question your visitors, preferably before arrival, about where they have been and what pests (weeds, insects or diseases) they may be carrying on their vehicle or shoes. Include a wash down area near reception, and remove all soil and plant debris and thoroughly clean machinery before it enters your orchard. Once a soil-borne disease is present it is almost impossible to eradicate.

Disease monitoring

Regular crop monitoring allows the detection of disease outbreaks at an early stage and provides a good opportunity to reduce disease spread. The effects of many diseases can be significantly reduced by removing infected plant tissues at the beginning of the disease cycle. Chemical applications, if required, are also much more effective when applied while disease pressure is very low. Most chemicals available for use by organic growers are protective, not curative, and need to be present on the plant prior to the arrival of disease.

Inoculum reduction

The primary aim of plant pathogens, like all living creatures, is to reproduce. Plant pathogens seek out a susceptible host, infect it, and then quickly move on to produce more inoculum (i.e. fungal spores or bacterial ooze), which can be dispersed to the next plant and thereby continue the cycle of disease spread. As well as producing short-term infective units, many plant pathogens also produce special spores or structures which allow the pathogen to survive long periods of unfavourable conditions (winter or dry weather). It is important to remove as many of these infection and survival structures (both short and long term) as possible.

(iii) Removing leaves, branches and fruit mummies

Fallen leaves, twigs, rotten fruit and other apple plant debris provide a good source of food on which plant pathogenic fungi survive. They should therefore be removed, or thoroughly broken down as soon as possible.

Regular maceration of fallen leaves and fruit during the season, using mechanical mulchers or mowers, can assist in this process. There are some products on the market that claim to assist with the breakdown of plant material. Nitrogen-rich fertilisers can also help to increase the breakdown of plant tissues. Before use, always check to make sure that these products meet the requirements of your certifying organisation and target market.

Recycle plant material very carefully. If composting or mulching apple material (i.e. branches, thinnings, leaves or fruit) make sure that the plant tissues break down completely, otherwise you could simply be reintroducing the pathogen/disease into your orchard.

Natural decomposition of leaves on the orchard floor over winter is not usually sufficient in Australia to completely remove fungal spores. Adding organically-approved nitrogen can help, as nitrogen is commonly the most important missing ingredient for micro-organism assisted decomposition of apple leaves. When composting apple leaves, remember that composting (at 60-71°C) does not kill spores, it simply removes the substrate on which they survive. The addition of composted manures to apple leaf composting mixes may be required to complete leaf breakdown.

It is important to note that relying on the removal of infected leaf litter will only work for isolated orchards, as leaf litter (and/or spores) from a neighbouring orchard can blow into a clean one and provide inoculum.

(iv) Over-wintering inoculum

It is essential that no infected leaf litter, twigs, branches or mummified fruit survives the winter. All of these plant tissues are excellent sources of nutrition for the resting spores of fungal and bacterial diseases, and can enable large amounts of inoculum to survive in your orchard ready to attack your crop again the following season.

(v) Creating environments that are unfavourable to disease

Reducing humidity

Most diseases require moist, humid conditions for spore germination and initial infection. By reducing humidity, you reduce the opportunity for pathogens to start, and continue the disease cycle.

- Do not use overhead irrigation, as wetting infected leaves or leaf litter on the ground will release spores. The raised humidity will assist infection, especially for apple scab.
- Weed control is important. Tall weeds growing very closely to trees significantly increases humidity and the chance of pathogen infection.

Increased humidity can also lead to the production of more succulent growth, which is highly susceptible to infection (especially with powdery mildew).

If possible, plant your orchard so that the prevailing winds blow along, rather than across the rows. This will increase air flow and reduce physical damage due to branches hitting one another. Prune trees (refer to Pruning and Training) to increase air circulation within the tree, and reduce excessive shading. Heavily shaded areas of the tree will stay wetter for longer, thereby increasing humidity and the possibility of infection and disease development.

(vi) Disease monitoring/management

Monitor your orchard regularly. Disease management strategies are much more effective if applied early in the infection cycle. In some cases it is possible to significantly reduce the level of disease in an orchard by early removal of symptomatic tissues. This is especially important for fungal diseases such as powdery mildew, which produce large numbers of spores.

Remove diseased branches and fruit mummies in winter. During fruitlet thinning, place discarded apples into the alley ways to be macerated by mowing, and broken down as quickly as possible.

An optimal tree structure will permit good air circulation within the tree, increase the visibility of disease symptoms at an early stage and provide effective control of shoot growth (lush new growth is more susceptible to diseases such as apple scab and powdery mildew).

(vii) Reduce spread of inoculum

By reducing the spread of disease inoculum within and between blocks of trees, a significant reduction in overall disease can be achieved.

Frequently clean shears/secateurs with alcohol when pruning, and always do this after pruning a diseased tree. Always use machinery in the cleanest (least diseased) part of the orchard first, and wash down machinery after use in diseased blocks. Hose down tractors and mulchers to prevent movement of soil and spores (especially important if spraying in areas with powdery mildew) and remove any plant debris.

(viii) Orchard design

If possible, plant a new block of trees rather than converting an existing block to organic status. This provides several important benefits:

- The opportunity to plant disease resistant varieties (especially important for apple scab).
- Trees can be trained to have an open structure to allow quick drying and good penetration of sprays.
- Rows can be planted so that the prevailing wind blows along the rows (reducing drying times, humidity and physical damage to the trees and fruit).
- Trees can be planted into raised beds, to improve drainage.
- Water-efficient drip or sub-soil irrigation can be installed more easily. Overhead and under-tree sprinklers significantly increase humidity levels within the canopy, increasing the potential for disease development and spread.

If converting a conventional orchard, consider the following important points:

- Choose a well-managed orchard, with as few established disease and pest problems as possible. It is a mistake to think that a patch of trees that struggled with pests and diseases using conventional techniques will suddenly thrive under organic conditions.
- Avoid orchards with soil compaction problems.
- Start the organic conversion process just prior to harvest (i.e. apply the last non-organic inputs). Remember that it will take three years from the time of the last non-organic input to reach organic status.

(ix) Tree training

It is important when training young trees to consider the potential for cracking the bark when bending branches into shape. Cracked bark forms an excellent entry point for disease, and all wounds should be dressed during the growing season.

Apart from the usual foliar and trunk diseases mentioned below, wood rotting fungi can easily invade unprotected wounds under the right environmental conditions.

Wounds made during dormancy (i.e. winter pruning) are less likely to become infected, but any cuts leaving wounds larger than a 20 cent piece will benefit from treatment with wound dressing. This can be even more effective if a small amount of copper is mixed into the dressing.

(x) Hail netting

Hail netting affects disease management in two main ways, i.e. through increased humidity and increased shading. As mentioned earlier, increased humidity can greatly enhance the ability of plant pathogens to infect and cause disease. Increased shading leads to the production of lush leaf growth, which is more susceptible to some diseases. The use of more dwarfing clonal rootstocks reduces or eliminates the shading effect of hail netting.

Apart from the prevention of hail damage, netting can also provide some protection of trees and fruit from birds and insects. However, if netting is to be your primary technique for managing insect and mammal pests, proper exclusion netting of the correct size and strength should be used rather than hail netting.

4.3.2 Allowable organic inputs

Using approved chemicals for disease control should be a last resort in organic systems. The potential reduction of the pathogen population caused by applying the chemical needs to be weighed up against the other effects of the chemical on the apple tree and beneficial organisms (especially soil microbes).

Most chemicals available for use in organic systems work on contact, rather than being systemically absorbed by the tree. Therefore good penetration of the chemical into the canopy of the tree is required, as is the ability to thoroughly coat all the leaves and branches.

It is important to understand the National Standard for Organic and Bio-dynamic Produce, and comply with the requirements of your certifying organisation. If you plan to export, always check the organic production guidelines for that country prior to application of disease management measures. Some countries demand much lower chemical residue levels (particularly of copper) than Australia.

It is also important to check with your certifying organisation that the products you wish to use are permitted. Remember that the onus is on you, the grower, to determine if the treatments you wish to apply are allowed by your certifying organisation and your target market.

(i) Copper

Copper can be a toxic chemical at high concentrations, and can kill beneficial organisms, especially soil microbes. By using products with the highest ratio of active copper to total copper content, you can reduce the total amount of copper applied, and therefore reduce the potential for copper toxicity. Remember, it is only the available/active copper ions that will have an effect on plant diseases.

Bordeaux mixture is a very crude formulation of copper and lime sulphur, and contains large amounts of copper with a proportionally small amount of available copper ions. Many areas of Europe, and even some areas of Australia, are currently suffering from toxic levels of copper in their soils due to heavy, long-term use of Bordeaux mixture.

If applied after bloom, copper sprays even at very low rates can russet the fruit.

(ii) Sulphur

Sulphur (including both wettable and lime sulphur) can reduce the short term photosynthetic capacity of leaves. So apply sulphur thoughtfully, especially on young trees.

Lime sulphur can be phytotoxic and burn leaves if applied during hot weather. It is also potentially harmful to mite predators.

Never mix sulphur and oil. Always make sure that there are at least two to three weeks between any applications of sulphur and oil.

(iii) Alternative products

These days there are a large number of new "alternative" products available for a whole range of uses. If you are considering using one of these products, and are unfamiliar with it, keep the following points in mind. These comments also apply to nutritional compounds and to products sold as "soil conditioners" and "soil improvers".

- Before use, always check that the product you wish to use is permitted by your certifying organisation.
- When testing new products, always leave an untreated area within the treated block or row for comparison.
- When speaking to salespeople ask for facts and figures, not testimonials, about their products.
- Sellers of quality products should be happy to provide you with small amounts of product to test, either for free, or at minimal cost.
- Always be wary of people selling "cure-all" products. While it is true that improved plant health can assist plants to cope with pests and diseases, many products make scientifically impossible claims.
- No product can cure virus-infected plants. Once infected, viral diseases are present in the plant for life.

A commonly repeated claim which is not based on any scientific evidence is that "Diseases only infect unhealthy plants". If a susceptible host and a viable pathogen are put together under favourable conditions, infection of the host will occur regardless of the health of the plant.

4.3.3 Foliar Diseases

It is important to note that the same common name is sometimes used for different diseases. Being familiar with (and using) the scientific name of the pathogen can help to avoid confusion.

(i) Alternaria leaf blotch and fruit spot (caused by Alternaria species)

Although *Alternaria* leaf blotch (caused by *Alternaria* species) has been recorded in Australia for many years, the relatively new disease *Alternaria* fruit spot has only been recorded at production limiting levels in Queensland and New South Wales. There is also some evidence to suggest that there are several types of *Alternaria* causing leaf blotch symptoms in Australian apples, and that these types of *Alternaria* may vary between the major production areas.

International literature commonly refers to *Alternaria mali* as the cause of *Alternaria* leaf blotch in apples. At the time of writing, it is not clear whether the pathogen causing *Alternaria* leaf blotches and fruit spots in Australian apples is the same as the pathogen causing these symptoms overseas.

This disease should not be confused with *Alternaria* core rot or mouldy core, a postharvest storage rot caused by *Alternaria alternata*.

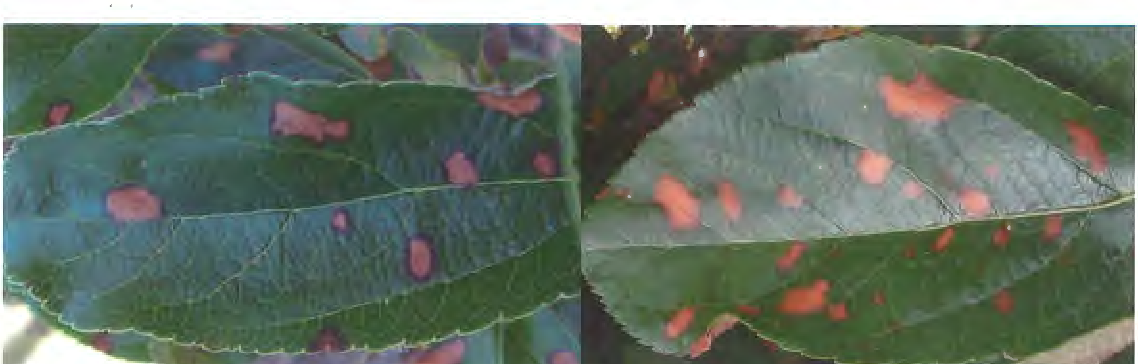

Plate 17. *Alternaria* leaf blotches on Royal Gala apples

Disease description

Alternaria leaf blotch

This disease is characterised by irregular (but often roughly circular) light brown-reddish shaped lesions, often with purple borders on leaves (Plate 17). These symptoms are also produced by a range of other problems, including physical damage. Therefore a diagnosis of *Alternaria,* based on leaf lesions alone, is not possible.

What distinguishes *Alternaria* leaf blotch from these other problems is that under the right weather conditions, *Alternaria* leaf blotches will continue to grow; and when the leaf is half covered by lesions, the leaves will tend to drop prematurely from the tree. Tree defoliation can be severe in rainy seasons, with complete defoliation as early as February common in some areas (i.e. North Sydney Basin of New South Wales).

Alternaria fruit spot

Small, slightly sunken, light to medium brown spots appear on the lenticels of the fruit, often after rain and usually no earlier than six-eight weeks prior to harvest (Plate 18). It is unclear at this stage whether *Alternaria* leaf spot is caused by *Alternaria* fungi (which are regularly isolated from these spots), or whether the *Alternaria* is simply an opportunistic secondary invader.

Interestingly, fruit spots do not appear during storage, and preharvest *Alternaria* fruit spots do not grow in size during cold storage. However, once removed from cold storage the spots can continue to enlarge, and provide an excellent entry point for other secondary fruit rots.

Plate 18. *Alternaria* fruit spot on Royal Gala fruit

Management

At this stage no organically certified disease management measures have been identified for *Alternaria* leaf blotch or fruit spot. However, good farm hygiene, including removal or complete breakdown of infected leaves, fallen fruit and mummified fruit is likely to be helpful, especially over winter. The application of a regular apple scab spray program, may also be helpful (see Apple Scab).

(ii) Apple Scab (caused by Venturia inaequalis)

Apple scab (commonly known as Black spot in Australia) is the most serious disease of apples world-wide, and when susceptible varieties are grown significant effort is required to effectively manage this disease.

Plate 19. Royal Gala (left) and Granny Smith (right) leaves and fruit infected with apple scab

Disease description

Leaf spots on young leaves start as light, olive-green spots, 3 mm in diameter, with a diffuse, irregular, almost velvety edge. The spots darken and enlarge with age, taking on a "scab-like" appearance. If left unchecked, severely affected leaves will eventually become completely covered by the scabs, and the distorted leaves may drop from the tree.

The most serious symptom of apple scab occurs on fruit. The small, dark, corky spots with black, broken margins (Plate 19) can significantly reduce the number of fruit that can be marketed.

Management

The lifecycle of apple scab has been well studied, and many disease prediction/monitoring systems have been developed. Most of these systems rely on mathematical equations to provide a risk level of infection; determined by mathematical modelling, these systems correlate several vital weather measurements (temperature, rainfall and leaf wetness), with the stage of fruit development and the number of spores released.

Cultural management

The most successful form of disease management for apple scab is to grow resistant varieties.

Overwintering leaf material is the main source of primary inoculum in the spring, so it is vital that all leaves, twigs and fruit from the previous season are broken down or removed prior to the emergence of new leaves in the following season.

Do not use overhead irrigation, as wetting leaves on the ground will release spores, and the higher humidity will assist infection.

Chemical control for resistant varieties
If you are in a large apple growing area, with significant apple scab disease problems, you may need to augment resistant varieties with the application of a few chemical sprays each season. This is especially so when trees are young and infection periods are severe, and on mature trees each spring at the time of highest infection risk.

For apple scab resistant varieties, use a reduced number of the sprays suggested below for susceptible varieties.

Chemical control for susceptible varieties
If growing susceptible varieties, you will need to use a comprehensive spray program to protect your trees from apple scab infection. Early season copper sprays, followed by the preventative use of wettable sulphur, or the curative use of lime sulphur, are suggested. It is important to be timely with the application of these sprays. If you delay or miss a spray there may be little opportunity to catch up, as chemicals must be applied before spores have a chance to germinate. The most essential and critical time for control of apple scab is from green tip through to full bloom, when new tissues (emerging flowers and leaves) must be covered at all times.

For precise chemical application timings, refer to your local orchard plant protection guide, or subscribe to a local apple scab disease warning service. Also remember to keep within the annual limit for copper use allowed by your certifying organisation and target market.

Finally, even the best organic management program for apple scab will still result in some infection being present in the orchard. As an organic grower you will just have to accept that you will lose some of your fruit to this disease.

(iii) Bitter Rot (caused by Glomerella cingulata)

Bitter rot should not be confused with Bitter pit, which is a physiological disorder of the fruit caused by calcium deficiency.

Plate 20. An advanced Glomerella lesion on Granny Smith fruit. Note the concentric circles of spore forming structures in the centre of the lesion

Disease description

The most obvious symptoms occur on fruit, and start as small, soft, sunken, circular, light-brown spots. These spots enlarge rapidly, turn darker and often rot large sections of the fruit. If the infection is old enough, concentric rings of very small black pimples will form within the centre of the spot. These are spore-forming structures which can start to ooze pink spores in humid conditions (Plate 20). Symptoms often appear as fruit approach maturity.

Leaf and twig infections can also occur. Small, irregular, brown spots may appear on leaves, with cankers forming on 'spurs' (small twigs bearing fruit buds). These symptoms are much more common in warm, wet weather.

Management

Monitor orchards from early November onwards, and remove all infected fruit, twigs and spurs. During dormant pruning remove and destroy all mummified fruit and infected twigs.

There are currently no effective chemicals permitted for use in the National Standard for Organic and Bio-dynamic Produce. This disease will most likely infect some of your fruit every season.

(iv) Powdery Mildew (caused by Podosphaera leucotricha)

Plate 21. Powdery mildew spores on the surface of an apple leaf

Symptoms
Powdery mildew is typified by the appearance of masses of greyish-white, "powdery" mycelium covering the surface of leaves (commonly underside first –Plate 21), twigs, blossoms and fruit. Tips of fruiting twigs and terminal shoots are especially vulnerable. If fruit and leaf buds become severely affected they can fail to develop properly, while affected flowers frequently wither and fail to set fruit. Powdery mildew can also russet the fruit and reduce fruit size.

Disease description
The fungus overwinters in dormant flower and leaf buds, and resumes growth in spring, when it infects new leaves and blossoms. Infection is particularly common from the pink stage of flowering onwards, with masses of spores easily blown by the wind within, and between, blocks of trees.

Infection is favoured by high humidity and moderate temperatures (19-25°C), typically when overnight dews are followed by dry, sunny days. As the season progresses and genuinely hot weather occurs, the risk of infection lowers, with spore viability significantly reduced at temperatures above 28°C. Cooler autumn weather can lead to fresh outbreaks, but these rarely cause production-limiting levels of disease.

Management
Avoid highly susceptible varieties, and where possible plant resistant varieties. If susceptible varieties are grown, then an early spray program and thorough removal of diseased shoots and leaves throughout the season will be required.

Apply lime sulphur three times during the blossoming period, between pink bud and petal fall. Remove infected shoots during winter pruning and infected leaves, shoots and blossoms during the season to reduce inoculum. It is good practise, and highly effective, to walk the rows of trees on a weekly basis, and remove infected shoots into a bag/container for disposal well away from the orchard.

Controlling vegetative growth can help to reduce spread, as secondary infection of powdery mildew can only occur on very young tissues.

(v) Sooty Blotch (caused by Gloeodes pomigena)

Plate 22. Sooty Blotch on Granny Smith apple

Symptoms
Dark-grey to dull-black blotches of indefinite shape and variable size (Plate 22) can develop on fruit in late summer, particularly in warm, wet weather. Granny Smith apples are particularly prone to sooty blotch in humid weather.

Disease description
Sooty blotch is not commonly found in orchards using a regular apple scab spray program, but can occur in organic orchards if no copper or sulphur is applied during wet seasons.

Management
This disease is usually controlled in non-organic orchards by a regular apple scab spray program, but a combination of sulphur sprays and cultural methods can be effective for organic growers. In particular, prune trees, control weeds and drip irrigate to reduce humidity within the canopy. Reduced shading and increased air flow may also help.

4.3.4 Viruses

There are several viruses present in Australia which infect apples, with Green Crinkle disease, Apple Mosaic virus and Apple Ring Spot virus the most common. The importance of all of these viruses decreased substantially in the 1980's and 1990's due to the use of virus-tested propagating material. However, instances of "the odd infected tree" are becoming more common in Australia, and badly affected trees should be removed. These "odd" trees often show symptoms only under stress, i.e. drought.

Plate 23. Apple mosaic virus symptoms on apple leaves

Symptoms

Apple mosaic virus is characterised by irregular pale-coloured (Plate 23) areas that develop on expanding leaves in spring. These areas may appear as small red-brown spots, flecks, vein-net patterns, or bands along the veins. As the season advances, the symptoms become paler and severely affected leaves often fall from the tree.

Green crinkle disease causes small and malformed fruit, sometimes with small russetted areas in skin depressions. Water conducting tissues beneath the depressions tend to be greener than normal.

Apple ring spot virus causes two types of fruit symptoms. The most obvious is a pattern of dark-brown, concentric, incomplete circles which develop as the fruit ripens. Irregular patches of rough russet, brown in colour with narrow bands of dark-brown tissues around the margins, are also common.

Symptoms for all of these viruses will often initially appear on a single branch or side of the tree.

There are also some symptomless viruses, which cause no visible change in the tree but can significantly reduce yields.

Management

It is vital to use virus-free propagating material. Most viruses can be transmitted by grafting or budding, and are usually spread by the use of infected propagating material. If an infected plant is used for propagation all of its progeny will be infected. There are no effective treatments against virus diseases. Infected trees should be removed and destroyed, and on no account used as a source of propagation wood.

4.3.5 Trunk diseases

The term collar rot is routinely used as the common name for several diseases. In Australia the two diseases most likely to be called collar rot are caused by *Sclerotium rolfsii* (*Sclerotium* collar rot) and *Phytophthora* (*Phytophthora* trunk rot).

(i) Sclerotium collar rot (caused by Sclerotium rolfsii)

This disease is routinely referred to as Collar rot in Queensland, where Phytophthora trunk rot remains uncommon. In the United States of America, this disease is called Southern Blight.

Symptoms

The first symptoms of *Sclerotium* collar rot are typically changes in leaf colour (yellow, reddish or greying-purple), wilting and general symptoms of water stress. Closer inspection usually reveals a rotten ring of trunk tissue either just above, or below the soil surface, often completely encircling the stem. If the soil is moist, white tufts of fungal mycelia can sometimes be seen covering the affected area. The most distinctive visual symptom is the presence of small, spherical, initially creamy-white, but turning brown then black resting structures (sclerotia) either on the affected tissue or in the soil nearby.

Disease description

Sclerotium rolfsii is a common pathogen of a range of crops (especially vegetables and weeds); and is a regular inhabitant of cropped soils. Infection is often more serious when apples are planted into ground that has previously been used for growing vegetables for a number of years. Sclerotia are the primary source of inoculum for this pathogen, and can survive in the soil for many years.

Management

Inspect trees regularly, especially if planted into ground previously used for vegetables. If detected early, *Sclerotium* collar rot can be treated by removing soil from close to the trunk near the soil surface, cutting out the infected tissue, applying wound dressing paint and leaving the affected area exposed (clear of soil) for at least ten weeks. Be careful to keep the cut area of the tree clean while exposed, and apply organically approved wound dressing immediately. The addition of a small amount of copper to the wound dressing paint can be helpful in reducing secondary fungal infections.

(ii) Phytophthora trunk rot (caused by Phytophthora species)

There are two diseases of apple trees caused by *Phytophthora* species. These are commonly referred to as Collar or Trunk rot, and Crown or Root rot. In Australia, we generally talk about *Phytophthora* trunk rot, which affects the scion of the tree, and *Phytophthora* root rot, which affects the rootstock.

Symptoms

As with *Sclerotium* collar rot, the first noticeable symptoms of Phytophthora trunk rot are often foliar. This disease usually causes general tree unthriftiness, including lack of extension growth (and even stunting), changes in foliage colour (often to yellow or red) and water stress.

Trunk rot affects the scion, just above the graft union, and is usually found on mature trees, but can affect younger trees. A dry, grey to dark depressed area, with no gum exudation generally visible on the outside, can be seen when the bark is cut away.

Disease description

The spores of this fungus (oospores) can survive the winter in the absence of apple trees or moisture. The oospores germinate to produce zoospores, which can move through water to infect the rootstock crown through roots or the scion through cracks or damage on the bark, branches or leaves.

Phytophthora diseases are highly dependent upon warm, wet environmental conditions for infection and symptom expression.

This disease has become much less prevalent in recent years, due to the practice of raising the graft union above the soil line at planting.

Management

Plant trees into raised beds with well-drained soils, and avoid saturated areas or 'wet spots' in fields. It is vital to reduce periods of soil moisture saturation at this time.

Avoid or reduce damage to tree trunks during planting, as damaged bark provides an excellent entry point for spores, especially if soil is splashed into the wound. Continue to protect the scion bark of trees from damage after planting (e.g. using rabbit guards), and keep mowing blades well clear of tree trunks.

If detected early *Phytophthora* trunk rot can be treated by stopping the progress of the pathogen into healthy tissues. If possible cut out the lesions, by slicing trunk tissues right back to sapwood, ensuring the cutting passes through the graft union, and prying out the affected tissues. Alternatively, cutting a groove down to the sapwood surrounding the lesion can be effective. Cover substantial wounds with wound paint.

Finally, irrigation drippers should be placed 45-60 cm away from tree trunks, to prevent soil splash and reduce humidity. Weeds close to the tree trunks should also be removed.

4.3.6 Soil-borne diseases

As a general rule, soil-borne diseases are best combated in an organic system by high levels of soil microbe diversity, free draining soils and good general plant health.

(i) Phytophthora root rot (caused by Phytophthora species)

Symptoms

As mentioned previously, this disease is sometimes referred to as Crown rot. As with *Phytophthora* trunk rot, the first symptoms noticed are often foliar. This disease usually causes a general lack of tree health, including lack of extension growth and stunting, changes in foliage colour (often to yellow or red) and water stress. When severe, some varieties can show dieback of branches.

Disease description

When examined, roots are often brown and rotted in appearance, with a dark depressed lesion/s extending upwards from the root crown towards the graft union (Plate 24). These are visible when the bark is removed. During dry weather, trees may appear to recover from the disease, but symptoms will return with wet weather. Depending upon their size, trees can take several years to finally die.

Management

When planting apple trees in an area where *Phytophthora* root rot has been a problem in the past, the use of resistant or less susceptible rootstocks is recommended. Keep in mind that rootstocks may have different levels of resistance or susceptibility in different production areas, so you should check with your state department of agriculture for varieties suited to your region.

Plant trees into raised beds with well-drained soils, avoiding saturated areas or 'wet spots' in fields. Planting cover crops in alley ways has been shown to reduce excess soil moisture, when compared to mulched alley ways or bare ground.

Plate 24. Phytophthora root rot

Irrigate trees thoughtfully. Apply water in irrigation cycles that just wet the soil to field capacity, to minimise the period of soil saturation. Allow sufficient time for soil to drain before the next irrigation.

Be particularly careful if replacing trees in a mature orchard. The new, and therefore younger trees will require less water and may quickly become infected if over-watered, and the soil remains saturated. Avoid movement of soil and infected plant material into new, uninfected areas.

(ii) White Root Rot (caused by Rosellinia necatrix, previously Dematophora necatrix)

White root rot has only been recorded from the Granite Belt in Queensland, where it has caused significant losses for many growers over the last two decades.

Plate 25. Mature apple trees killed by White root rot

Symptoms
As the name suggests, White root rot affects the newly produced 'white roots' put out by apple trees in early spring each year. Trees develop a generally unthrifty appearance with leaf yellowing, cessation of root growth, small leaves, premature leaf fall and small, shrivelled fruit. The symptoms can look similar to those caused by *Phytophthora* root rot. Older trees can die over one to two seasons (Plate 25), while newly planted trees can die in a few months.

Crown
The very base of the trunk, at soil level, can show signs of a dark, wet rot; especially if kept moist by weeds or wet weather. A distinct margin is usually visible between the infected and healthy bark, with a thin layer of white fungal growth found under the diseased bark (Plate 26).

Roots
Affected roots have dark, wet looking surfaces, often with healthy looking wood underneath. Strands of white fungal growth are often present in the soil and leaf litter surrounding the roots. In severely affected plants the whole root ball often breaks away from the trunk if the trunk is tugged from the ground.

Disease description
Although *Rosellinia* does not form resting bodies, the fungus can survive for long periods on old rotted roots and root debris in the soil. The roots of various native trees and weeds can also act as a food source for the fungus; however, these plants may or may not show disease symptoms.

Plants become infected when their roots come into contact with roots from adjacent infected trees, or rotted roots that are left in the soil from previous infections.

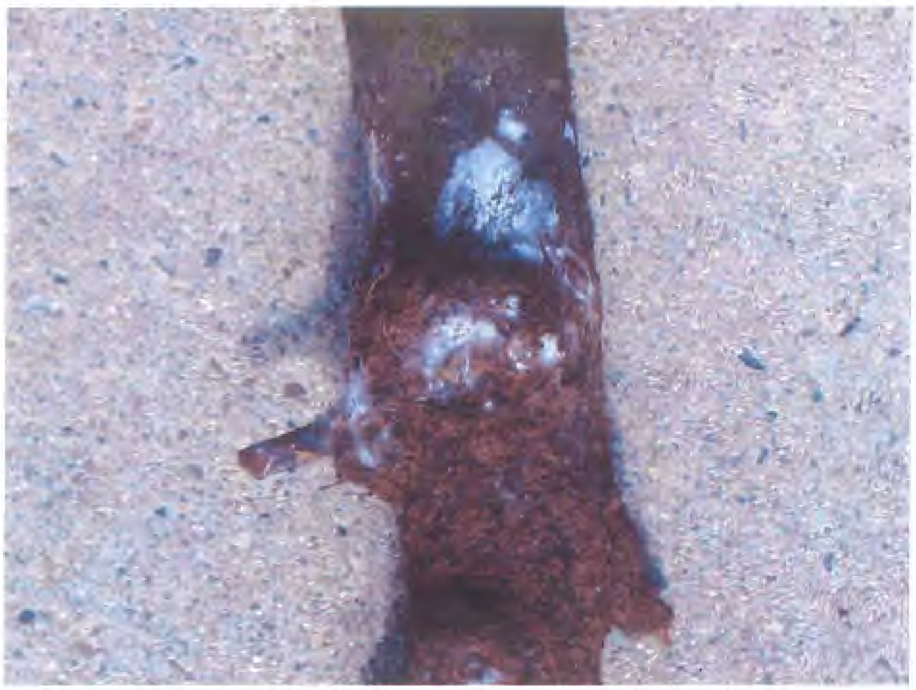

Plate 26. White root rot on apple tree crown with white mycelia under the bark

Management
Do not plant apples in ground with a history of White root rot. The problem is currently incurable.

Land recently cleared of native vegetation or previously planted with apples should also be treated with caution and if possible avoided, especially in the Granite Belt, Queensland.

Once trees are diagnosed with White root rot, remove them as quickly and carefully as possible, preferably before death, to enable easier and more complete removal of roots. Once the tree/s have been removed, seal off the area of affected soil using subsurface soil barriers. Do not replant apples in this area.

If apples must be replanted in the same soil, soil sieving to remove all residual tree roots can be helpful. Avoid movement of soil and infected roots or rotted root material into new, uninfected areas.

(iii) Apple Replant Disease

Apple replant disease is a common problem in orchards where apples have been replanted into ground previously used to grow apples. Triggered by a number of biotic and abiotic factors, the exact cause of the problem varies between sites, but can involve plant parasitic nematodes, soil-borne fungi and bacteria, soil chemistry (pH), and nutrient imbalances, especially insufficient available phosphorous. In Tasmania research has shown soil-borne bacteria to be the principle cause, with plant parasitic nematodes also reducing production.

Symptoms

Apple replant disease can cause a range of variable symptoms. However, typical symptoms include severe stunting, shortened internodes, rosetted leaves, and reduced fruit production. Affected trees tend to have small root systems with lots of fibrous roots, and often fruit two to three years later than unaffected trees.

Management

The only practical management method for organic growers is prevention. This entails selecting a site that has not previously been planted to apples or if such a site must be used, thoughtful soil preparation and crop rotation between plantings (as detailed in the Site Selection and Preparation section). Soil tests, including measurements of available nutrients, plant parasitic nematode counts and pH tests may also be useful in site selection.

Further information

A range of insect and disease warning services are available to assist growers with monitoring of their orchards. Contact your State Department of Agriculture representative or local horticultural consultants in your area for further information.

4.4 Apple Varieties

To set a good crop of quality fruit, apple trees generally require cross-pollination i.e. two different varieties grown in close proximity to enable the transfer of pollen (primarily done by bees) from one variety to the other.

Some commercial varieties are currently grown successfully using organic production systems (e.g. Red Delicious, Gala, Pink Lady™). However, these require a high level of management to control pests and diseases, and may not be the best choice for orchardists growing organic apples for the first time. Undoubtedly, apple varieties with some level of pest and/or disease tolerance are desirable, making the task of producing organic fruit somewhat easier.

The more common commercial apple varieties are described in a range of literature (see Suggested Reading) and on the web. For example, on the Apple and Pear Australia Ltd (APAL) website (www.apal.org.au) there is a link to a downloadable Australian apple information chart which lists the twelve most commonly grown apples in Australia. Of the varieties listed, Cripps Pink (Pink Lady™), Lady Williams, Cripps Red (Sundowner™), Braeburn and Granny Smith are extremely susceptible to apple scab (apple black spot), Gala, Hi Early (and other Red Delicious types), Golden Delicious and Fuji are moderately susceptible, whilst Jonathan is generally acknowledged as being less susceptible to apple scab.

A number of other apple varieties from around the world are reported as having tolerance to some pests and/or diseases. For example, several varieties with genetic resistance to the apple scab fungus *Venturia inaequalis* have been developed by breeding programs overseas and in Australia. Some of these are also tolerant of other diseases such as powdery mildew. Resistance to codling moth has been reported in only two varieties (Black Oxford and Arkansas Black), however these are old American varieties from the 1800's and are not commercial.

Varieties with apple scab resistance that are readily available in Australia include Florina, GoldRush, Liberty, Prima, Scarlett O'Hara, Svatava and Topaz. The Department of Primary Industries & Fisheries, Queensland (DPI&F) apple breeding program at Applethorpe Research Station has also developed a number of selections that are resistant to apple scab. The scab resistance in all the aforementioned varieties and selections is derived from a single gene (V_f from *Malus floribunda*). Caution is therefore required to avoid exposure of these resistant varieties to constant pressure from apple scab in an orchard situation. A copper-based green tip spray is strongly recommended, as are orchard hygiene measures to minimise inoculum levels in the orchard e.g. leaf sweeping to remove and mulch leaf litter. Such basic cultural practices will reduce the likelihood of the resistance gene breaking down over time.

4.4.1 Varietal descriptions of scab-resistant apples

The variety descriptions given below are an amalgam of first-hand observations made at Applethorpe Research Station (with the exception of GoldRush, Svatava and Topaz) and descriptions taken from reference material produced by nursery suppliers and overseas researchers.

(i) Florina: Developed in France and maturing mid-season (ripens six weeks after Gala). Medium size, 70% purplish-red on yellow ground colour, with shiny waxy bloom. Off-white to cream flesh, medium texture and firmness, sweet, good eating quality. Moderate susceptibility to powdery mildew. Tolerant of fire blight.

(ii) GoldRush: Developed by the Purdue, Rutgers and Illinois (PRI) co-operative breeding program in the USA (tested as Co-op 38). No significant quantities are grown yet. Late season variety (four weeks after Delicious), medium sized with greenish/yellow skin, and slight russeted lenticels. Good storage life, with off-white to cream flesh, firm, medium to coarse texture, crisp and juicy. Tart flavour at harvest, but softens and develops a rich, balanced flavour after a period of cold storage. Moderate resistance to fire blight. Tolerant of powdery mildew. Licensed to Flemings Nurseries.

(iii) Liberty: Released from the New York State Agricultural Experiment Station in 1979. It is a very heavy cropping variety, producing medium sized fruit, tending flattish in shape. Deep 90% block red on greenish-yellow ground. Ripens just before Red Delicious. Crisp, pale yellow to white flesh, juicy, sub-acid flavour and medium texture. Highly resistant to apple scab, with moderate resistance to fire blight and powdery mildew.

(iv) Prima: A PRI variety (tested as Co-op 2). Recommended as a home-garden variety only, and not for commercial production. Early maturing variety (with Gala), bright red full block colour on yellow ground. Medium sized fruit with off-white flesh colour, crisp, medium texture with neutral to tart flavour. Tolerant of powdery mildew and fire blight.

(v) Scarlett O'Hara: Also a PRI variety (tested at Co-op 25). An early-mid season variety ripening at the same time as Red Delicious. Colour tends to develop slowly, and is often dull, muddy-red in appearance. Has breaking flesh which is pale yellow to cream, very firm and very crisp. Slightly coarse texture, sweet, sprightly and aromatic flavour. Stores very well for extended periods. Some significant problem with mouldy core in up to 50% of production in some years. Resistant to apple scab, and powdery mildew. Licensed to Flemings Nurseries.

(vi) Svatava: Developed in the Czech Republic. Medium sized, red striped, bi-coloured apple with yellow ground colour. Flesh is fine textured, juicy, aromatic with a good acid balance. Matures just before Golden Delicious and has a seven to eight month storage life. Exclusive to the Australian Nurseryman's Fruit Improvement Company (ANFIC).

(vii) Topaz: Another Czech Republic variety. Medium sized, red-orange on yellow-orange ground colour with stripes on up to ¾ of the skin surface. Some slight russet in stem cavity. Yellow-cream flesh with fine texture. Firm, crisp and juicy with a sweet subacid flavour. Up to seven months storage life. Requires more attention to calcium than other varieties. Exclusive to ANFIC.

(viii) Apple breeding lines from DPI&F Applethorpe Research Station: A number of selections from the DPI&F apple breeding program are currently being field tested at several sites. Two of these show exceptional promise, and both are resistant to apple scab. The first selection (Plate 27) is early maturing (three weeks after Gala), and has a red skin colour with broken dark red over-stripe on a yellow-green ground. Flesh is medium textured, off-white, crisp, juicy and has a sweet, clean and mild low-acid flavour.

The second selection (Plate 28) matures in mid-season (just before Fuji), and has a broken red stripe to almost solid red skin colour. Fruit has a round to conic shape. Flesh is off-white, crisp, juicy with a mild, sweet/low acid flavour. This selection was granted provisional Plant Breeders Rights protection in 2005 and is nearing commercial release.

Plate 27. Early-maturing apple scab resistant selection from the DPI&F apple breeding program

Plate 28. Mid-season apple scab resistant selection under PBR protection, and being prepared for commercial release

4.4.2 Recommendations

Apple growers should consider the "big picture" before planting new orchards. This means taking into account all the pros and cons of growing particular varieties in your district. While some varieties may have an advantage in ripening early or late in the season, they may also be difficult to grow or have problems with attaining adequate fruit colour at harvest.

Varieties resistant to apple scab or with at least some tolerance, are essential in apple growing areas which have wet spring weather, and temperatures favourable for primary infections from green tip to post blossom (September to November in Australia). If you know that conventional spray programs have difficulty in controlling apple scab on a particular variety, don't try growing it with organic control measures.

From DPI&F assessment of scab resistant varieties tested from the mid 1980's to 2000, only Florina and Scarlett O'Hara are considered to have potential for commercial production. Be aware however, that Scarlett O'Hara is highly susceptible to mouldy core.

New varieties like GoldRush, Svatava and Topaz remain untested in Australia, so be guided by the advice of your nursery supplier.

Organic apple growers also need to bear in mind that the later maturing varieties have fruit on the tree for a longer time each season. Hence these varieties are more exposed and vulnerable to pest, disease, and weed pressures, and more costly to grow than earlier maturing varieties.

In summary, select varieties for their consumer appeal and agronomic characteristics. Plant a mix of varieties which are best suited to your area, your target market, and have a spread of maturity dates that allow co-ordination of farm operations and labour for harvesting at optimum maturity.

4.5 Rootstocks

A range of apple rootstocks are available that can be used to control tree vigour and contribute to ease of orchard management. Apple rootstocks are mainly categorized according to their effect on tree vigour, and are given vigour ratings that are expressed as a percentage in comparison to a standard seedling tree, or by more general descriptive terms such as dwarfing or semi-dwarfing.

The interaction between the rootstock and the scion variety also influences tree size and vigour. For example, "spur type" varieties have an abundance of fruit spurs and vegetative growth that consists of a limited number of short vegetative shoots (due to short internodes). When grown on a clonal rootstock, "spur type" varieties therefore produce a smaller, more compact tree with less growth than a "standard" variety grown on the same rootstock.

Rootstock performance also varies with soil type and growing conditions. State Department of Agriculture recommendations or a consultant's advice for each district should be followed to ensure that the best scion and rootstock combination are used for planting.

With the trend to higher density plantings, smaller, more precocious trees that crop early are required to ensure high yields within four years of planting and hence early financial returns on investment. For these reasons rootstocks in the vigour range from dwarf to semi-dwarf are desirable. Vigorous rootstocks such as Merton 778 and Merton 793 are no longer used in modern apple orchards, as trees on these rootstocks are significantly less productive than trees on more dwarfing rootstocks.

Apple rootstocks for high density planting include:

- M.9 is a dwarfing rootstock (35% size of Seedling) which is very precocious and produces a tree approximately two metres tall. Many clones of M.9 exist, and include M.9 EMLA (heat treated to remove latent virus, and more vigorous than the original M.9), Pajam 1 and Pajam 2 (clones of M.9 developed in France). Trees on M.9 tend to have poor anchorage and require support from a trellis structure or individual stakes to keep the tree upright and carry the crop load. The graft union has a characteristic "bulge" indicative of a graft incompatibility contributing to the dwarfing effect. M.9 rootstocks are susceptible to woolly apple aphid infestation, but have some resistance to Sclerotium collar rot caused by *Sclerotium rolfsii* (see Disease Management). Well-drained deeper soils are preferable to attain good tree size.
- M.26 is more vigorous than M.9 (40% size of seedling) but has less vigour than MM.106. Trees grown on M.26 rootstock are highly precocious and have better soil anchorage than M.9. However, support from trellis structures is still beneficial to keep the tree upright and to support the crop load. M.26 rootstocks are susceptible to woolly apple aphid infestation, and mildly susceptible to Sclerotium collar rot (caused by *Sclerotium rolfsii*). As with most other rootstocks, the productivity of M.26 declines if trees are drought stressed or growing in water logged soil conditions.
- Ottawa 3 (O.3) is a dwarfing rootstock that has better soil anchorage than M.9 and produces a tree 35–40% the size of Seedling. Ottawa 3 is susceptible to woolly apple aphid and sensitive to *Tomato ring spot virus*, but resistant to Sclerotium collar rot. O.3 has performed well in trials at Lenswood, South Australia.
- MM.106 is semi-vigorous (65% size of Seedling) and of similar vigour to M.7. This rootstock has been widely used throughout Australia, and when well-managed produces consistently heavy crops. Soil anchorage is good but the tree size is too large for very high density planting systems. MM.106 is resistant to woolly apple aphid, but is susceptible to Sclerotium collar rot (caused by *Sclerotium rolfsii*).

4.5.1 Inter-stems

Although rarely used, inter-stems are an alternative technique for manipulating tree vigour. M.9 is the most commonly used inter-stem, as it confers a dwarfing effect on the scion variety and, when grafted onto a rootstock with a better-developed root system (e.g. MM.106), avoids the problem of poor anchorage. In this case, a piece of M.9 scion wood (with three or four vegetative buds) is grafted onto MM.106 rootstock in the nursery and grown for a season. In the following year, a piece of scion wood of the desired variety is grafted onto the M9 inter-stem. In general, the longer the inter-stem, the more dwarfing is the effect on the tree. Inter-stem lengths may be between 15 cm and 30 cm.

4.5.2 Other Rootstocks

Other dwarf to semi-dwarf rootstocks, of the appropriate vigour required for high density plantings are either not fully tested under Australian conditions or are unsuitable for various management reasons. Examples include:

- Mark (MAC 9) - has compatibility issues with triploid scions (e.g. Mutsu, Jonagold), and may develop a physiological disorder which causes swelling of the rootstock at ground level. This condition is known as "root mass proliferation", and may appear four or five years after planting. The cause is unknown.
- P.1 and P.2 - not tested in Australia.
- M.7 - similar vigour to MM.106 and about twice the vigour of M.9. Prone to suckering.
- M.27 - very dwarfing and of limited use.

4.5.3 Pest and disease resistance

Resistance to woolly apple aphid is inherent in the medium vigour MM.106 rootstock, but not in the dwarfing rootstocks M.9 and M.26. Other rootstocks with resistance to woolly apple aphid are Northern Spy, and the Malling Merton series of rootstocks which includes MM.102, MM.104 and MM.109 (see Suggested Reading). The bacterial disease fire blight (caused by *Erwinia amylovora*) is not present in Australia. Even though MM.106, M.9 and M.26 all have varying levels of sensitivity to fire blight, their use at present can still be recommended for organic orchards in Australia.

4.6 Tree Management

4.6.1 Soil Management and Tree Nutrition

The National Standard for Organic and Bio-dynamic Produce (the Standard) outlines general principles for soil management, and provides a basis for managing soils in organic cropping situations. The broad aim is to create a closed cropping system with few external inputs as nutrient cycling is a key feature of organic production. Simply put, nutrients are extracted from the soil by plants and eventually returned to the soil again via the breakdown of plant residues by soil microbes and other organisms such as earthworms. Cultural practices should generate sufficient organic matter to maintain or increase humus levels. These processes require sustained effort over a long period of time to achieve a balanced system.

The Standard permits the following methods to maintain or increase the fertility and biological activity of the soil.

- Use of legumes and green manure crops.
- Sheet composting of animal manures (see notes and restrictions in the Standard).
- Application of fully composted organic matter from selected sources, as outlined in the appendices of the Standard.
- Use of bio-dynamic preparations and methods.
- Appropriate use of cultivation and tillage equipment which preserves or improves soil structure.
- Incorporation of livestock into the farming system.

In apple orchards, a combination of some of these management strategies is required to maintain soil fertility and offset the effects of crop removal (apple harvest) on the nutrient status of trees and the soil. The Standard specifies limited use of external inputs, and encourages on-site nutrient cycling. In practice, this may be difficult to attain in apple orchards on poorer soils, especially if the yield of apples is to be maintained. Some fertilizers derived from natural sources are allowable inputs. However, as a general rule, application of fertilizers of any sort should be on a needs basis rather than routine practice. Soil and leaf analysis should be done annually to assess the need for nutrient applications, and to substantiate the use of approved fertiliser products for auditing purposes.

Growing legumes as part of a permanent sod culture between the tree rows with one or more pasture grass species, is recommended as a source of nitrogen in organic orchards. Bare untreated legume seed (no fungicide) can be obtained from seed companies, and must be inoculated with the correct species specific *Rhizobium* to allow nodulation and nitrogen fixation on the legume's roots. Clover and vetch are commonly used legumes often sown with perennial rye grass. Mowing of the sward during the season also recycles nutrients back into the soil, through decomposition. Some legumes such as white clover are an alternate host for thrips which can have implications in pest management (refer to Managing Insect Pests).

Green manure crops are primarily grown to improve the soil and are an important first step in preparing land for orchard establishment. They should be cut and turned back into the soil whilst lush and green, as this aids rapid and easy breakdown in the soil under favourable conditions. Green manure crops provide organic matter which captures nutrients that may otherwise be lost from the soil due to leaching. Forage sorghum, or a mixture of legume (e.g. lucerne) and non-legume (e.g. oats) are examples of green manure crops suitable for building up the soil prior to the planting of apple trees.

The National Standard for Organic and Bio-dynamic Produce does not allow the application of animal manures and by-products, unless they are fully composted. Sheet composting on-site is not really an option in orchards. It is preferable to bring in organically certified compost, and apply it as a soil amendment along tree rows and/or to the sod between the tree rows.

4.6.2 Soil Chemistry and pH

The nature and structure of soils is a complex topic beyond the scope of this publication. Soils vary in a range of factors such as:

- origin
- type and texture
- moisture holding capacity
- pH and buffering capacity
- organic matter content including beneficial soil organisms such as bacteria and earthworms.

These factors all affect the availability of nutrients to plants, and hence the ability of plants to grow.

The essential elements derived from the atmosphere and water, are oxygen (O), hydrogen (H) and carbon (C). These are the building blocks of plant sugars. A further 13 elements essential for plant growth are derived from the soil: nitrogen (N), phosphorus (P), potassium (K), sulphur (S), calcium (Ca), magnesium (Mg), boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo) and zinc (Zn). These elements are important in plant growth and development processes, and as constituents of plant structures such as leaves and fruit.

Of the factors which affect plant growth in general, soil pH has a fundamental effect on plant nutrition. This is due to changes in the balance of nutrients available to plants, as soils become either too acid (low pH) or alkaline (high pH). As soil pH decreases, elements such as phosphorus, magnesium, calcium and molybdenum become less available to plants. Other elements such as aluminium, iron, and manganese may become more available, and even reach toxic levels. For example, aluminium and manganese toxicity may occur in plants where the soil pH is below pH 5.0. In alkaline soils (with pH over 7.5) zinc deficiency may occur and calcium ties up phosphorus, making it unavailable to plants.

Soil pH analysis is done using water to give a pH (w) value or by using calcium chloride to give a pH ($CaCl_2$) value. The calcium chloride method is considered to be more accurate and the resultant pH value is approximately 0.8 of a unit lower than the pH (w) for the same sample. This is important because the pH is measured on a logarithmic scale where an increase or decrease of one unit reflects a ten fold change in acidity or alkalinity. A difference of two pH units represents a 100 fold change. The pH range is from acid (below pH 5.0), to neutral (centred on a pH 7.0), and to alkaline (above pH 7.5).

For apple trees, a pH of 6.0 - 6.5 is the ideal range which ensures the availability of the major and minor elements required for crop nutrition. Soil pH also has an impact on the biological activity in the soil. The ideal range for soil biodiversity is between a pH of 5.5 and 7.5, and beneficial bacteria and earthworms disappear from the soil if the pH is too acidic or too alkaline. Further, low soil pH can reduce the plant's ability to resist disease-causing fungi that attack tree roots (e.g. White root rot and *Phytophthora*), especially if the tree is already stressed due to nutrient deficiency or toxicity.

Most apple orchard soils in Australia tend to be acidic in their natural state and become further acidified due to leaching of nutrients from the tree root zone as a result of heavy rain or long irrigation cycles (particularly in sandy soils). Acidification occurs due to an increase in hydrogen ions on soil colloids which displace cations like calcium and magnesium. Leaching of anions such as nitrate, sulphate and chloride also takes place.

Agricultural lime ($CaCO_3$) or dolomite (lime with 8% Mg CO_3) are most commonly used to adjust soil pH, and must be thoroughly incorporated in the soil profile to have the desired effect. These products are not readily water soluble and have little influence on soil pH if applied to the soil surface without being ploughed in. Soils with a low buffering capacity (i.e. less ability to resist changes in pH) acidify quickly and require particular attention to liming requirements over time. The need for liming should be based on well interpreted soil analysis samples.

4.6.3 Compost Teas, Their Uses and Production

(i) What is a compost tea?

A compost tea is a water extract of compost that is 'brewed' to increase the numbers of micro-organisms in it (bacteria, fungi, protozoa, nematodes). Compost tea is not a water extract of manure. Compost tea is also by definition not a simple extract (leachate) of compost.

Compost teas can be applied to plants as a foliar spray or as a soil drench. As a foliar spray, the tea provides beneficial organisms for the control of diseases and nutrients for leaf absorption. As a soil drench, teas deliver beneficial micro-organisms that can develop biological barriers around roots, develop an appropriate soil biology, and develop and restore biological activity in soils (nutrient recycling, decomposition and nitrogen fixation).

(ii) Quality of compost teas

In order for compost teas to be effective they must contain an appropriate balance of different micro-organisms. Both numbers and types of micro-organism in a final tea, can be affected by any of the following:

- Starting material (inoculum or source of organisms),
- Microbial food (nutrients added to the brew as a food source for the organisms),
- Method of brewing,
- Hygiene (introduction of non-beneficial microbes), and
- Application equipment.

The starting material can be either compost or microbial concentrates which are available commercially. If compost is used as a starting material, its source, quality and age will all affect the quality of the final brew. If fungal-dominated compost teas are required (the best suited types for soil applications to perennial fruit crops), then composts developed from wood wastes should be used. The quality of compost will determine both the numbers and proportions of different micro-organisms present. Aerobic composts developed under controlled conditions will generally be the best source of starting material. The fresher the compost is, the higher the numbers of active microbes.

Microbial concentrates are a simpler alternative to compost as a starting material. However, it is wise to verify the origin of such concentrates and check that their composition suits your needs (fungal-dominated versus bacterial-dominated).

The types of nutrients added to a brew will affect the final balance of fungi and bacteria. For fungal-dominated teas nutrients rich in humates, soluble kelps and soluble fish products should be used. If bacteria-dominated teas are required, nutrients should predominately be fulvates and simple sugars (cane sugar, molasses).

The method of brewing will have a major impact on the quality of the final tea. Aerated brewing is generally preferred. Good aeration during brewing ensures that the beneficial microbes required will be dominant in the final tea. Aeration can be provided via venturis or perforated pipes. The temperature during brewing will determine the length of brewing time. Higher temperatures will result in shorter brewing times. Generally, temperatures of 20-28 degrees will have a brewing time of 20-24 hours. Lower temperatures will require longer brewing times to achieve high microbial numbers in the final tea.

Finally, teas should be applied within 24 hours of brewing if the microbe numbers and composition achieved during brewing are to be transferred to the field. Soil applications can be done through conventional equipment used to apply herbicides, provided pressures are kept at or below 60 psi.

Alternatively, special flood nozzles can be used. Foliar sprays can be applied through conventional air blast sprayers or boom sprayers. Thorough plant coverage is essential however, with at least 70% surface cover required to get benefit from the application.

4.6.4 Managing Weeds

(i) Know Your "Enemy"!

Any plant that is growing in the wrong place may be described as a "weed".

Some of the characteristics of plants which become weeds include:

- The ability to set large quantities of seed for dispersal by wind, water, on farm implements, and vehicles.
- Rapid growth of a large number of individual plants which compete with the crop for soil moisture and nutrients.
- Seeds which remain dormant in the soil and germinate over an extended period of time. Seeds buried by cultivation remain dormant and germinate when further cultivation brings them to the surface.
- Plants with vegetative structures (propagules) which can survive in the soil for a long time and grow into new plants when conditions are favourable. Examples of these structures include tubers, corms, stolons (above ground runners) and rhizomes (below ground stems).

Learning about weed life cycles and growth characteristics helps to formulate successful control strategies.

(ii) What harm do weeds do?

Weeds compete with trees for water and nutrients. This competition may significantly reduce tree growth and yields. Some weeds are also hosts for insect pests such as thrips and apple dimpling bugs, however, this may be balanced by the additional presence of beneficial insects and predators. Lush weed growth increases moisture and humidity around the base of trees, and may consequently favour the germination of disease spores on leaves and fruit. Excessive growth of tall weeds into trees will limit spray penetration. Some noxious weeds must be eradicated by law.

(iii) Management Strategies

Appropriate strategies derived from the Plant Protection section (3.7) of the National Standard for Organic and Biodynamic Produce include:

- Hand Hoeing (chipping)
- Cultivation
- Cropping and crop rotations to eliminate weed competition
- Mowing to prevent weeds from setting seed.
- Mulching
- Thermal weeders
- Integration and timing of farm operations to control weeds.

Hand Hoeing

Hand hoeing to remove weeds is only practical when the weeds are small and few in number. If a new weed species is introduced into the orchard, it may be possible to remove the seedlings by hand at an early stage, before they mature and set seed.

Cultivation

During orchard establishment, cultivation is essential to prepare the soil for planting and to incorporate soil amendments. This disturbance of the soil lays it bare and indirectly prepares a seedbed for weeds. Previously buried weed seed may break dormancy and grow. Whilst alleyways can be cultivated after tree planting, it is more difficult to control weeds within tree rows. This is a typical problem in newly planted orchards.

After planting, the use of cultivation equipment within tree rows is generally impractical (unless purpose-built equipment is available), and would likely damage apple tree roots.

Successive cultivations of the alleyways, are effective in killing weeds by bringing new seed to the surface and killing young seedlings, however this practise also damages soil structure and may cause erosion problems. As a rule, cultivation should only be used to achieve specific management goals such as the establishment of a new orchard block or the preparation of soil for sowing cover crops or permanent sod culture.

Cropping and crop rotations

It is good practice to grow green manure crops in rotation for a minimum of one year (ideally two or more years) before replanting apple trees. This is also an effective strategy for managing soil fertility and limiting weed growth. After cultivation, the area should be seeded heavily under favourable soil moisture conditions to encourage rapid establishment of the desired green manure crop. The aim is to smother weeds by creating too much competition from beneficial plants.

Normal orchard practice in Australia is to develop a permanent sod culture between the tree rows of the orchard. Generally this is a combination of a grass and a legume. This practice is beneficial because it provides a permanent soil cover which competes with and smothers weeds, improves infiltration of rain into the soil, and prevents soil erosion. Legumes also fix nitrogen in the soil which is subsequently available to the tree. Mowing of the grass/legume sward favours and encourages these species over many invasive woody weeds such as Fat Hen (*Chenopodium album*), Cobblers Peg (*Bidens pilosa*) and Stinking Roger (*Tagetes minuta*). Out competing weeds with more desirable species, and limiting the ability of weeds to set seed allows other management strategies, such as the addition of mulch along tree rows to become a more viable option for weed management.

Mulching

Approved mulching materials are applied to the soil in a layer thick enough (approximately 20 cm) to prevent weeds from growing. The advantages of mulching include weed suppression, retention of soil moisture and the protection of the soil surface from erosion. Other benefits include cooler soil temperatures which favour microbial activity, earthworms and apple tree root growth. In addition, the layer of mulch in direct contact with the soil breaks down, releasing a steady, longer term source of nutrients which can be exploited by the trees.

The National Standard for Organic and Bio-dynamic Produce specifically states that mulches used in organic production systems should be derived from natural materials, and not contain prohibited substances. Whilst materials that are sourced from certified suppliers are preferred, mulches from non certified sources can be also used (e.g. straw) if certain conditions are met. Specifically, the mulch must be applied to the soil surface and not directly incorporated into the soil. Documentation should be requested from the supplier to verify the chemical free status of the material being used as mulch.

Certain types of woven synthetic sheeting (weed matting) can also be laid onto the soil surface to suppress weeds. These types of material are difficult to apply to tree rows, and may tear easily. Trials on the Granite Belt with a woven weed matting product showed that the synthetic mulch was eventually overwhelmed by weeds which seeded on the surface of the mulch then took root through the material. The provision is made in the National Standard for Organic and Biodynamic Produce that such material should not be buried in the soil, and must be retrieved from the environment after use.

Thermal weeders

Thermal weeders are available commercially, and use steam generated by gas burners to apply heat (500°C) to plant tissue. The heat causes the cells in the plant to expand and burst, and the treated plants die back. One company has successfully used this equipment for weed control in vineyards. This method is very effective, however the machines are very expensive ($20,000 plus).

Flame weeding equipment works on a similar principle to steam equipment, but is not recommended due to the risk of setting fires and causing possible damage to irrigation lines and trees.

Integration and timing of farm operations to control weeds

Managing weeds rather than trying to eliminate them is the key to success in organic farming systems. This relies on knowledge of weed physiology and life cycles. Weeds can be managed by sequencing operations such as cultivation, cover cropping, mowing and mulching to reduce the number of weeds and their ability to set seed.

For example, repeated mowing close to the ground will encourage grasses to predominate over broadleaf plants. Grasses have a low growing point which will allow them to regenerate rapidly, whereas broad leaf plants cannot readily recover as their growing points are removed, and seed production cannot occur. A combination of mowing, with the planting of cover crops and/or the establishment of permanent sod in the inter-rows, changes the composition of the plant community growing between the tree rows in favour of beneficial plants such as legumes. Such strategies are employed as a long term approach to manage weeds, rather than eliminate them.

Other strategies

No organically acceptable herbicides are registered for commercial use in apple orchards at this time. One product based on pine oil (which is an allowed organic input) is registered for domestic purposes with the Australian Pesticides and Veterinary Medicines Authority.

4.6.5 Pruning and Training

A detailed description of the pruning and training of apple trees is not the province of this manual, and several excellent publications are available that comprehensively cover this topic. There are many different training systems for apple which are appropriate to all orchards, whether organic or conventional. These include 'vase' trees that were common in older wide-spaced orchards, 'free-standing central leader' trees which are particularly popular at medium planting densities (1000 – 1500 trees/hectare), and 'supported' trees grown at higher densities in systems such as Tatura trellis, slender spindle, vertical axis and 'V' trellis, to name a few.

Orchard design and planting density are two key issues that influence the pruning and training strategies subsequently used. The yield and fruit quality of apple orchards is largely dependent on the light interception by trees, and the distribution of this light within the tree canopies. Internal tree shading can reduce fruit bud development, yield, fruit size and colour. It is no longer adequate to produce high yields from your trees. It is essential that the apples you produce are of the high quality demanded by consumers.

When designing and planting an orchard, begin with the end in mind! Key factors to consider are:

- Trees should be planted in north-south rows wherever possible. North-south rows intercept more sunlight in summer than east-west rows, and have superior patterns of light distribution. The southern side of trees in east-west rows can become excessively shaded and yield poorly. This effect is worse in orchards with narrow alleyways, and as tree vigour and tree height increase. Sometimes it may not be possible to plant north-south rows due to topography or other factors.

- The most productive orchards in Australia have midseason light interception of 60%, with tree height approximately 3.0 metres.

- It is far more desirable and efficient to achieve 60% light interception by growing shorter (3.0 metre) trees in high density systems, than by growing more vigorous, taller (4.0 metre) trees.

- High density systems of 2500 trees/hectare using dwarf to semi-dwarf rootstocks are appropriate under Australian conditions. As tree density increases, it is important to produce significant crops of apples within three years of planting to quickly recoup establishment costs.

- The planting of high quality, well-feathered (branched) nursery trees is critical to obtaining high early returns from intensive apple plantings. Discuss your tree quality requirements with your nursery supplier.

- Trees should always be pruned and trained as discrete units, with a well-defined, unpruned leader to regulate the tree and maintain a balance between vegetative growth and fruiting wood.

- At higher tree densities, a trellis structure is essential to maintain tree structure and to support branches and heavy crops of apples.

- Tree size and shape influence disease management and the penetration of sprays into the canopy. Good air circulation within and between trees can significantly lower humidity and limit the development of disease symptoms and inoculum. This is especially important for apple scab management in organic apple orchards.

When dormant (winter) pruning young non-bearing trees, it is important to only make cuts if absolutely necessary. The objective is to encourage growth to fill the allotted space of each tree, and to produce crops within two to three years of planting. Heavy pruning reduces yields and sets the tree into a vegetative growth pattern, with excessive numbers of upright shoots. This especially occurs when more vigorous rootstocks are used.

Think carefully about any pruning cut you make on young trees, and always maintain a single upright growth as a dominant leader. The leader must always be the highest point of the tree. Cuts should only be necessary to remove side branches that are excessively vigorous and are not required, or to remove dead or diseased wood. Bending and tying of branches is far more preferable than making a pruning cut. Tying of branches and removal of newly-emerging shoots from unwanted sites on the tree can be done in early spring.

In the dormant pruning and training of mature trees, a balance of vegetative and fruiting wood is required. Aim for a high proportion of two, three and four-year-old fruiting spurs as these generally produce high quality fruit. Again, as with young trees, minimal pruning combined with branch bending and tying should be practised. Cuts should only be made if absolutely necessary to shape trees, remove unwanted growth or remove diseased wood. It may also be necessary to remove strong upright growths that are competing with the main leader of the tree. This can also be done in summer.

The response of trees to dormant pruning is highly dependent on rootstock. Too many cuts made to trees on vigorous rootstocks can lead to excessive regrowth and declines in yield and fruit quality. Mistakes made in excessively pruning trees on dwarf or semi-dwarf rootstocks are less expensive, as the trees have a greater tendency to produce fruit buds rather than vegetative growth. The trap with more dwarfing rootstocks is that trees may be cropped too heavily in their second and third years, effectively stunting them.

Summer pruning can be an effective tool to help control tree vigour, increase light penetration and improve the colour of apples in shaded parts of the tree. In Australia, seasonal shoot growth of apple trees predominantly occurs between petal fall (late September-mid October) and December, at which time fruit bud development for the following season's crop occurs. Removal of unwanted shoots during this period is less invigorating to the tree than if done in winter, and helps expose developing fruit buds to adequate light.

The removal of leaves affects the photosynthetic capability of the tree, so therefore needs to be done in moderation. Excessive summer pruning can potentially reduce fruit size. Removal of excess shoots (by secateurs or breaking out by hand) two to three weeks prior to harvest significantly aids fruit colour development, which is particularly important with bi-coloured apples such as Cripps Pink (Pink Lady™). Late-season leaf stripping is used by some growers as a rapid technique to improve light penetration to shaded apples within the canopy.

Of particular relevance to organic apple orchards, dormant pruning can be used as a strategy to remove excess fruit buds. This helps to reduce the time spent hand thinning fruitlets in the following spring. Care is required to ensure that in doing this, the vegetative/fruiting balance of the tree is not disturbed.

The comments on pruning and training are necessarily broad and general. The reader is encouraged to refer to specific texts on this topic, or to consult your local horticultural consultant for advice specific to your orchard.

4.6.6 Thinning

Apple trees are naturally biennial bearing, producing a heavy crop in one year followed by a lighter crop the next. Varieties differ in their tendency to biennial bearing. To improve fruit quality apple growers need to regulate the crop each season. Excess fruit can be removed by hand (hand thinning) or by using various chemical sprays at blossoming and in the few weeks following petal fall. Unfortunately, in organic production systems, the use of chemical thinners is prohibited. Apart from hand thinning, the only other viable period to adjust crop load is during winter (dormant) pruning, when excess fruit buds can be removed by the judicious use of pruning cuts. (see Pruning and Training above). The objective of fruit thinning is to achieve a consistent yield of fruit from one growing season to the next.

Five percent of flowers on an apple tree is sufficient to set an economic crop. Fruit thinning is a management tool to regulate the crop load as determined by the tree size and age. Excessive fruit set produces a heavy crop of small apples and may cause branches to break under the weight. In young trees, excessive fruit set causes tree stunting because the fruit and growing shoots compete for the tree's food resources. In contrast, too few fruit can also cause problems with fruit quality because the larger fruit grow too quickly and cannot absorb sufficient calcium leading to physiological disorders such as Bitter Pit. This particularly occurs on young trees being cropped for the first time.

Hand thinning should be done as early as possible during the fruit development period following petal fall. This will reduce competition between fruitlets, produce the desired fruit size, and maximise yield at harvest. The ideal timing is four to six weeks after petal fall. At this stage many of the weaker fruitlets (due to inadequate pollination) will start to shed. Staff employed for thinning work should always remember that the largest fruitlets on the tree at the time of thinning, will be the largest fruit at harvest (similarly, the small fruitlets will be the smallest fruit at harvest). For this reason, broad instructions to staff regarding spacing fruit evenly along branches may result in good quality fruit being thinned off and smaller fruit left on the tree. Larger apples, in clusters of two or three fruit, should be left in preference to evenly spaced smaller fruit.

Experienced thinners may thin trees by "eye" to what they consider is an appropriate crop load for each tree. A more precise approach to hand thinning is to count the number of fruit set on a sample of trees, then work out a desired crop load and the number of fruit to remove. Crop load may be determined based on the tree size. By measuring the tree girth, the trunk cross-sectional area (TCA) is calculated and the number of fruit per cm^2 of TCA determined. For example at a crop load of 5 fruit per cm^2 on a tree with TCA of $20cm^2$, 100 apples would be left on the tree and the remaining fruit thinned off. Similarly, 7 fruit/cm^2 TCA on a $20cm^2$ TCA tree would leave a desired crop load of 140 fruit. These techniques are used to visually demonstrate to staff the desired crop load and allow the fruit thinning to be more consistent throughout the orchard. Contact your local horticultural adviser for further information on this concept.

Conventional orchard management often utilises a variety of chemicals which thin flowers and fruitlets at various stages in their development. These chemicals include products such as plant growth regulators and insecticides. However, use of these "thinners" is not allowed in organic production. Lime sulphur sprays are an allowable input which may have a thinning effect on flowers. Unfortunately, the effect on crop load is not consistent, and excessive use of lime sulphur is not desirable. Apart from the judicious use of winter (dormant) pruning, hand thinning of apple fruit remains the preferred option for organic production systems.

4.6.7 Biodiversity

Biodiversity is a term quite often used in relation to organics, but its significance is often overlooked in horticultural and agricultural production systems. Broadly speaking, biodiversity is the extent of variety of species and populations in any given ecosystem(s) and includes plants, animals and micro-organisms.

Biodiversity may be considered at three levels:

- Genetic diversity – the spectrum of genes within a species (the gene pool). Different populations of the same species may have genes which are unique and not found elsewhere. Conservation of this genetic resource is important to both natural systems and agriculture.
- Species diversity – the variety of species living within a habitat or area. It is a recognised fact that natural systems support a large number of organisms which tend to be in balance and self-regulating.
- Ecosystem diversity – the variety of ecosystems found in one place. It is the interaction of a community of organisms within their physical environment. An ecosystem may be a large area of native bushland or as small as a waterhole or creek.

The National Standard for Organic and Bio-dynamic Produce recognises the importance of biodiversity in sustainable agriculture, and its impact on the environment. The general principles are outlined in section 3.3 "Landscape Management and Biodiversity", and are:

- establishing and/or retaining native vegetation on farm;
- managing rangelands, waterways, floodplains, rivers, streams and wetlands;
- provision of wind breaks and non-cultivated buffer zone areas.

The accompanying standards in section 3.3.1 and 3.3.2 specify that:

- Operators must include landscape management and biodiversity within organic/bio-dynamic management planning.
- Operators must develop 5% of their property as natural vegetation areas, grasslands or other reserves which are non-cultivated and non-intensively grazed within five years from the date the production unit attains in-conversion status.

The biodiversity principles and standards need to be addressed in the "Organic Management Plan" of the individual orchardist. This plan is developed as part of the orchardist's organic certification process.

5. Harvesting and Postharvest Handling

Certified organic producers have documented procedures to ensure that all produce can be traced back to where it was grown. This includes postharvest handling and storage. Where part of the farm is certified, it is necessary to keep this produce separate from non-certified produce grown elsewhere on the farm. Contamination and mixing of certified and non-certified produce is unacceptable. To avoid this situation, a documented system is necessary to track all produce from harvesting in the field, through packing and storage on farm to consignment to market. These systems are compatible with quality assurance schemes, and audited as part of the certification process.

Certified retailers and wholesalers have similar systems in place which allow the produce to be traced through the marketing chain to the consumer. The integrity of products labelled as "Certified Organic" or "In-conversion" is maintained as it can be traced at every step in the marketing chain.

6. Marketing and Price Premiums

Reported price premiums for organic produce vary greatly and may not necessarily reflect the returns obtained by producers. Australian Government figures (DAFF 2004) quote an average price premium of 31% for organic apples, based on retail survey data across Australia. The same source also quotes survey data which canvassed the willingness of Australian consumers to pay <u>any</u> price premium for organic food. It was found that 28% of consumers won't pay any premium at all, while a further 21% were unsure if they would pay a premium. From this it can be concluded that price may be a key factor in the purchasing decisions of nearly 50% of consumers when comparing organic produce with produce from conventional growers. Furthermore, the DAFF report also states that leading retailers believe that consumers will not pay price premiums for organic produce above 15%.

The expectation of most organic producers is that a sizeable premium will be realised for certified organic produce in comparison to mainstream market prices. Aside from the desire to make a good return on the orchard investment, the risks involved in organic production need to be factored into the expected returns. These risks range from fruit being downgraded due to pest and disease damage, to total crop loss from the failure of available management strategies to contain pest and disease outbreaks. This situation is further compounded by environmental risks such as hail or drought. These risks to production may affect the viability of growing apples organically in some districts.

Continuity of supply and seasonal variations in supply may affect the price received for organic apples. Fresh market fruit needs to be sold quickly, and small consignments of fruit are easier to sell on this basis. Can the market sustain premium prices for larger consignments of fruit? The answer is most probably no. This is supported by the retail survey data quoted by DAFF. Anecdotal evidence also suggests that some growers only market enough produce to sustain the premium prices, and consign the rest of their production through conventional market channels which sell the produce without the organic status.

For organic apple production to develop into a larger industry, high volumes of fruit are required to grow and sustain the market. Wholesalers and processors are important to the organic industry because of their ability to soak up peaks in production. Supermarket chains will only carry fruit if it is in sufficient quantity, and if there is guaranteed continuity of supply. Premiums for organic fruit would likely be less because of the reluctance of the retail chains and many consumers to pay for organic produce which is competing against mainstream alternatives.

Organic apple production carries a lot of production risks which need to be considered in assessing the viability of growing organic apples in a particular district. The costs of organic apple production are higher than conventional apple production, and this needs to be matched with a price premium if organic apple growing is to be viable. Many consumers and retailers may not be willing to pay a high premium, especially if from their point of view the only perceivable point of difference is the "certified organic" logo on the packaging.

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www.bfa.com.au
www.nasaa.com.au
www.organicfoodchain.com.au
www.organicgrowers.org.au
www.safefood.qld.gov.au

9. AQIS accredited certification organisations

Information kits and application forms can be accessed via the internet or by using the following contact details:

- Australian Certified Organic (ACO) The certification arm of the Biological Farmers of Australia (BFA). Address: PO Box 350, Chermside, QLD. 4032. Phone: 07 3350 5706. Fax: 07 3350 5996. Email: info@australianorganic.com.au. Web addresses: www.australianorganic.com.au and www.bfa.com.au
- Biodynamic Research Institute (Demeter). Address: Powelltown, Vic. 3797. Phone: 03 5966 7433. Fax: 03 5966 7433.
- National Association for Sustainable Agriculture (Australia) Ltd. (NASAA). Address: PO Box 768, Stirling, SA 5152. Phone: 08 8370 8455. Fax: 08 8370 8381. Email: enquiries@nasaa.com.au Web Address: www.nasaa.com.au
- Organic Food Chain (OFC). Address: PO Box 2390, Toowoomba, Qld. 4350. Phone: 07 4637 2600. Fax: 07 4696 7689. Email: ofc@organicfoodchain.com.au Web Address: www.organicfoodchain.com.au
- Organic Growers of Australia (OGA). Address: PO Box 6171, South Lismore, NSW 2480. Phone: 02 6622 0100. Fax: 02 6622 0900. Email: oga@nrg.com.au Web Address: www.organicgrowers.org.au .
- Safe Food Queensland (SFQ). Address: PO Box 440, Spring Hill, Qld. 4004. Phone: 1800 300815. Email: info@safefood.qld.gov.au Web Address: www.safefood.qld.gov.au .
- Tasmanian Organic-Dynamic Producers (TOP). Address: PO Box 434, Mowbray Heights, TAS. 7248. Phone: 03 6266 0330. tas_organicdynamic@yahoo.com