Second edition

Department of **Employment, Economic Development and Innovation**

The passionfruit growing guide

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Passionfruit Australia Inc

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Know-how for Horticulture™

Queensland Government

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Contents

About this guide

This edition of *The passionfruit growing guide* is a substantial update of the first edition, which was published in 2006. Each chapter deals with a specific aspect of the development and management of a passionfruit plantation. The reverse of each chapter title page provides a detailed list of the contents of that chapter.

This guide has been written for prospective, new and established growers; it addresses all aspects of passionfruit growing, from site selection and planning through to harvesting and marketing the fruit. It provides practical advice on propagation, fertilising, irrigation, and pest and disease control. Also, it includes information on varieties of passionfruit, plantation budgeting, chemicals registered for use on passionfruit and useful contacts.

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- Primary authors: Peter Rigden and Simon Newett (former Department of Primary Industries and Fisheries, Queensland)
- Contributing authors: David Peasley (Peasley Horticultural Services); Jay Anderson, Jeff Daniells and Ken Pegg, (former Department of Primary Industries and Fisheries, Queensland); John Dirou (New South Wales Department of Primary Industries); Ian Constable, Jeff Hornery, Scott Maltby and Keith Paxton (grower members of the former Australian Passionfruit Industry Association executive).

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Understanding the passionfruit plant

Chapter 1

The aim of passionfruit growing is to produce high-yielding crops of good-quality fruit and to do so profitably and sustainably. To achieve this, the grower needs a good basic knowledge of the plant, how it grows and what governs fruit production and quality. These topics are covered in this chapter:

Passionfruit terminology and parts of the plant

The following description of the parts of the passionfruit plant refers to the purple varieties and Panama selections that are grown commercially in Australia. The terms used to describe the main parts of the plant are shown in Figure 1.1.

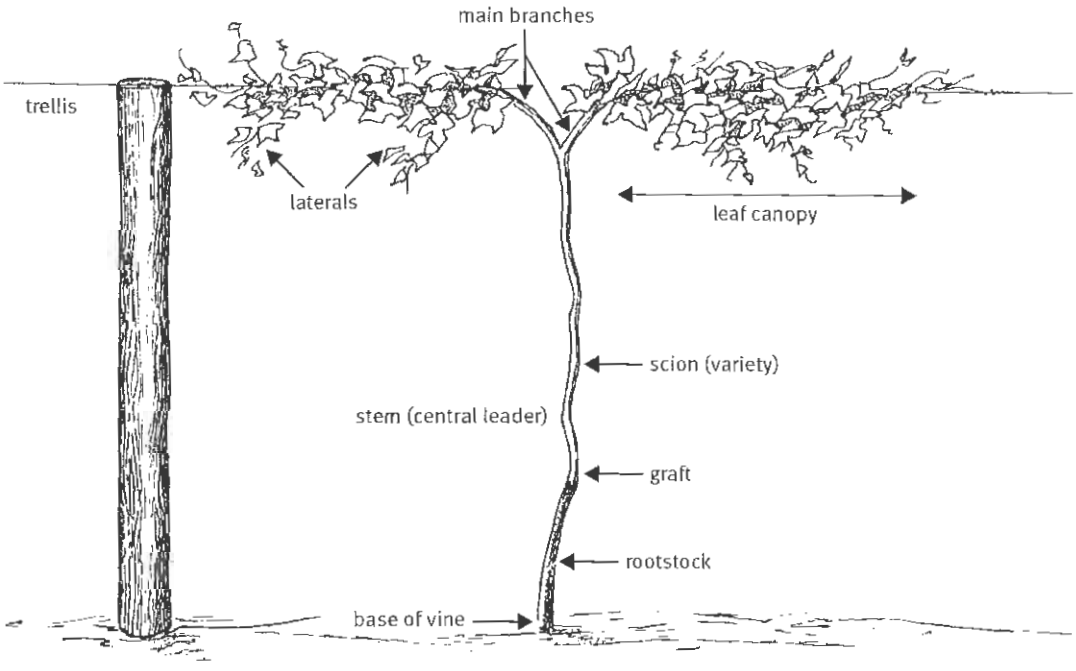


Figure 1.1 Passionfruit terms used in this guide

Vegetative growth

The passionfruit is an evergreen, semi-woody perennial vine with medium to large, single or three-lobed leaves that are 8 to 10 centimetres long. In suitable conditions, vines grow very vigorously using spiralling, unbranched tendrils produced in the leaf axils to climb over and along trellises (see Figures 1.1 and 1.2).

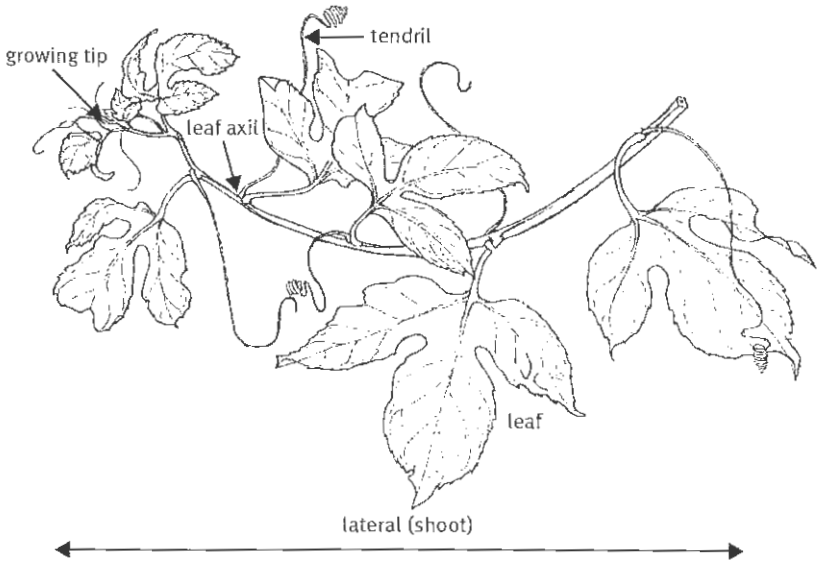


Figure 1.2 Vegetative growth of the passionfruit

Flowers

Passionfruit flowers are bisexual. They are large (4 to 5 centimetres in diameter) and each flower has five sepals, five petals, five well-developed stamens and a three-part style in the centre (see Figure 1.3). The flowers are particularly showy and have two rows of threadlike rays (called a corolla), which are purplish at the base and whitish towards the tip. The solitary flowers are borne in the leaf axils of new growth.

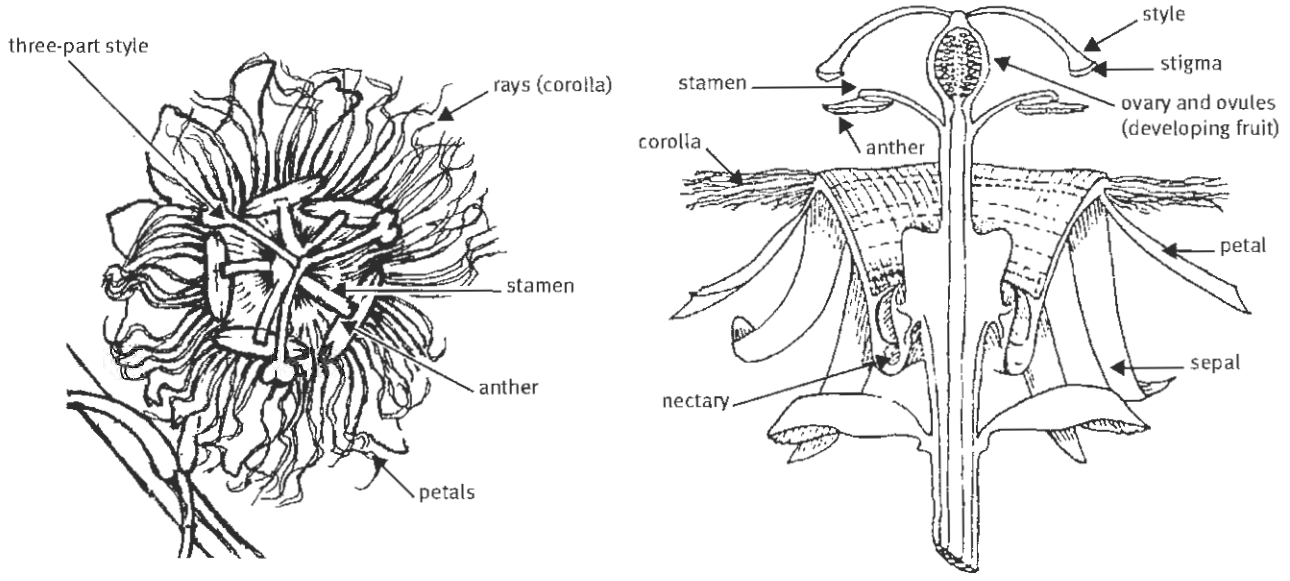


Figure 1.3 The passionfruit flower: normal appearance (left) and diagrammatic cross-section (right)

Fruit

The fruit are round to oval, are 7 to 10 centimetres in diameter and have a leathery rind. The skin colour ranges from red through to dark purple and on Panama selections may also be speckled in appearance, with white flecks. Depending upon the variety, the pulp colour varies from yellow to orange-red; it is sweet, aromatic, juicy and contains small brown or black edible seeds (see Figure 1.4).

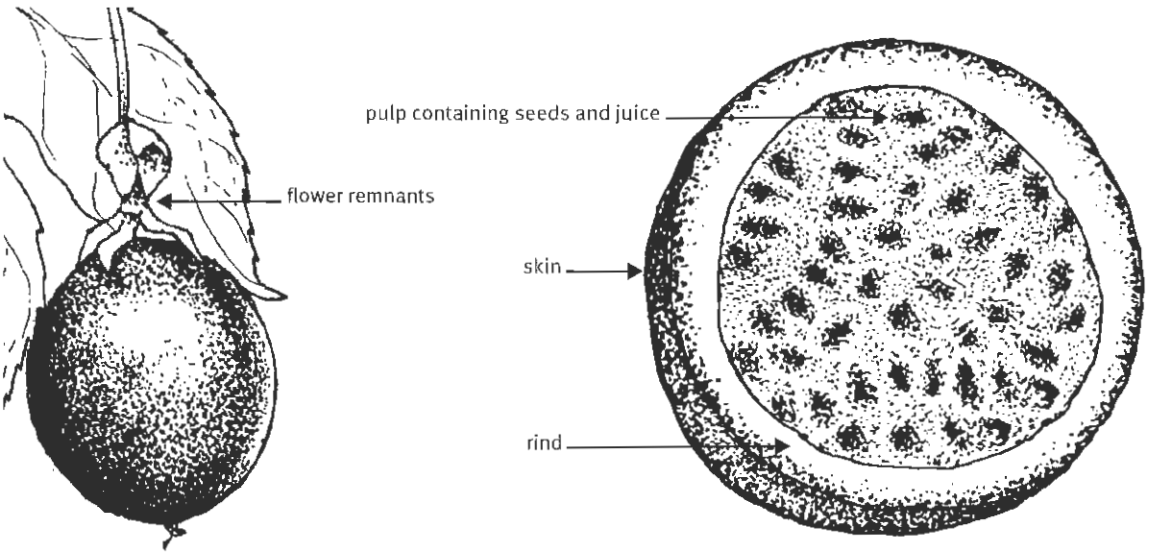


Figure 1.4 Fruit of the passionfruit

Passionfruit species and varieties grown in Australia

Passionfruit belong to a very large plant family known as Passifloraceae, which includes about 550 species. The most important genus (group of related species) of this family is *Passiflora*, which contains about 400 species. Only about 10 of these species are cultivated commercially. In most countries, passionfruit production is based on selections of the golden passionfruit, *Passiflora edulis* forma *flavicarpa*, which grows best in tropical climates.

In tropical Australia, growers commonly cultivate various selections of the golden passionfruit; these are generally referred to as the Panama selections. Most of the Panama selections grown commercially are purple or reddish in colour; the yellow or gold-coloured variants are not currently suitable for the Australian market.

In subtropical regions, a large proportion of the Australian passionfruit industry is based on growing varieties produced by crossing the golden passionfruit, *P. edulis* f. *flavicarpa*, with the black passionfruit, *Passiflora edulis* forma *edulis*, a temperate climate species. These varieties, originally selected for their dark skin, are commonly referred to as purple varieties because of their dark purple skin colour. These crosses are more tolerant of cooler conditions in winter and are more suited to subtropical climates than the Panama selections are, though some Panama selections can be grown successfully on some sites in subtropical regions.

In cooler regions of Australia with temperate climates, passionfruit is not grown as a commercial crop on any significant scale, but black passionfruit varieties can be grown successfully in domestic gardens.

Other species of passionfruit grown in Australia (but not commercially significant) are:

- *P. alata*—fragrant granadilla or winged-stem passion flower
- *P. antiquiensis*—similar to *P. mollissima*
- *P. laurifolia*—yellow granadilla or bell apple
- *P. lingularis*—sweet granadilla
- *P. maliformis*—sweet calabash or hard-shell passionfruit
- *P. mollissima*—banana passionfruit
- *P. quadrangularis*—giant granadilla

The following species are also found in Australia but do not produce edible fruit:

- *P. caerulea*—blue passionfruit
- *P. incarnata*—vine apricot, wild passionfruit or May pop

The annual cycle of the passionfruit plant

The phenology (growth pattern) of passionfruit can vary significantly depending upon the environment and management. The following information, based on observations made in the Nambour area of south-eastern Queensland (which has a coastal subtropical climate), illustrates the general trends.

Vegetative growth

In the tropical and subtropical areas (where most passionfruit is grown), vegetative growth is continuous throughout the year, though it slows considerably during July and August in cooler districts. There is a peak of vegetative growth in September to October and another in February to March. There is often a slight lull in growth in December, coinciding with the summer peak of fruit production.

Root growth

Like vegetative growth, root growth is continuous throughout the year but in cooler areas slows during the height of winter. However, there is a noticeable flush of root growth in May to June. This is presumably initiated by the winter slowdown in leaf growth and probably involves relocation of carbohydrate reserves from wood and leaves to the roots to condition the plant for winter.

Flowering and pollination

Flowers are produced in leaf axils. Flowering generally follows the cycle of vegetative growth but is tempered by variety and climate. If there is no vegetative growth, no flowers will be produced by the plant.

The commonly grown purple varieties generally have two flowering peaks, one in early spring (September to October) and the other in autumn (about February to April). In the cooler areas, there is almost no flowering during the cooler winter months (July to August) and a slight drop in flowering in December, coinciding with the summer peak of fruit production. The precise flowering pattern of a variety depends very much on the environment and can vary considerably.

Flower buds generally take about 30 to 40 days to develop from initiation to the open flower stage. In black passionfruit, flowers open at dawn and essentially close before dawn on the following day. In golden passionfruit, flowers open at around midday and close at night on the same day. The purple varieties, being intermediate between the black and golden passionfruit, vary within this range but generally follow the cycle of the black passionfruit more closely.

Flowers of the purple varieties are self-compatible (can be fertilised by their own pollen) and set good crops without cross-pollination from another variety.

Flowers of the golden passionfruit are self-incompatible and so cannot be fertilised by their own pollen. However, because Panama selections such as Panama Red, Pandora and McGuffies Red are not pure *P. edulis* f. *flavicarpa* (they probably have some *P. edulis* f. *edulis* parentage), they have enough variability to be self-compatible.

Insects, particularly honey bees, are the main pollinators. The flowers are attractive to bees, having good nectar, a high sugar content and heavy, sticky pollen. Beehives are not normally used or needed in passionfruit plantations because many feral bees and other pollinators (such as flies and native bees) are active in passionfruit plantations.

Pollination needs to occur during the relatively short period of flower opening. Several factors may lead to either poor pollination or a complete failure of pollination:

- The stigmas are unreceptive for some of this period and the pollen may be shed late in the flowering period, when the stigmas are no longer receptive.
- Periods of rain or misty weather can cause the pollen to swell and rupture when it becomes wet, rendering it unviable.
- Bees are not active during wet weather and so do not visit open flowers.
- The passionfruit flower is very attractive to bees and they can strip flowers of pollen before the stigmas become receptive.
- The anthers and the receptive stigma are separated by some distance, which can inhibit pollination, especially by smaller insects visiting the flowers.
- Temperatures above 38 °C and low humidity can lead to very poor or no fruit set. Growers have observed that low humidity is more of a problem in the Panama selections than in the purple varieties.
- Boron deficiency, which results in poor pollen tube growth, can cause poor fruit set.
- Excessive nitrogen can promote vegetative growth at the expense of fruit set.

Fruit development

After pollination and fruit set, it takes from 60 to 90 days for the fruit to develop and mature. Maximum growth, mainly of the fruit skin, rind and seeds, is in the first 20 days. Juice develops late in the period, just before maturity.

The cycle of fruit production follows those of vegetative growth and flowering. After several fruit have set, the growth and flowering of a shoot or branch slows (or may cease) and only resumes when the first fruit set begin to mature. Generally about 9 fruit are set per branch, but in young, vigorous, healthy plants, there can be 20 or more. This stop-start effect is thought to result from either competition for carbohydrates between developing fruit and vegetative growth, or a translocation of growth inhibitors from the developing fruit to the shoots.

In purple varieties, there is a major peak of fruit production in midsummer (December to January) following the major peaks of growth and flowering in September to October. There are generally two smaller peaks of fruit production, one in about March to April and the other in about June to July. Fruit production is generally poor in October and November (a consequence of little or no flowering in winter) and May (due to the slight lull in growth and flowering during the summer production peak). The cropping pattern of a variety can vary considerably depending on where it is grown because of environmental factors.

Fruit production cycles of the golden passionfruit and the black passionfruit differ from those of the purple varieties. The golden passionfruit has a single extended cropping season from late summer through autumn and into early winter. The black passionfruit produces a heavy continuous summer crop and virtually no winter crop.

Composition of fruit

Analysis of passionfruit pulp has provided the nutritional data in Table 1.1. This is only a general guide; composition will vary depending upon the variety and growing conditions. Pulp usually makes up 40% to 50% of the total fruit weight.

Table 1.1 A nutritional analysis of passionfruit pulp

Category	Content per 100 g of pulp	Category	Content per 100 g of pulp
Water	74.4 g	Vitamin C	18 mg
Energy	194 kJ	Thiamine	0.03 mg
Protein	3.0 g	Riboflavin	0.14 mg
Fat	0.3 g	Niacin	2.5 mg
Glucose	2.3 g	Carotene	0.75 mg
Fructose	1.9 g	Potassium	200 mg
Sucrose	1.5 g	Sodium	19 mg
Starch	0 g	Calcium	10 mg
Dietary fibre	13.9 g	Magnesium	28 mg
Malic acid	0.48 g	Iron	0.6 mg
Citric acid	3.5 g	Zinc	0.8 mg

Source: Dr Ron Willis, University of NSW, *Food Technology in Australia* vol. 39 (11), November 1987

Environmental effects on growth and flowering

Vegetative growth and flowering can be influenced by several environmental factors: temperature, sunlight, wind, humidity and soil water.

Temperature

Temperatures above 30 °C promote strong vegetative growth but inhibit flowering. Where the odd flower is produced, fruit will not set because pollen germination is also inhibited. Temperatures below 15 °C reduce vegetative growth and flowering. Where flowers are produced in cool conditions, fruit set is poor because pollen germination is reduced significantly at temperatures below 20 °C. Cooler temperatures also increase the severity of passionfruit woodiness virus. The best production comes from temperatures between about 20 °C and 25 °C, where there is an effective compromise between excessive vegetative growth and flowering, and where pollen germination is favoured. Effects of temperature on vegetative growth and flowering are illustrated in Figure 1.5.

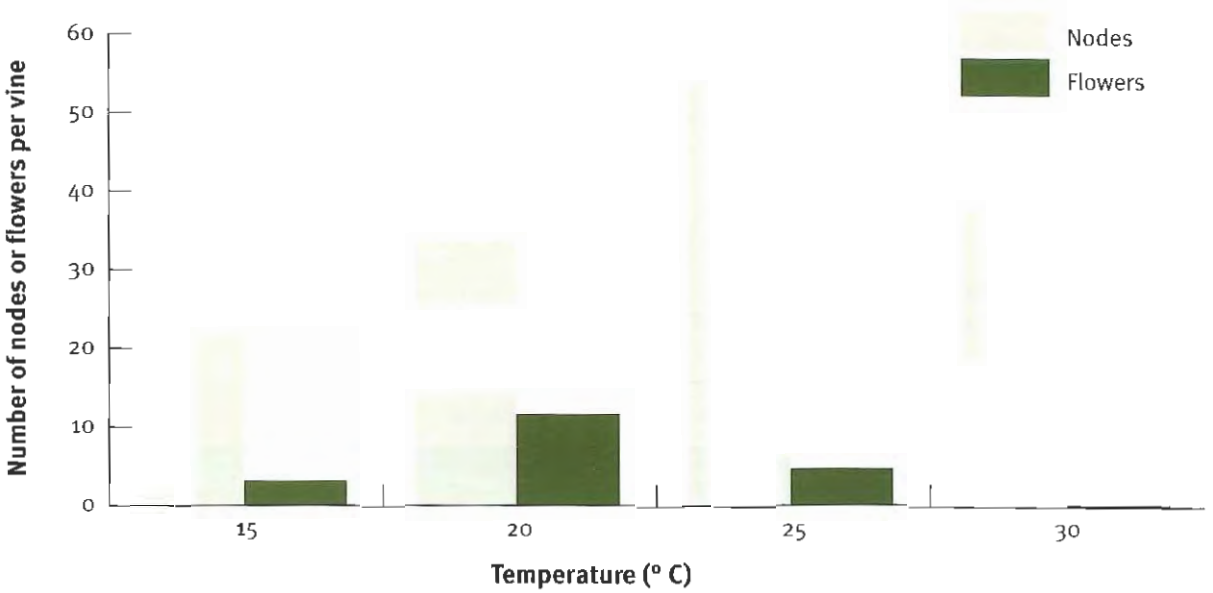


Figure 1.5 Effects of temperature on vegetative growth and flowering

Sunlight

Where plants are shaded, for example from windbreaks, strong vegetative growth may still occur (though it may be etiolated), but flowering is inhibited. A milder effect may also appear under prolonged overcast weather. In some cases, fruit may drop. The effect of sunlight on flowering is illustrated in Figure 1.6. Note that solar radiation in the subtropics on a sunny day in summer is about 25 megajoules per square metre per day. On a sunny day in winter, it is 12 megajoules per square metre per day. In overcast conditions, solar radiation reduces to about 10% of these values.

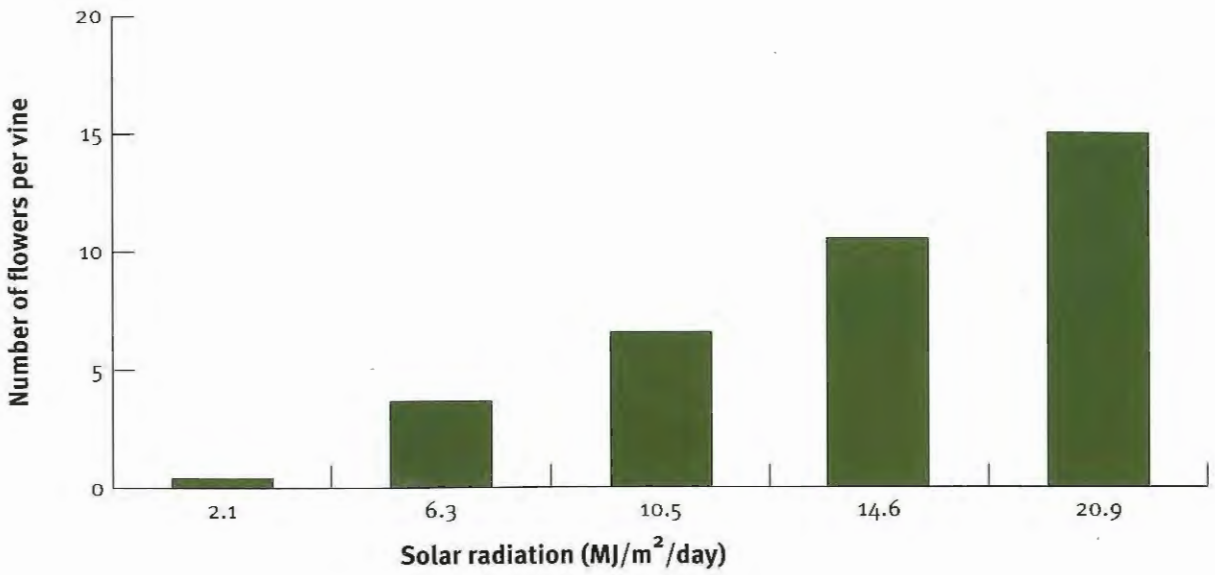


Figure 1.6 The effect of sunlight on flowering

Wind

Passionfruit plants are very sensitive to wind. Cold winds reduce vegetative growth and vigour and increase the impact of passionfruit woodiness virus. Hot, dry winds dehydrate the flowers, reducing pollination.

Humidity

Free water from rain or mist that comes into contact with the flowers causes the pollen grains to burst, reducing pollination. Low humidity from wind dehydrates the flowers, also reducing pollination.

Soil water

Water stress reduces vegetative growth and flowering (see Figure 1.7). It also leads to smaller fruit with reduced pulp and increases the amount of fruit drop.

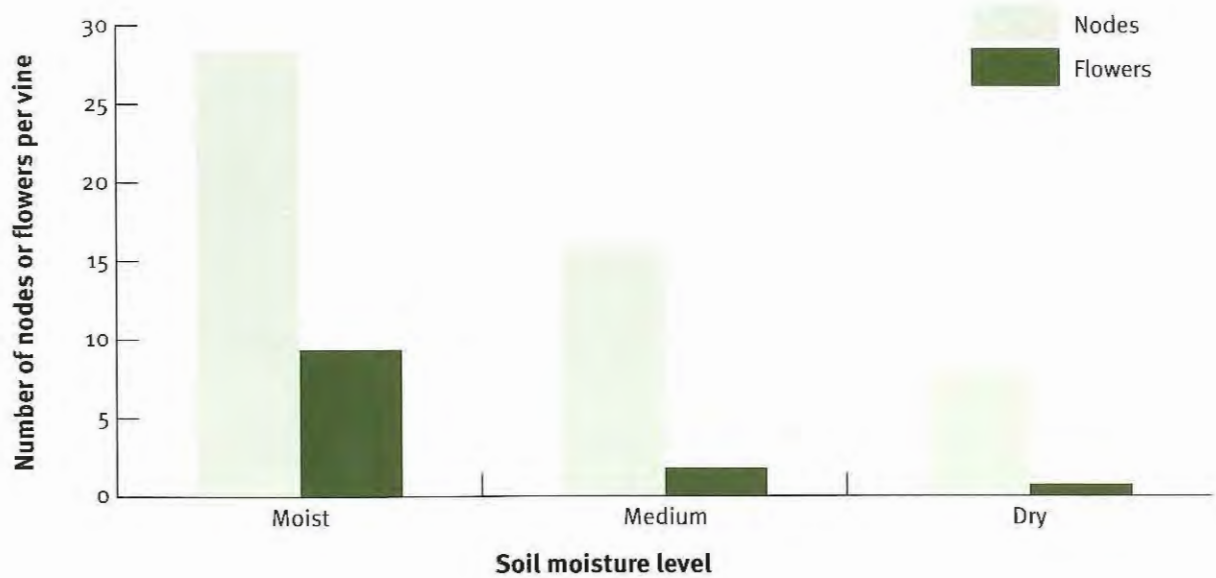


Figure 1.7 Effects of soil water on vegetative growth and flowering

Implications for crop management

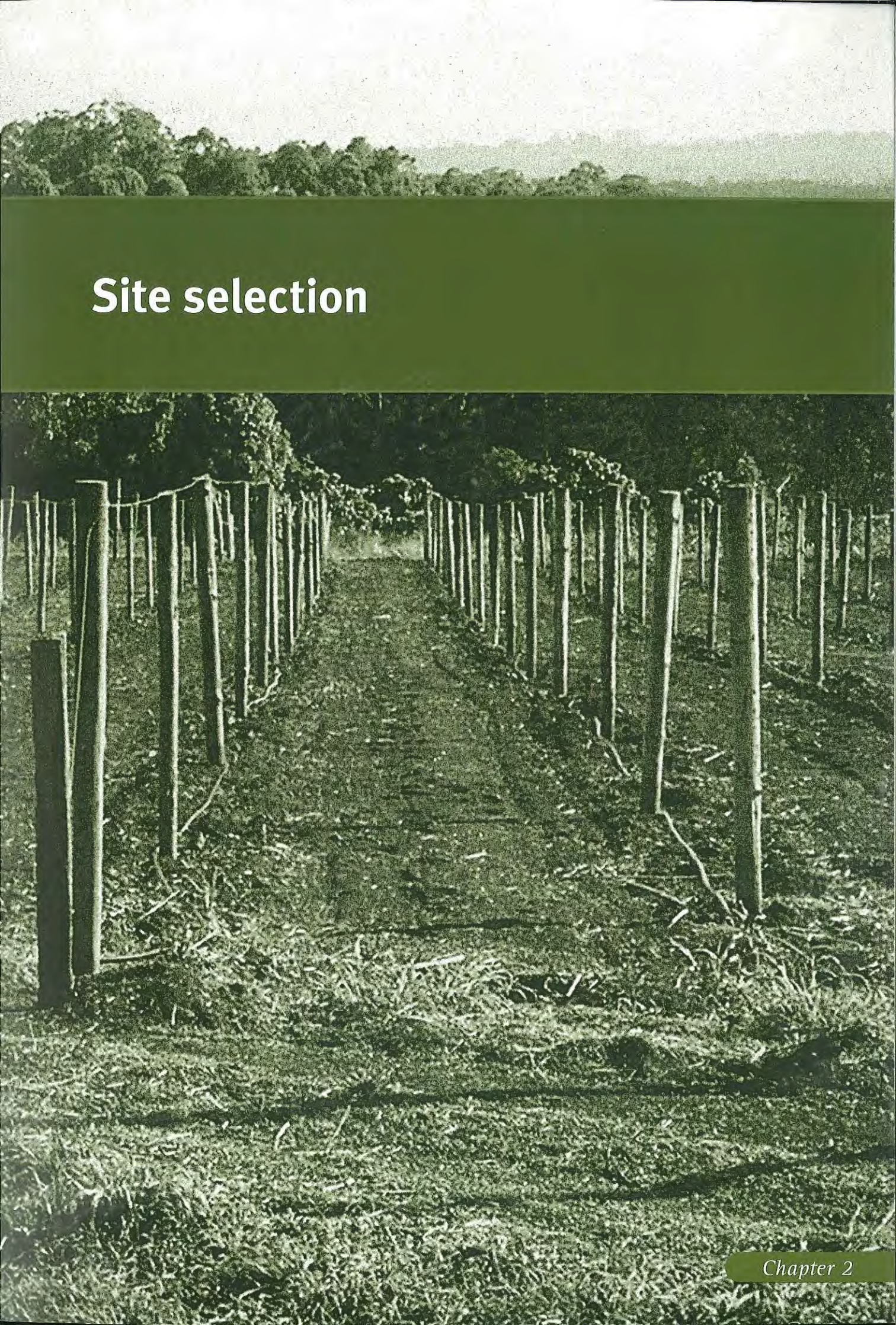
Since flowers are initiated in the leaf axils of new shoots, fruitfulness in passionfruit depends initially on the rate of vegetative growth. The best potential production comes when there is active vegetative growth for most or all of the year. The first aim of crop management is to minimise, where possible, any factor that slows or stops vegetative growth. The second aim is then to minimise, where possible, any factor that reduces the flowering and fruit set on that vegetative growth.

To achieve the desired fruit production times (which are generally when markets are favourable), growers need to understand the optimum growing conditions.

The important management issues are:

- Select the warmest site to maximise the amount of time vines are exposed to favourable temperatures (within the range 20 °C to 25 °C).
- Ensure that vines are not shaded by windbreaks or other trees, particularly during winter. Where possible, run rows in a north–south direction to maximise the area of vines exposed to sunlight.
- Provide sufficient wind protection to avoid vine stress, wind damage and dehydration.
- Avoid using overhead irrigation. This will prevent damage to pollen by irrigation water.
- Start with healthy vines propagated using scion material taken from vines that are free from virus symptoms, true to type and grafted onto a rootstock that is resistant to fusarium wilt.
- Ensure the vines get the best start by carefully preparing the planting site and using good planting techniques.
- Provide optimum conditions for vine growth by supplying adequate fertiliser; maintaining adequate soil moisture; controlling weeds, diseases and pests; and mulching to create a better root environment.

Site selection



Chapter 2

Passionfruit plants are very sensitive to environmental stress and so the choice of site is very important. The passionfruit plant is not hardy and in its natural rainforest environment it is protected from environmental extremes. Passionfruit grown on an unsuitable site will give a lower yield at higher cost than passionfruit grown on a favourable site. Unsuitable sites will definitely reduce profits and could even result in a financial loss. Careful site selection is essential and should take into account the following factors:

Growing regions

In Australia, commercial passionfruit is grown mainly in regions with tropical or subtropical climates. There is limited production in the temperate regions of Western Australia (see Figure 2.1).

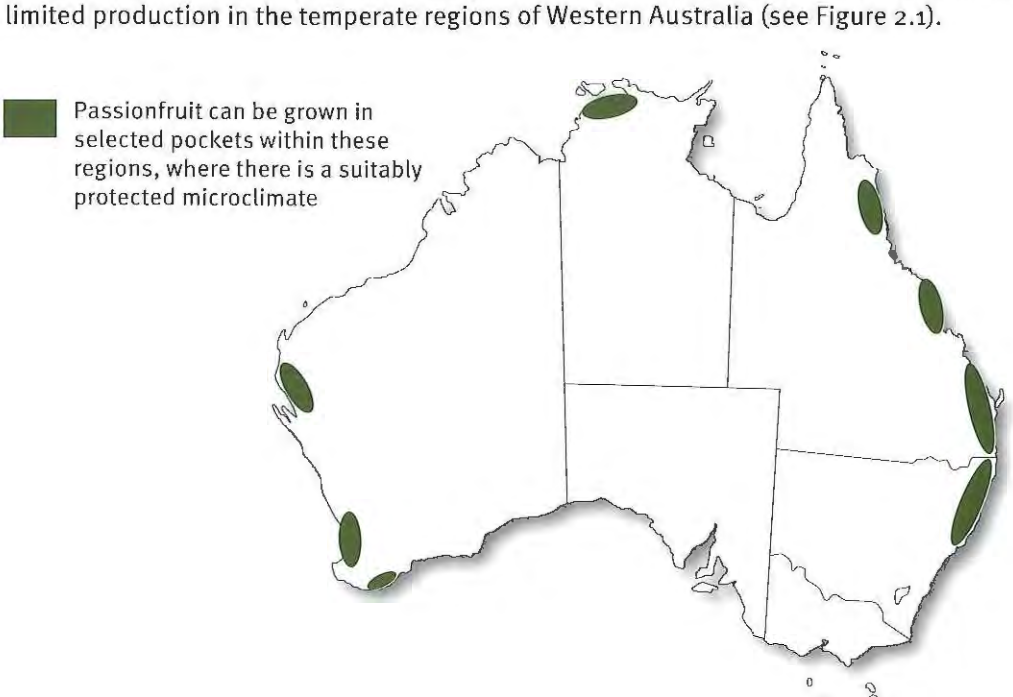


Figure 2.1 Passionfruit-growing regions in Australia

Soil

Passionfruit can grow and crop successfully on a range of soils. They have poor tolerance to salinity and to extremes of pH; the optimum pH range is 5.5 to 6.5 using the 1:5 soil:water pH test. They can be grown on infertile soils with reasonable soil structure, although the yields are reduced if inadequate amounts of fertiliser are applied.

Passionfruit plants are susceptible to a number of root diseases that are associated with wet soil and do best in well-drained, fertile, loamy soils. On shallow or heavy-textured soils, they are best planted on mounds, as this helps to improve soil depth and surface drainage. Soil with poor internal drainage is difficult to improve without laying drainage pipes, which can be costly.

The best soils for passionfruit are free-draining with no heavy clay or rock shelves within half a metre of the surface.

Soils to avoid are:

- heavy clay soils, because they restrict root development and favour root diseases
- rocky soils, because they damage machinery, make vehicle access difficult and contain stones that can be flicked up by slashers and injure vines (which leads to disease problems)
- very light, sandy soils, because they have low water-holding capacity and poor retention of nutrients; however, this type of soil is used successfully in Western Australia with specialised management
- poorly drained and shallow soils, because they restrict growth and may lead to vine death
- soils in areas that flood.

Slope

As a general rule, select level to gently sloping ground. Gentle slopes allow excess water to drain away safely without causing water logging or soil erosion. A moderate slope that allows cold air to drain away can be an advantage in regions where frost is a potential problem. Cost of production increases as slope increases and on very steep slopes the extra expense can be prohibitive.

Slopes of less than 15% are preferred for safe machinery operation and to allow a wider range of options for farm layout, row direction and control of soil erosion. They allow easier all-weather access to the crop, which is vital for harvesting and pest and disease control. All sloping land will require some erosion control.

Clearing steep slopes for cultivation is not permitted in some regions of Australia, so check with local authorities, councils and the state government agency responsible for land clearing.

Aspect

A protected situation is very important. It will provide a suitable growing environment, reduce fruit skin marking from wind ruh and allow better pest and disease control. Slopes facing away from prevailing winds are preferred, and these are generally north or north-east facing in eastern Australia. These sites generally maximise sunlight, are warmer and are better protected from the damaging winds from the south and west.

In Western Australia, protection is needed from hot, dry easterly winds in summer on inland sites and from cold south-westerly winds in winter on coastal sites.

Row orientation and length

Site features such as slope or a narrow block shape may limit row orientation options. In the subtropics, sites with rows running north–south allow the greatest interception of sunlight and provide better shade protection for fallen fruit. Where rows run east–west, sunburn damage to mature fruit that has fallen onto the ground between the rows is high, especially in summer. Where vines are grown on pergolas, alignment of row direction is not important, since the vines will form a complete canopy over the pergolas, protecting the fruit from sunburn.

Long rows improve machinery efficiency and decrease costs, but breaks in long rows about every 50 metres are needed to allow efficient collection of harvested fruit.

In tropical regions, sunburn damage to fruit hanging on vines on rows running north–south can be severe, especially on the western side of the trellis. In these regions, aligning rows east–west helps to prevent sunburn and to reduce soil temperatures under the vine. The use of pergolas, A-frame trellises and T-bar trellises helps to alleviate sunburn damage. (See Chapter 6 for more details of these structures.)

Climate

Passionfruit are adapted to tropical and subtropical areas with good rainfall. However, for commercial fruit production there are disadvantages where wet and humid conditions prevail. These conditions will promote fungal leaf and fruit diseases and reduce the effectiveness of the fungicides. In addition, rain or mist at flowering can rupture pollen grains, reducing pollen viability and fruit set.

Extreme temperatures and/or low humidity will affect fruit set. Temperatures below 15 °C restrict growth and flowering; they also exacerbate the effects of passionfruit woodiness virus. Temperatures above 30 °C promote strong vegetative growth but inhibit flowering. Pollen germination is reduced significantly at temperatures above 30 °C and below 20 °C. At temperatures above 38 °C, the fruit of purple varieties will not set and their flowers may drop off. The best production comes with temperatures between about 20 °C and 25 °C. This is because there is an effective compromise between excessive vegetative growth and flowering, and pollen germination is favoured.

Traditionally, the purple varieties have been best suited to subtropical climates while Panama selections have been better suited to tropical climates. However, new variety selections have wider geographic bases, and it may be possible to grow a mix of purple varieties and Panamas in many areas.

During hot, dry weather, no buds are formed, but after summer rain a lot of buds will quickly appear. This results in troughs and peaks in fruit production.

Sites need to be frost-free and sheltered from wind. Purple varieties may not be killed by a light frost, but they will lose their leaves and subsequent yields will be reduced. Panama selections are more susceptible to frost than purple varieties are and can easily be killed by a light frost.

Where plants are shaded, for example by windbreaks, strong vegetative growth may still occur but flowering is inhibited. A milder effect may also appear under prolonged overcast weather. In some cases, there may be excessive fruit drop.

Shelter and wind protection

Protection from damaging winds is essential. The natural habitat of passionfruit is the rainforest, a very sheltered environment. Cultivated passionfruit will not thrive on exposed sites.

Wind can reduce vegetative growth, flowering and fruit set. It can also increase the severity of passionfruit woodiness virus. Wind exposure causes stress that significantly reduces the vigour of plants; this can reduce yield and quality and make the plants more susceptible to pests and diseases. In addition, movement of fruit in the wind against leaves, vines and trellises causes rub marks on fruit, rendering them unsuitable for the fresh market. Wind also increases evaporation, resulting in a greater irrigation need. Unprotected plantations have less flexibility in spray application, and sprays are more subject to drift.

Wind protection can be offered by natural stands of timber, but planting of dedicated windbreaks is recommended where natural windbreaks are absent. Artificial windbreak structures can be effective and will not compete for water and nutrients but are expensive to construct. (See Chapter 4 for detailed information on windbreaks.)

Water supply

Irrigation is essential if high-quality fruit is to be produced. In coastal areas with good summer rainfall, a water reserve of 3 to 5 megalitres* per hectare of plantation is necessary to maintain production, depending upon rainfall. In the very hot, dry summers of southern Western Australia, 10 to 15 megalitres of irrigation water per hectare may be needed. As passionfruit is very sensitive to salt, water salinity should not exceed a conductivity of 800 microsiemens per centimetre (µS/cm).

Check that you have access to enough good-quality irrigation water. As a general rule, two years supply is regarded as the minimum level for maintaining a crop throughout periods of drought.

Check with your local council and state water authorities regarding any licensing needed and/or fees payable for harvesting irrigation water in your area.

Proximity to markets and transport

Carefully consider the location of the site in relation to your expected main markets, the cost of freight to these markets and the distance to the nearest transport depot. Freight companies do not necessarily pick up at the farm gate and there is usually a minimum consignment if they do. Many growers have to deliver to the nearest transport depot, which may require time-consuming and relatively expensive trips in the farm vehicle.

If a fruit-processing outlet is nearby, some income can be derived from fruit that is not suitable for the fresh market. On average, about 30% of the crop is unsuitable for the fresh fruit market. Processors pay around $1.00 per kilogram of fruit, so freight cost will be a crucial factor in the determining the viability of this market. Check with processors to discuss prices and to see if they offer freight assistance.

* 1 megalitre = 1 000 000 litres

Labour availability

Passionfruit vines require regular attention throughout the year. Vines cannot be left to fend for themselves for any length of time and most of the work needed to care for them requires significant manual labour. Some important points are:

- The maximum area that two people can look after for most of the year is about 3 hectares, and even then extra help will be needed for harvesting in peak periods. (This is only a guide, and significant variations can arise from differences between sites.)
- During summer, harvesting of purple varieties needs to be done once every day for single-wire trellises, and in some situations, twice or even three times per day. This is needed to avoid sunburn damage to mature fruit that has fallen to the ground.
- It can be difficult to find suitable employees who are happy to work the short hours and make the early morning starts that are needed to avoid sunburn injury to fruit.
- Growers and employees must be physically fit to do the work required in a passionfruit plantation.

Native vegetation

Clearing of native vegetation is regulated in some regions of Australia, so check with the local authorities, councils and state government agencies responsible for land clearing in your state.

Social and environmental issues

Be aware that society places many environmental demands on growers. Some are legally enforced, while others are simply community expectations. Consider the following:

- Generally, people are suspicious of any spraying activity that takes place on a farm, even when the spraying is legal and justified. Some growers find that their businesses are significantly affected by neighbours' concerns.
- Check with state and local authorities regarding the need for irrigation licences and their availability.
- Chemical users certification may be required to purchase, transport and use chemicals in some areas.
- Check with local councils for restrictions on land use and zoning.
- Where plantations are bordered by creeks, rivers and other watercourses, appropriate management strategies are needed to avoid environmental impact problems. These can arise from, for example, shed waste (disposal of fruit not suitable for the market), soil run-off, chemical spray drift and nutrients leaching into drainage water.
- Plantations that are close to rainforests and national parks may present management problems, such as damage to vines by pests. Pests that are usually problems near scrub or forest areas are wallabies and other protected native mammals; cockatoos; feral animals (such as pigs and rats); and insect pests such as fruitspotting bugs. Some of these animals can and will destroy vines.

Planning and layout

Planning is probably one of the most important steps in ensuring the long-term profitability and stability of your plantation. Good planning will save time and effort over the whole life of the plantation; this is because plantation layout can affect land degradation and subsequently vine health, soil fertility and ease of access. Mistakes made at the establishment stage are difficult and costly, if not impossible, to correct. Here are the things you need to consider:

Overleaf: General layout and run-off control plan for a plantation on steeper slopes (Courtesy of NRM Facts: Erosion control for bananas)

Planning plantation layout

Consider *all* of the following when planning the layout of your plantation.

The best site

The location of the plantation should suit the needs of the passionfruit plant; do not rely on planning and management to offset poor location. Chapter 2 covers the critical aspects of this topic.

A planning map

Prepare a map of the farm showing the intended plantation site and mark on it existing features such as roadways, standing timber, watercourses and slope direction. On the map develop a plan showing access roads, buildings, windbreaks, vine rows, surface drains to control run-off, erosion-control structures, water-harvesting and storage structures (dam sites), irrigation systems and so on. An example of this type of plan is shown on page 17.

Table 3.1 lists a number of fact sheets on property planning that are available from the Queensland Department of Environment and Resource Management (DERM). Visit their website at www.derm.qld.gov.au to obtain these sheets.

Table 3.1 DERM fact sheets related to property mapping and planning

Fact sheet	Topic
L70	A guide to property mapping
L71	Choosing a property map
L72	Property mapping—useful sources of information
L73	Property mapping—adding information
L74	Property mapping—measuring distance and area
L75	Using topographic maps
L76	Computer-based property mapping and recording
L77	Property plans—when should they be prepared?

All-weather on-farm access

All-weather access is vital for the efficient management of a plantation. This provides unhindered machinery movement for harvesting, spraying and other field operations. Roads and access tracks can be easily maintained if water from adjoining fields is directed away from them. Tracks should be 3 to 4 metres wide to allow for the movement of machinery without damaging the vines.

Where possible, follow these guidelines:

- Locate access tracks on ridgelines, so that water will be shed away from them. Where tracks must run across the slope, regularly divert the water across them to prevent a build-up of water on the top side (which could cause erosion).
- Always direct run-off away from access tracks.
- Use contour drains to move run-off to stable watercourses/gullies.
- Use concrete pipes when crossing major drainage lines, especially those with regular trickle flows. Alternatively, use concrete or rock inverts (where the track is depressed) to let water flow safely across.
- Most access tracks require 'whoa-boys' or speed bumps to catch and divert water safely off the track. Make these no more than 50 metres apart and ideally where the slope changes or there are suitable outlet points.

Row direction and length

Row orientation is important. Try to run the rows north–south, as this maximises light interception and makes the best use of sunlight. It also provides better shade protection for fallen fruit, which are particularly susceptible to sunburn.

An exception to this rule is in tropical regions, where sunburn damage to fruit hanging on vines on rows that run north–south can be severe, especially on the western side of the vines. East–west rows help prevent this and reduce soil temperatures under the vines.

If vines are grown on pergolas, row direction is not critical. The vines will form a complete canopy over the pergolas, protecting the fruit from sunhurn.

Row direction options may be overridden by other factors:

- Irrigation. In some situations, row direction may need to suit the design needs of the irrigation system. Consult a qualified irrigation designer for assistance.
- Slope. On slopes of less than 15%, rows can run across or up and down the slope. On slopes greater than 15%, rows should run up and down the slope to allow safe machinery operation.
- Block shape. A narrow block shape may limit row orientation options.

Long rows are preferred for machinery efficiency, but breaks in long rows about every 50 metres are needed to allow efficient collection of harvested fruit. Breaks allow small vehicles (such as quad bikes) and pickers to easily cross between rows during harvesting. Where a single-wire trellis is used, breaks in rows can easily be made by not planting a vine between two posts and keeping runners from the neighbouring vines pruned off the top wire between these posts. Leaving the top wire in place maintains the tension on the trellis and avoids the need for extra anchor posts. Simply remove the lower wire (if there is one) and either hury or re-route the irrigation pipe along the top wire so that small vehicles and harvesters can pass through.

Windbreaks

Passionfruit performs best on sites that are warm and well protected from winds. In most regions, the major damaging winds come from the south-east, south and west, so windbreak protection on at least these sides of the plantation is essential. There are a number of windbreak options:

- Retain existing natural timber stands and plant trees and shrubs to supplement these where necessary. Leave windbreaks on all sides of the intended plantation site where possible. Leave timber on all major drainage lines, as this vegetation will protect the watercourse from erosion.
- Plant tall, quick-growing grasses such as bana grass. When planted in spring, it will form a dense windbreak by the next winter. Eacb year, deep rip close to the bana grass to sever its roots–this will prevent it spreading into the root zone of the vines.
- Plant trees and shrubs. Two or three rows of trees and shrubs provide the best protection.
- Erect artificial windbreaks. These are commonly constructed from mesh materials such as shadecloth. They are expensive but provide instant protection, require less room than planted windbreaks and do not compete with the passionfruit for water and nutrients.

Chapter 4 provides detailed information on windbreaks.

Natural watercourses

Disturb any creeks and depressions as little as possible. Leave or plant a buffer of trees along creek banks to keep them stable. Do not plant vines in dry creek beds or depressions (where run-off naturally concentrates). Maintain these areas with a good ground cover of natural vegetation, planted native shrubs or grass.

Surface run-off and erosion control

For detailed information on erosion control, refer to *Soil conservation measures—Design manual for Queensland.* This is available from the DERM website at www.derm.qld.gov.au

It is essential to carry water safely through the plantation. Uncontrolled run-off will remove valuable topsoil and expose surface roots to desiccation, waterlogging and rootrot. Surface structures such as diversion and contour banks and U-shaped drains and waterways will safely divert run-off into stable watercourses. Contour banks and across-slope drains will shorten the distance that water can race downhill. These structures must be correctly designed, constructed and maintained, because their failure will result in increased soil erosion.

The most effective ways of preventing erosion are avoiding bare soil and ensuring inter-row areas are grassed. When developing a layout for the plantation, consider the following:

- For slopes up to 7%, the row direction can be determined by the factors covered under 'Row direction and length' above.
- For slopes greater than 7%, access for machinery becomes a more important consideration. Shallow-gradient rows that run across the slope cause only minor machinery slippage. This means there is less damage to soil and erosion-control structures than there would be from machinery trying to climb steep slopes in wet conditions.
- Avoid slopes greater than 15%, but if they are planted, run rows up and down the slope for safer machinery use. A gradient of 15% is regarded as the safe maximum limit for working a two-wheel-drive tractor across the slope, although in wet conditions access may be limited. Cut-off contour banks running across the slope will he required at least every 30 metres to intercept run-off (see plan on page 17). These need to be constructed so that machinery can easily move over them without causing damage; any damage could allow water to escape and cause erosion.
- In the Darwin region, avoid slopes greater than 3% because torrential monsoonal rains can cause severe erosion on them.
- The plantation may need to be protected from water flowing from land directly above it by a diversion bank at the top of the site.
- Do not plant vines in depressions or low points, as these carry run-off during storms and can remain wet for long periods. Maintain or replant these areas with a low-growing, vigorous grass such as couch, carpet grass, African star grass or kikuyu. Your state government's horticultural department staff, local consultants and growers may be able to help you identify grasses suitable for your area. The grass must be regularly slashed to assist the rapid removal of run-off from the plantation.

Diversion banks

Diversion banks are artificial run-off control structures that are used to divert water flow safely into stable grassed waterways, natural depressions or constructed waterways.

Failed run-off control structures will greatly increase soil and crop damage. To minimise the risk, ensure any diversion banks have a gradient between 1% and 5% (see Table 3.2, page 22) and are large enough to handle the water from the catchment above.

Gradients less than 1% may not remove water quickly enough and will therefore increase the likelihood of overtopping. Gradients greater than 5% (or sometimes less, depending on soil type) can result in erosion after construction but before grassing. To prevent scouring of the drain channel, establish a creeping or sward-type grass such as couch, carpet grass, African star grass or kikuyu in the channel.

Table 3.2 Diversion banks: maximum recommended gradients for different soil types and bank lengths

Diversion structure length (m)	Maximum gradient		
	Gravelly soil	Sandy soil	Stable clay soil
50	3%	3%	5%
75	3%	2%	4%
100	2%	2%	3%
150	1–2%	1%	2%

The gradient can be up to the maximum at the beginning and then reduced as it flows towards the outlet. For example, on a sandy soil the first 50 metres could be 3% , the next 100 metres 2% and the remainder 1% until it reaches the outlet.

To avoid water ponding along the banks, locate drains using a dumpy level, a hand level or a water tube level. The banks need to be high enough to prevent overtopping.

Waterways

Waterways should be located in the natural run-off flow paths. This ensures that if run-off exceeds the capacity of a waterway, the excess water will not divert and flow through the crop.

Construct waterway channels below ground level to allow rows and drains to discharge into them. Make them wide enough to ensure that the water does not have to flow too deeply (and therefore quickly). Also, make them flat-bottomed so that water will not concentrate in one area and so that they can be easily mown. Stabilise them with couch, carpet grass, African star grass or kikuyu before they are required to carry run-off.

If a waterway is to carry large volumes of water, obtain professional assistance with its design.

Mounds and U-shaped waterways

Where there is a limited depth of good topsoil (less than 30 centimetres), build low-profile mounds to improve soil depth. Mounds may also be required on heavy soil and in high-rainfall areas for maintaining aeration in the root zone.

Planting on mounds can also be considered for deeper soils. Mounds maximise surface drainage away from roots and help with harvesting because the fallen fruit roll away from the mounds into the inter-row space and are easier to collect. (However, if they are not collected promptly, this may lead to more sunburn.)

Construct mounds using a grader or tractor-mounted blade. Grade the soil from the inter-row space to build the mounds (see Figure 3.1), but make sure that the inter-row space can be mowed easily. Do not incorporate clay subsoil into the mound. Establish a grass sward in the inter-row space to minimise soil erosion.

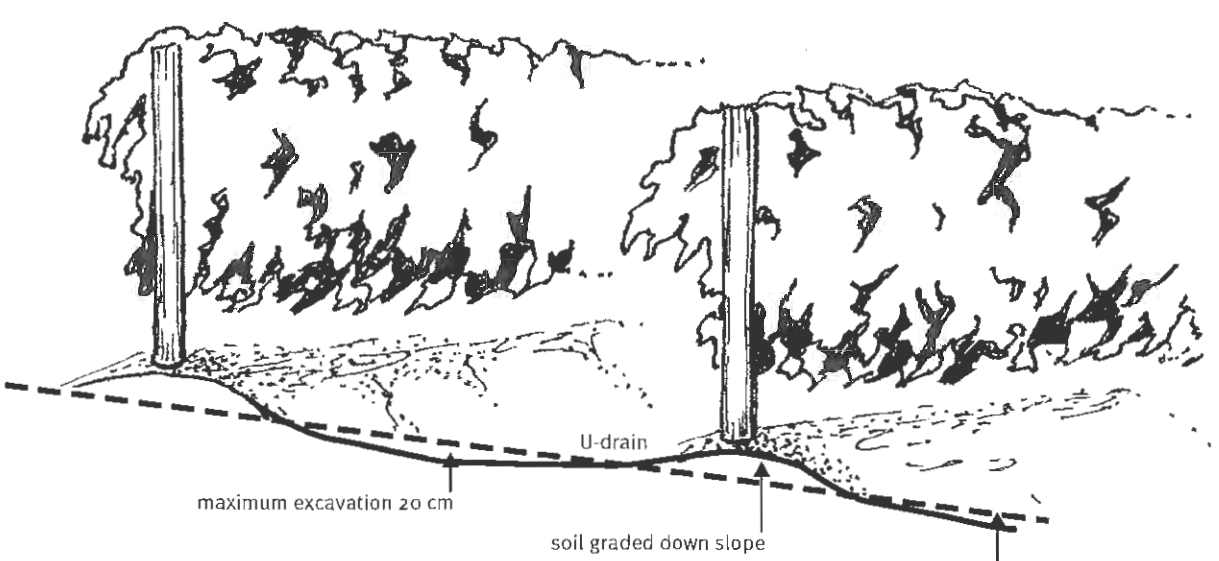


Figure 3.1 Mounds on across-slope rows with a wide U-shaped cross-section that can be mowed easily

For unmounded rows across the slope, construct U-shaped run-off control waterways every second or third row; run these to another waterway or natural drainage (see Figure 3.2). The maximum distance between the run-off control structures should be about 15 metres. Construct shallow, wide, U-shaped waterways in the centre of the inter-row spaces to control water flow; they will also provide some drainage. Excavate to a maximum depth of 20 centimetres. Use a grader or tractor-mounted blade to make the U-shape as wide as possible, so that the waterways are easier to mow. Grass these waterways as soon as possible and maintain grass cover, as this is critical for control of erosion.

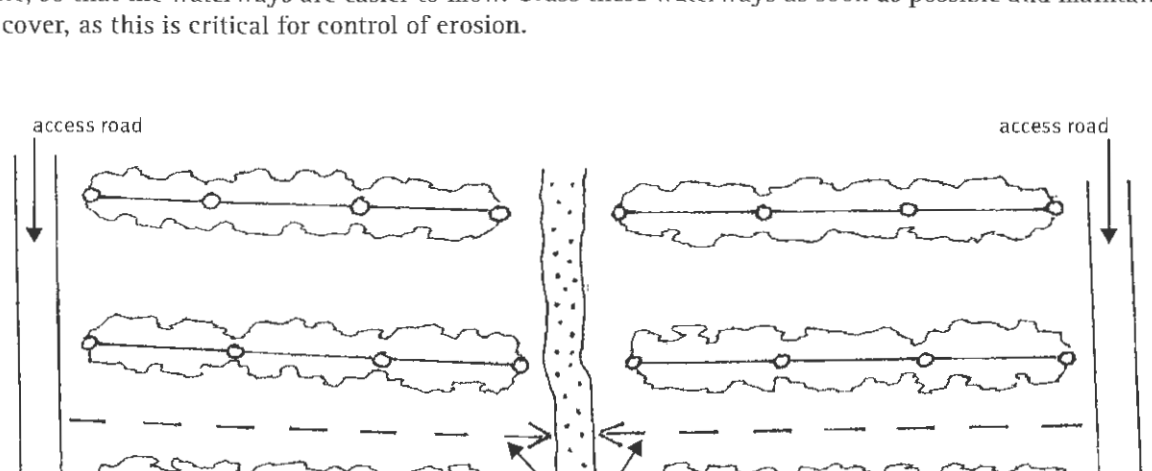


Figure 3.2 Across-slope rows with U-shaped run-off control waterways (plan view)

If the rows run perfectly up and down the hill and the rows are mounded, U-shaped waterways are not needed. Each row will carry its own small amount of run-off and as long as the inter-row space is grassed, no erosion will occur.

Where there is a side slope to the row direction (which will almost always happen somewhere on a curved hill) and mounds are used, the row mounds need to be large enough to keep the water within each row. If the mounds for each row are too small, the mounds will divert water for a distance across the slope until the water exceeds capacity and overtops. Once one row is breached, the rows below will fail because there is a concentration of water in an area *not* designed to cope with it.

If overtopping is likely, instead of using mounds, construct U-shaped run-off control structures in the inter-row spaces to control side slope run-off (see Figure 3.3). Excavate between the rows to construct the U-shaped run-off control structures every few rows (or every row if necessary)—but run these down the slope. This is better than running U-shaped drains across the slope and cutting across the rows, as these would be almost impossible to maintain. Over time, the machinery traffic would reduce their water-carrying capacity to almost nothing, resulting in erosion problems.

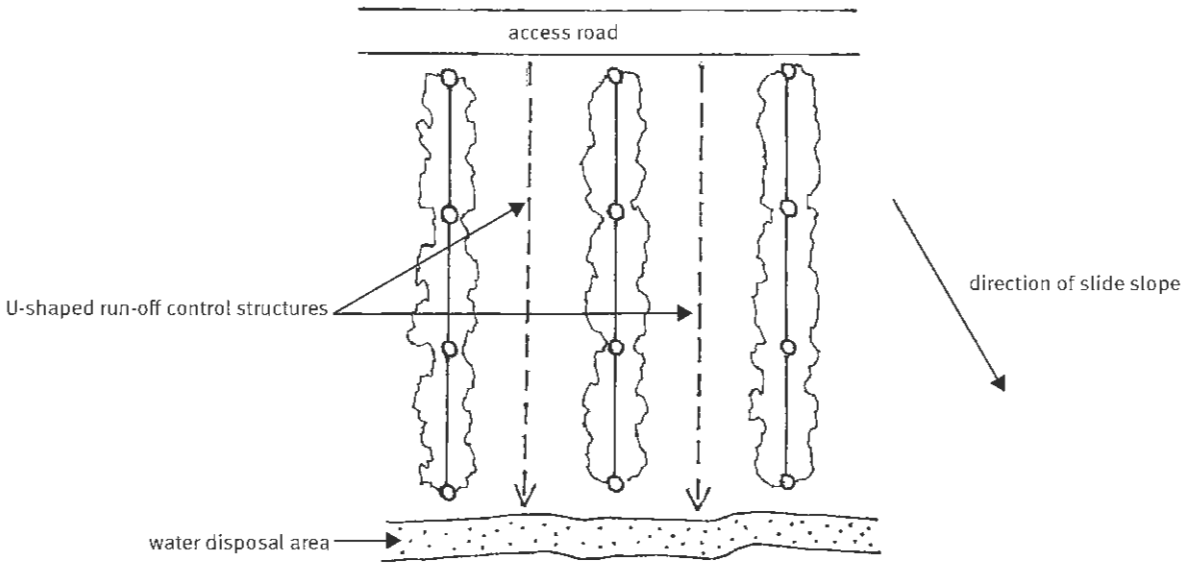


Figure 3.3 Down-slope rows with U-shaped run-off control structures

Water harvesting and storage

A good farm layout should incorporate water harvesting. This means that run-off is removed from the plantation site and directed into a dam.

The type of irrigation system used should be integrated into the farm layout to be compatible with erosion-control structures, access roads and drainage. Locate irrigation mains and hydrants close to access tracks. When planning irrigation, seek specialist advice from a qualified irrigation designer.

The bigger picture

Following these planning principles will benefit you and your farm as well as your catchment and community. Joint government and community initiatives encourage people to cooperate on a catchment basis to reduce the off-site effects of land degradation. Adopting the recommended planning principles will reduce community problems such as:

- poor water quality (resulting from nutrients contained in run-off)
- siltation of rivers, streams and harbours
- algal blooms in water storages
- loss of production caused by soil erosion.

For further information on how you can be more involved at a community level, contact Landcare and catchment management groups in your area.

Windbreaks

Chapter 4

Passionfruit evolved in a sheltered rainforest environment and the vines are very susceptible to wind damage. Exposure to wind reduces—or in severe case prevents—vegetative growth, flowering and fruit set. In addition, wind-rub blemishes on fruit can be caused by the movement of fruit against leaves, stems, trellis posts and wires. Careful site selection and the use of natural stands of timber will help, but additional planted or artificial windbreaks are often needed to maximise wind protection.

This chapter provides information on establishing effective windbreaks:

Windbreak design

To be effective, tree windbreaks must be carefully designed. It is best to establish windbreaks well before passionfruit are planted, so that protection is provided from the start. If this is not possible, temporary windbreaks with fast-growing species such as *Pennisetum purpureum* (bana grass, also known as elephant grass) and giant sorghum can be used between rows then removed once permanent windbreaks are sufficiently grown. Initial use of temporary windbreaks may also help the establishment of permanent windbreaks.

When designing the plantation, consider carefully where the prevailing winds come from in your area and establish windbreaks accordingly. Also take into account the placement of windbreaks in relation to access roads and vine rows. The key features to consider when designing windbreaks are permeability, height, length, width, formation and gap allowance.

Passionfruit grown on overhead pergola trellises need more substantial wind protection than most single-wire trellis plantings because of the height of the overhead canopy and the area of the trellises.

Permeability

A permeable windbreak (see Figure 4.1) allows wind to filter through it and provides a larger zone of protection than a solid windbreak does.

Figure 4.1 A permeable windbreak

A dense windbreak that blocks all wind causes the highest reduction in wind speed, but its effectiveness is limited to a narrow protection zone directly behind the break (see Figure 4.2). A major problem with a dense windbreak is the turbulence caused downwind close to the windbreak. Dense windbreaks are not suitable for plantation protection but can be used around small areas that need special shelter, for example around buildings.

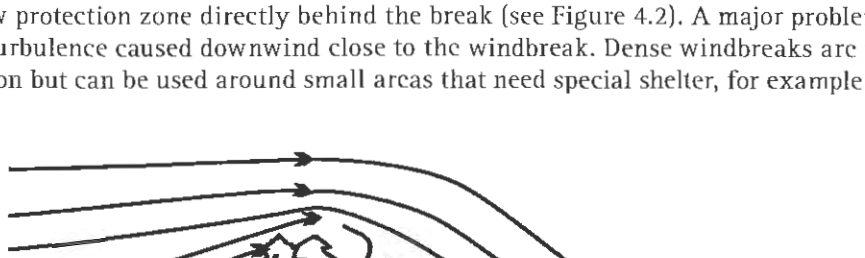


Figure 4.2 A dense windbreak

Height

The higher the windbreak, the longer the protection zone. On level ground, a windbreak can reduce the wind speed for a distance of up to 25 times the height of its trees. Maximum wind protection is achieved within a distance of 5 to 15 times the tree height.

Length

Because wind swirls at the ends of a windbreak, windbreaks should stretch for some distance without any gaps. If a windbreak is too short, wind is deflected around it, leading to increased wind at the ends. Doubling the length of a windbreak increases the protected area by up to 4 times (see Figure 4.3). A windhreak should be at least 200 metres long if possible.

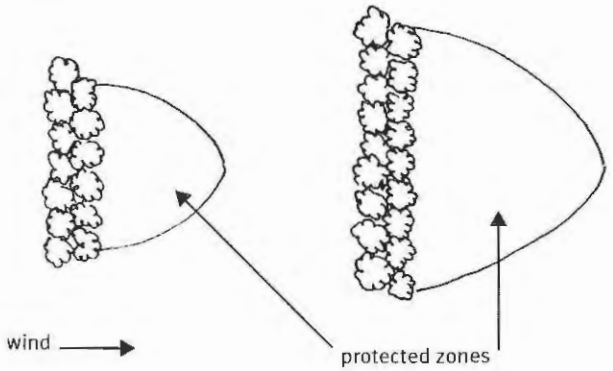


Figure 4.3 A short and a long windbreak

Width

For best results, the width of a windbreak should be *no more* than 3 times its expected final height. An excessively wide block of trees deflects the air upwards, but provides a shorter zone of protection on the downwind side (see Figure 4.4).

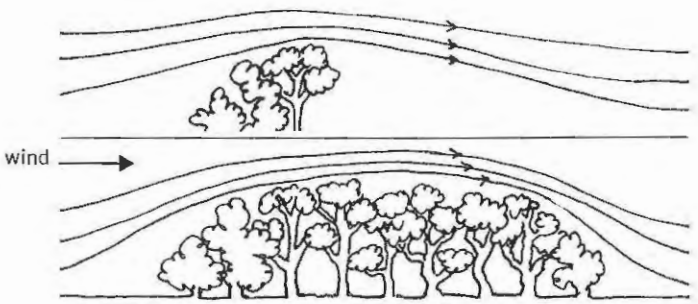


Figure 4.4 A narrow windbreak (top) and a wide windbreak (bottom)

Orientation

For maximum protection, a windbreak should be at right angles to the prevailing winds. For example, if the wind is from the south, the windbreak should run east–west.

Formation

Windbreaks with multiple rows are generally more effective than those with single rows. Single rows can be effective if the species used has fairly dense foliage to ground level. However, if one tree dies, a gap is created, which reduces the effectiveness of the windbreak. For this reason, windbreaks of between three and five rows are preferred, if space allows.

In multiple-row windbreaks, a variety of tree species with a range of sizes, shapes and foliage can be used to create a permeable barrier from the ground up to the height of the tallest trees.

Tall trees are generally best positioned in the centre, with smaller, bushy trees and shrubs on the outside (see Figure 4.5). In drier areas, two or three rows are sufficient. With any more than this, the inner rows will be competing for soil moisture.

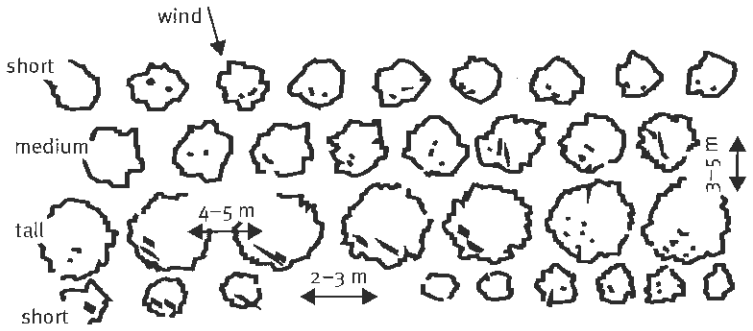


Figure 4.5 A multiple-row windbreak

Another approach that is sometimes used for wide multiple rows is to scatter the trees rather than plant them in rows. Trees and shrubs of different types are mixed across the windbreak to create a permeable barrier. This approach provides a wildlife corridor and habitat as well as a windbreak.

Gaps

Gaps are required for gates, roads and access tracks, but funnelling through these gaps can greatly increase wind speed in these areas. This problem can be reduced in wide windbreaks by angling the gap at 45° to the prevailing wind (see Figure 4.6).

Other solutions are to plant trees outside the main windbreak to block the gap, or to widen the gap to reduce the funnelling effect.

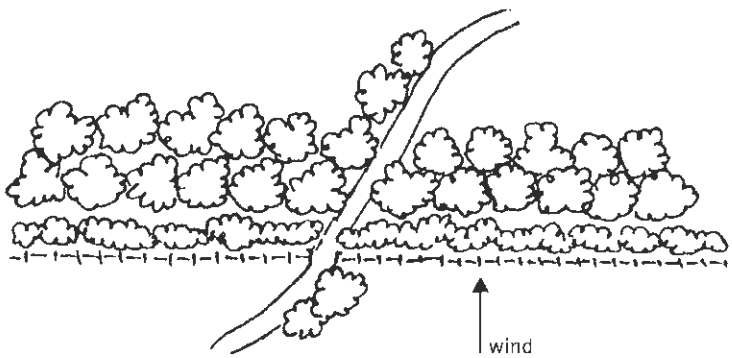


Figure 4.6 A windbreak with a gap at 45°

Choosing windbreak species

Table 4.1 (page 31) lists the trees and shrubs that can be used as windbreaks. Select species that suit your local area and grow reliably, because gaps caused by the loss of trees will reduce the effectiveness of the windbreak. Specialist native plant nurseries may provide advice on selecting trees for windbreaks. Your state government's horticultural department staff, local consultants and growers may be able to help you identify species suitable for your area.

Eucalypts are the best choice if windbreaks are established when planting the passionfruit; they grow rapidly (2.5 to 3 metres a year) and will provide rapid protection. Slower growing trees should be planted several years before the vines are planted.

Observations after cyclones in northern Queensland showed that fast-growing species such as tallowwood (*Eucalyptus microcorys*) and pine trees were prone to break and expose the plantation to the full force of the wind. In addition, debris from the shattered trees caused severe damage to plantations. The windbreaks that stood up best were natural belts of eucalypt trees that had been preserved to act as shelter belts, in particular belts of Moreton Bay ash (*Eucalyptus tessellaris*). Rainforest species fare badly in cyclonic weather, tending to break easily.

The best long-term protection is achieved by mixing low-storey and high-storey species (see Figure 4.7).

Figure 4.7 A windbreak planted with tall, medium and short tree species

Figure 4.8 A young Casuarina cunninghamiana *windbreak*

As a temporary measure, bana grass can be quickly established from planted billets and used until permanent windbreaks become effective. Make sure that the bana grass is not allowed to grow too thick or it will become difficult to manage. Hedges of this grass provide a refuge for rats and other vermin, so eradicate the bana grass once the permanent windbreak is established. In the interim, say every 2 years or between crops, slash or mulch the bana grass and burn the resulting trash. The grass will reshoot and regrow quickly.

River she-oak (*Casuarina cunninghamiana*) is very effective (see Figure 4.8) but can shed its lower limbs as it matures.

Experienced growers report that lemon-scented tea-tree (*Leptospermum petersonii*) forms a very good windbreak.

Clumping bamboo has given good results, but its roots must be ripped every 1 to 2 years, depending on how close it is to the vines, to reduce its competitiveness for nutrients and water. Ripping after rain can be deeper and will give better results.

Cadagi (*Eucalyptus torelliana*) grows very quickly and has been widely used in the past but is no longer recommended. It is prone to shed limbs and is a favoured host for the red-shouldered leaf beetle, a significant pest of passionfruit.

Table 4.1 Species suitable for windbreaks in passionfruit-growing areas

Main windbreak		
Scientific name	Common name	Suitable for single-row windbreak
Allocasuarina torulosa	Rose she-oak	
Callitris columellaris var. *columellaris*	Coast cypress pine	✓
Casuarina cunninghamiana	River she-oak	✓
Eucalyptus acmenoides	White mahogany	
Eucalyptus siderophloria	Grey ironbark	
Lophostemon confertus	Brush box	✓
Melaleuca bracteata	River tea-tree	✓
Melaleuca leucadendron	Broad-leaved tea-tree or weeping paperbark	✓
Melaleuca quinquenervia	Broad-leaved paperbark	✓
Melaleuca styphelioides	Prickly-leaved paperbark	✓
Syzygium australe	Creek satinash or creek lilly pilly	✓
Syncarpia glomulifera	Forest turpentine	✓
Syzygium luehmannii	Cherry satinash	✓
Syzygium floribundum (formerly *Waterhousia floribunda*)	Weeping lilly pilly	✓
Lower storey		
Scientific name	Common name	Suitable for single-row windbreak
Acacia salicina	Cooba or willow wattle	
Acacia saligna	Golden wreath wattle	
Allocasuarina littoralis	Black she-oak	
Malaleuca salicina (formerly *Callistemon salignus*)	White bottlebrush	✓
Malaleuca viminalis (formerly *Callistemon viminalis*)	Weeping bottlebrush	✓
Leptospermum petersonii	Lemon-scented tea-tree	
Tristaniopsis laurina	Kanooka box or water gum	

Windbreak establishment and maintenance

Take care when preparing the site and planting the windbreaks to ensure the plants get the best possible start.

- Deep rip rows to at least 60 centimetres before planting. If ripping downhill, lift the toolbar every 30 metres to prevent water scouring down the rip lines.
- Buy from a reputable nursery. Seedling stock should be between 12 and 20 weeks old. It is sometimes possible for a nursery to arrange a special sowing for orders of 500 or more seedlings.
- Place windbreak trees at least 7 metres away from the vines to prevent competition for water and nutrients. This will also provide room for machinery to turn on headlands and to carry out root ripping.
- Plant tall trees 4 metres apart and short species 2 to 3 metres apart. Mulch well with coarse straw.
- Fertilise the trees regularly with small quantities of all-purpose fertiliser to promote rapid growth.
- Maintain a weed-free area around the trees and mulch.
- Prune the trees for shape during establishment and remove any broken or damaged limbs.
- In the establishment phase, replace dead trees as soon as possible.
- Design the irrigation system to water the windbreak trees as well as the passionfruit vines. Regular watering will ensure windbreak trees establish quickly.
- Prevent windbreak trees competing with passionfruit vines by deep ripping in a line parallel to the windbreak and about 3 to 4 metres from the trees every 2 to 3 years. Do not rip too closely to the windbreak trees, as this can weaken their anchorage and make them more likely to blow over in high winds. Position farm tracks adjacent to windbreaks to use this strip of less productive land.
- Monitor the windbreaks for pest and disease problems, and treat them as necessary.

Artificial windbreaks

These are used by some growers. If you choose to use them, remember:

- They are quick to set up but can be expensive to erect.
- They are low maintenance once erected.
- They do not compete with the crop for light, water and nutrients.
- They do not harbour pests like fruitspotting bugs or green ants.
- Their limited size means that they afford only limited protection.
- Unlike timber, they have no end-life value.

Varieties, rootstocks and spacings

A number of passionfruit varieties are grown in Australia and new releases from the breeding program of the Australian Passionfruit Industry Association (APIA) become available to the industry from time to time. Four varieties are shown on page 33; note the variation in size and colour of these passionfruit. They are (clockwise from top left) the Sweetheart, Pandora, Misty Gem and McGuffies Red varieties.*

Variety performance is very variable and difficult to predict. It depends on both the management of the vines and the environment in which the vines are grown. The only sure way to assess if a variety is suitable for your farm is to grow some on a trial basis. However, you can use the following information as a general guide to help you decide which varieties to consider:

* In 2011, APIA changed its name to Passionfruit Australia Incorporated. See Appendix B for contact details.

Australian passionfruit—species, varieties and commercial status

Almost all passionfruit varieties grown commercially in Australia are derived from two forms of one species—the black passionfruit (*P. edulis* f. *edulis*) and the Panama passionfruit (*P. edulis* f. *flavicarpa*). Some are pure derivatives of the individual forms, but most are crosses between the two that are known collectively as 'purple varieties'. The crosses are unique to Australia. The main characteristics of the two forms and the crosses are outlined in Table 5.1 (page 37).

Black passionfruit met consumer acceptance up to the 1950s, when they were decimated by fusarium wilt and passionfruit woodiness virus. The purple varieties have undergone intensive selection to provide pest and disease tolerance, enhance production and improve fruit quality. The Panama varieties have not undergone the same intensive genetic improvement as the purple varieties. The purple varieties make up the bulk of the industry in Queensland, New South Wales and Western Australia. In the Northern Territory, mainly Panama Red is grown.

Crosses between *P.edulis* f. *edulis* and *P. edulis* f. *flavicarpa* combining high production and tolerance to disease were bred by the Queensland Department of Primary Industries (DPI) at Redland Bay in the early 1960s. The purple varieties derived from this program, such as 'E 23', 'Lacey' and '3-1', became the mainstay of the Australian industry for many years.

However, during the late 1970s, these varieties lost their vigour. Their fruit became smaller and their vines became more susceptible to viral and fungal diseases. In an attempt to regain vigour and provide better control of viral diseases in these varieties, a scion wood accreditation scheme was established. This scheme aimed to select the best available mother vines for the supply of propagation material to nurseries. During this process, a vine grown in Upper Burringbar in New South Wales was selected and named 'Tom's Special'. This variety had particularly strong and vigorous growth, large sweet fruit, high pulp recovery and better disease tolerance than the DPI varieties. However, it had the limitations of a short cropping season and lower yields.

In 1986, at the New South Wales Department of Primary Industries Centre for Tropical Horticulture in Alstonville, Tom's Special was used as a parent in a crossing program with E 23, Lacey and 3-1. This resulted in the release in 1989 of two new varieties, 'Supersweet 1' and 'Supersweet 3', which had large, sweet fruit with a high pulp content. These varieties, together with Tom's Special, superseded the DPI varieties in popularity.

In the 1990s the New South Wales based breeding program was successful in crossing a range of parent material. This resulted in the release of the new varieties '96A', '96B' and '96C' in 1996 and 'Misty Gem' and 'Pinto' in 1998. The variety '152' was released in 2001.

Subsequently, APIA began a crossing program to broaden the genetic base and further improve sweetness, pulp recovery, dark skin colour, taste and cropping pattern. Six selections were tested by growers in a range of environments throughout the growing districts. They were evaluated for productivity, resistance to pests and diseases, appearance, taste and suitability to the local environment. Three varieties were released after internal quality assessment and consumer panel tests: these were named 'Sweetheart', 'Jumbo Gem' and 'Tropic'.

The purple varieties E 23, Barlow's Special, Purple Gold, Lacey, 96C, Supersweet, Tropic, Tom's Special, 152 and Jumbo Gem are no longer recommended for commercial production. Their fruit quality, vigour and yield are not as good as those of Misty Gem and Sweetheart.

'Sunshine Special' is a popular variety grown and available in Western Australia only. This variety has not been fully assessed or described in detail. It was a chance seedling selection and has similar characteristics to the purple varieties. Its large, oval-shaped fruit have an attractive purple-green colour (less purple in winter). It shows cold tolerance and has an extended cropping season but it is reported to have variable pulp content. Its tolerance to diseases has not been properly assessed. It is propagated from cuttings with reportedly good results.

What makes a good variety?

A good commercial variety should have the following characteristics:

- a rich purple skin colour (traditionally consumers' preference); some Panama selections such as McGuffies Red and Pandora are also popular (but variable pulp recovery can be a problem in other Panama selections)

- good fruit size (preferably in the range of 90 to 120 fruit per 18 litre carton for purple varieties and 40 to 95 for Panama)
- vigorous growth with high yields
- some cold tolerance to maintain vigour in winter and to resist passionfruit woodiness virus
- a long cropping period
- good flavour (sweet and not too acidic) and good pulp recovery
- some tolerance to serious diseases
- fruit with smooth skin that is fairly resistant to marking.

The characteristics of key varieties are provided in Table 5.1.

Rootstocks

Purple varieties are grown as grafted plants, as the rootstock provides protection from some root problems. A superior selection of the golden passionfruit rootstock strain that is resistant to the soil-borne fungus *Fusarium oxysporum* f. sp. *passiflorae* is used as a rootstock to prevent fusarium wilt. These rootstock selections have the added advantage of some resistance to phytophthora rootrot and nematodes. They are *not* resistant to the disease commonly known as 'base rot' caused by another soil-borne fungus, *Fusarium solani*.

Seed for these rootstocks is currently available from DEEDI's Maroochy Research Station (phone 07 5453 5800). Check that your nursery supplier is using a rootstock seed that is resistant to fusarium wilt.

Some Panama selections with a high resistance (approximately 98%) to fusarium wilt can be used as satisfactory rootstocks; consult your nursery about these.

There is ongoing rootstock breeding and selection to find rootstocks that have more cold tolerance and are therefore less susceptible to passionfruit woodiness virus. Therefore, improved rootstocks may become available.

Panama selections are best grown as seedling plants to avoid transmission of viral diseases. Also, being mainly of *P. edulis* f. *flavicarpa* origin, they have a high degree of natural resistance to fusarium wilt.

Figure 5.1 Batches of rootstock seed tested for resistonce to fusarium wilt; on the left, resistant rootstock seedlings that have been inoculated with Fusarium oxysporum *and are growing well; on the right, susceptible rootstock seedlings that also have been inoculated but have mostly died*

Table 5.1 Summary of the characteristics of passionfruit species and varieties

	Black passionfruit (*P. edulis* f. *edulis*)	Panama passionfruit* (*P. edulis* f. *flavicarpa*)	Purple varieties (*P. edulis* f. *edulis* × *P. edulis* f. *flavicarpa*)
Varieties	Nellie Kelly Norfolk Black	Pandora McGuffies Red	Sweetheart Misty Gem
Climatic suitability	Good chilling tolerance Suitable for cooler subtropical and temperate areas	More sensitive to cold than purple or black varieties Typically more suitable for tropical areas but will grow in many areas from northern Queensland to northern New South Wales	Intermediate chilling tolerance Suitable for central and southern Queensland and northern New South Wales Some varieties (e.g. Misty Gem) also suitable for tropical areas
Fruit character	Dark purple skin Small Thick, leathery rind Fine, sweet flavour Often poor pulp recovery	Skin colour varies through year and ranges from yellow through pinkish to red-purple Large Can have a thick rind Pulp recovery varies from light to very good (may improve with careful selection of lines) Pulp sack separates easily from rind (which detracts from appearance) Very sweet flavour but can be acidic, especially in cooler areas (may improve with careful selection of lines) Very diverse genetically and so has a wide range of colours and flavours Harvested by picking off the vine once or twice a week	Greenish purple to plum-coloured skin Medium to large Thin rind compared to Panama More acidic and aromatic than black passionfruit but less than Panama Good balance of sweetness and acidity High pulp recovery Harvested by daily collection off the ground in summer (twice weekly in winter)
Plant performance	Highly susceptible to passionfruit woodiness virus and fusarium wilt Produces a large summer crop with little or no fruit during winter and spring Susceptible to leaf diseases	Some resistance to diseases such as fusarium wilt, blight and nematodes Can be established from seed, so plants are initially virus-free Has good vigour and tends to resist passionfruit woodiness virus May produce heavy crops but mainly in later summer and winter (timing varies between locations)	Not as tolerant as Panama to fusarium wilt and passionfruit woodiness virus When grafted onto a *flavicarpa* rootstock, will have resistance to fusarium wilt and nematode Most varieties have potential to set good crops for 10 months of year and give much higher yields than black passionfruit

* 'Panama' is a generic description of a type of passionfruit and is not the name of a specific variety. Pandora and McGuffies Red are considered superior to other Panama selections because of their better taste, appearance and pulp content. They are probably not pure *flavicarpa* and are thought likely to have some *edulis* genes. Other Panama selections such as Lakeland Special, Panama Red, Panama Gold and various individual grower selections of red Panama are available but are no longer recommended for commercial production.

Characteristics of the main varieties

The following information is given as a guide to assist growers in selecting varieties for different growing areas, market destinations and end uses.

The comments on each variety are based on results from several APIA* field trials set up in tropical and subtropical growing regions of Australia. Consumer acceptance and internal quality of fruit have been objectively measured.

Note that *P. edulis* f. *edulis* varieties such as Nellie Kelly are not detailed here, as they are not considered to be commercial varieties in the main production areas.

Check with your proposed market regarding current market varietal preferences. Other than variety and colour, a major factor affecting price is fruit size, with larger fruit normally attracting better prices. Prices for Panama selections and purple varieties often differ. Historical prices for the main capital city fruit markets can be obtained from Ausmarket Consultants at www.ausmarket.com.au

Important: The performance of passionfruit varieties and selections is very variable. It is significantly affected by geographical and climatic regions as well as different management systems. New growers should trial a small number of vines of any available varieties to assess performance on their site before deciding which varieties to grow in the long term. Similarly, experienced growers should trial any variety they have not grown before.

* In 2011, APIA changed its name to Passionfruit Australia Incorporated. See Appendix B for contact details.

Misty Gem

This variety is shown in Figure 5.2 and its characteristics are listed in Table 5.2.

Figure 5.2 Misty Gem passionfruit

Table 5.2 The characteristics of Misty Gem passionfruit

Main characteristics	Positives	Negatives
Most widely grown and popular purple variety Medium-sized fruit with consistently high pulp content Size: 100–140 count per 18 L carton Average fruit weight: 82 g Average pulp content: 47% Sugar: 13.7° brix Acidity: pH of 3	Very adaptable to a wide range of growing conditions; performs well under a wide range of temperatures Ideal fruit size for most of the crop: 100–120 count per 18 L carton Consistently high pulp content Long shelf life, low wastage and good value for buyers and consumers High general pest and disease resistance; resistant to anthracnose; hest virus tolerance of existing varieties Good cold and heat tolerance Highly suitable for processing Least susceptible to sunburn of all varieties Appealing flavour	Fruit colour can vary at different stages of the cropping cycle Fruit size varies with crop load, and can be too small if vines are stressed Susceptible to alternata spot Long gaps between production peaks in one trial area in south-eastern Queensland

Note that this variety is a product of APIA's breeding program and plant royalties are due on the propagation or purchase of plants. Fees are payable to APIA either on the supply of scion material or through the nursery at the time of purchase.

Sweetheart

This variety is shown in Figure 5.3 and its characteristics are listed in Table 5.3.

Figure 5.3 Sweetheart passionfruit

Table 5.3 The characteristics of Sweetheart passianfruit

Main characteristics	Positives	Negatives
Suited to warm, protected areas only; will not tolerate cold winds	Dark, attractive, shiny fruit	Not cold tolerant
Dark purple fruit, normally even colour	Ideal fruit size	Vines prone to dropping a few fruit
Size: 100–120 count per 18 L carton	Good, juicy pulp content	Uneven fruit colour and shape at the start and end of the cropping period
Average weight: 78 g	Excellent flavour—highest scores in taste panel tests	Unproven in northern Queensland
Average pulp content: 43%	Very sweet	Low vine vigour in some areas
Sugar: 15° brix	Tough skin and resists marking and shrivelling	
Acidity: pH of 3.3	Good shelf life	
	Outstanding disease resistance; highly resistant to anthracnose and resistant to other fungal diseases	
	Good productivity	
	Good fruit-to-leaf ratio	
	Pulp separates easily from skin	

Note that this variety is a product of APIA's breeding program and plant royalties are due on the propagation or purchase of plants. Fees are payable to APIA either on the supply of scion material or through the nursery at the time of purchase.

McGuffies Red

This variety is shown in Figure 5.4 and its characteristics are listed in Table 5.4.

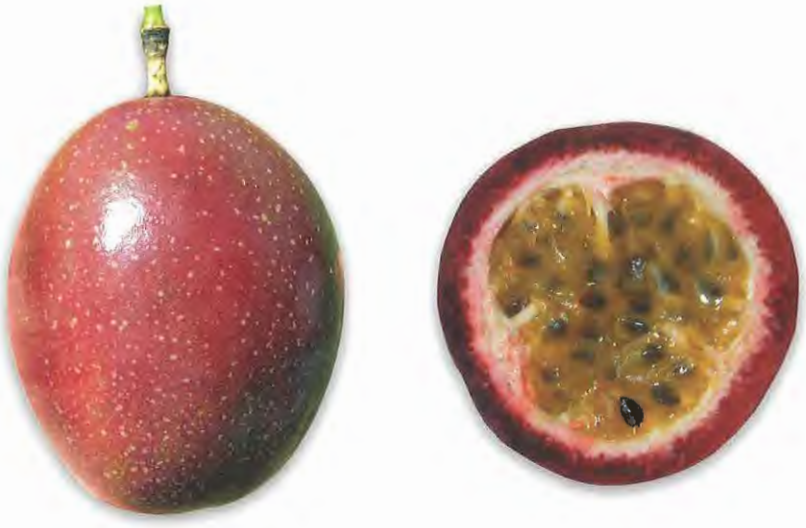


Figure 5.4 McGuffies Red passionfruit

Table 5.4 The characteristics of McGuffies Red passionfruit

Main characteristics	Positives	Negatives
Selected in Cooktown, northern Queensland	Long production period in subtropics (fruiting for most of the year)	Skin colour may darken to brown and taste can become more acidic under cool and cloudy conditions
Large, attractive reddish-coloured fruit with shiny skin	High market acceptance	Fruit size may he too large for some consumers
Slightly elongated, oval shape	High productivity	May lack sweetness under prolonged cool conditions or when there is insufficient leaf cover
Produces well in subtropical and tropical areas (more cold tolerance than other Panama selections)	High pulp content	Excessive vine growth may not suit pergola systems when grown for longer than 1 year
Grown in tropics to target high price period (September to November)	Excellent flavour, aroma and texture	
Develops bright red/pink colour with full sun and warm conditions	Very sweet taste with good acidity balance	
Can be grown as seedling (no grafting)	Attractive external colour and bright yellow pulp	
Tolerance to fusarium wilt still being evaluated	Pulp separates well from pith—no residue left in shell	
Size: 40–95 count per 18 L carton	Suited to single-wire trellis and pergola growing systems	
Average weight: 160–190 g (heaviest 232 g)	High tolerance to fungal diseases; virus tolerant	
Average pulp content: 46%	Good shelf life	
Sugar: 16.5–18° brix (February test)	Retains eating quality under long-storage conditions (e.g. waxing)	
	Not messy to eat or handle—juice remains in cells when cut	
	Good shape for packing	

Note that seeds or seedlings can be purchased from APIA-recognised sources. To maintain the purity of this selection, only use seed from fruit that has been protected from cross-pollination (see Chapter 18).

Pandora

This variety is shown in Figure 5.5 and its characteristics are listed in Table 5.5.

Figure 5.5 Pandora passionfruit

Table 5.5 The characteristics of Pandora passionfruit

Main characteristics	Positives	Negatives
Selected in south-eastern Queensland Large, heart-shaped Panama-type fruit Very juicy—free juice on cutting Tolerates a wide range of climatic conditions (tropics and subtropics, wet and dry) True-to-type seedlings show resistance to fusarium wilt similar to the DPI rootstock Size: 45–90 count per 18 L carton Average weight: 140–160 g (heaviest 220 g) Average pulp content: 49% (February, May and July) Sugar: 15–17° brix (February)	High market acceptance Suited to wide range of growing conditions Will tolerate cooler conditions High pulp and juice content Very sweet flavour High producer Attractive orange colour of pulp Virus tolerant	Skin can be dull colour and variable from green to grey/purple/orange depending on weather conditions Fruit and leaves susceptible to septoria spot Fruit may be too sweet for traditional customers Fruit size may be too large for some consumers May lack sweetness under prolonged cool conditions or when there is insufficient leaf cover Can shed fruit under extreme heat conditions (38–40 °C) Excessive vine growth may not suit pergola systems when grown for longer than 1 year

Note that seeds or seedlings can be purchased from APIA-recognised sources. To maintain the purity of this selection, only use seed from fruit that has been protected from cross-pollination (see Chapter 18).

Row and vine spacing

There is considerable variability of performance of the individual varieties in different environments and management regimes. Therefore, it is not possible to give specific recommendations regarding planting distances for varieties that will suit all situations. However, it is worth noting the following:

- Start with a small trial block for a new trellis system or a new variety, so that spacings can be tested and evaluated on your site prior to larger scale plantings.
- Some varieties do not grow as large as others and so can be planted at higher densities.
- Location has a major effect on the vigour of growth, though the exact effect is difficult to predict. Some varieties may grow very vigorously in a hot climate while others will grow less vigorously. Adjust planting density to suit.
- Sunburn protection for fallen mature fruit can be achieved by using closer rows. The orientation of the rows is also important; a north–south orientation is generally regarded as best in most areas, except the Northern Territory (see Chapter 3). Higher trellises and alternative trellis designs such as pergolas and T-bar trellises may also help to prevent sunburn injury.
- Wider rows increase sunburn but afford better air movement and so reduce diseases.
- In tropical areas, for the vigorous and quick-growing Panama selections, use wider spacings between plants.
- Closer vine spacings (down to as little as 2 metres apart) provide increased early yields but require a higher level of pest and disease management.
- Allow enough space between the rows for machinery to pass through when the vines are mature and have thickened out from the trellis.
- Wider rows are generally needed on steeper slopes.
- Be prepared to change as you expand your plantings and choose new varieties for the new areas.
- Narrow row widths may limit change to more vigorous, thicker-growing varieties in the future.
- Seek local knowledge.

As a starting point, consider the following general recommendations:

- **Single-wire trellises:** Leaving 3 to 6 metres between plants in the row and 3 metres between rows gives between 555 and 1111 vines per hectare. However, distances between rows can range from 2.5 to 6 metres, depending upon the size of machinery to be used in the plantation, as it must be able to pass easily between rows of mature vines.
- **Pergolas:** Generally, where pergolas are used, vines are replanted each year. Therefore the vines are planted only 3 to 4 metres apart along the row to encourage quick canopy development. The distance between the rows must be wide enough for compact machinery to pass down the rows.
- **A-frame trellises:** Plant spacing is critical with A-frame trellises. In general, less vigorous varieties such as Misty Gem and Sweetheart should be planted closer together (2 to 3 metres apart) than the more vigorous varieties such as Pandora and McGuffies Red (4 metres apart).

Arrangement of varieties in the plantation

In general, plant each variety as a single block. This makes it easier to manage the particular requirements of each variety.

Pollinator plants are not required for the purple varieties, as these are self-compatible. The Panama selections Pandora and McGuffies Red are not pure *P. edulis* f. *flavicarpa* (they are thought to have some *P. edulis* f. *edulis* parentage) and this provides enough variability for them to be self-compatible, so pollinator plants are not needed.

Trellising

Chapter 6

Passionfruit vines are usually grown on single-wire trellises, since these are relatively cheap and easy to construct. However, pergolas, A-frame trellises, fence trellises and T-bar trellises are also used. Talk to other growers in your area about their experiences and be prepared to trial different systems before deciding which to use on your property. The most important thing is to ensure that the structure is strong enough to support a considerable weight of mature vine and fruit for many years. This chapter provides general guidelines for the following:

Erecting a single-wire trellis

The most commonly used trellis for passionfruit is a single wire supported on posts about 2 metres above the ground (see Figure 6.1). The main branches of the vine are trained along the wire and the vine canopy hangs underneath. The trellis should consist of the following components:

- **Main strainer posts at the ends of the rows.** Use split hardwood or pine treated with copper chromium arsenic (CCA). Use posts of diameter 125 millimetres (small end) to 150 millimetres (big end) that are 3 metres long. Set the posts 1 metre into the ground. On very long rows, centre strainer posts may also be required. It is better to drive the posts into undisturbed soil using a mechanical post-driver than to dig holes and ram the soil around the posts. Post-driving allows trellises to carry a much greater load and significantly reduces vertical movement of the posts. Some fencing contractors provide post-driving services. The depth to which posts are driven or set also significantly affects their potential movement when under load. Posts driven to a depth of 1 metre can carry twice the load with only half the movement of posts driven to a depth of 0.75 metres. Driving the posts at a slight outward angle also helps to reduce post movement when the wires are strained.

- **Intermediate posts.** These should be located every 4 to 6 metres along the row, depending on vine spacing, and should be 2.75 metres long. Use split hardwood or CCA-treated pine posts of diameter 75 millimetres (small end) to 125 millimetres (big end). Set the posts 0.75 metres into the ground. Some growers use 2.4 metre or 3 metre long 100 millimetre diameter CCA-treated logs with no taper. Star pickets can be used instead of wooden posts.

- **Stays for strainer posts.** These are not necessary where posts are driven to a depth of 1 metre. However, in other cases, place one at each main strainer post and one on each side of centre strainer posts on long runs. Use 75 millimetre diameter hardwood or CCA-treated pine up to 3 metres long. Alternatively, brace the first and second posts in the row against each other using a wood or metal bar and wire tensioner, as shown in Figure 6.2 (page 48).

- **Top wire.** Use 10 gauge (3.15 millimetre diameter) galvanised wire. Strain the wire taut to take the weight of the vines. Permanent roller tensioners will make straining the wires and subsequent adjustment easier.

- **Second wire.** A second wire can be installed to hold the irrigation lateral out of the way of machinery. Secure this wire along the trellis about 50 centimetres above the ground. It does not need to be tightly strained. A disadvantage of using this wire is that falling fruit can be damaged if they hit it. The alternative is to lay the irrigation lateral along the ground and mount the sprinkler on a plastic stake pushed into the ground alongside the plant (see Figure 6.3, page 48). Young vines can be trained to a string tied from the top wire to a wooden stake in the ground.

Note: In the Northern Territory, trellises are usually made of steel to avoid damage by termites. Either star pickets or lengths of steam pipe are driven into the ground. Trellises are braced at either end by tying wire stays from the end posts back onto star pickets driven into the ground at 45°.

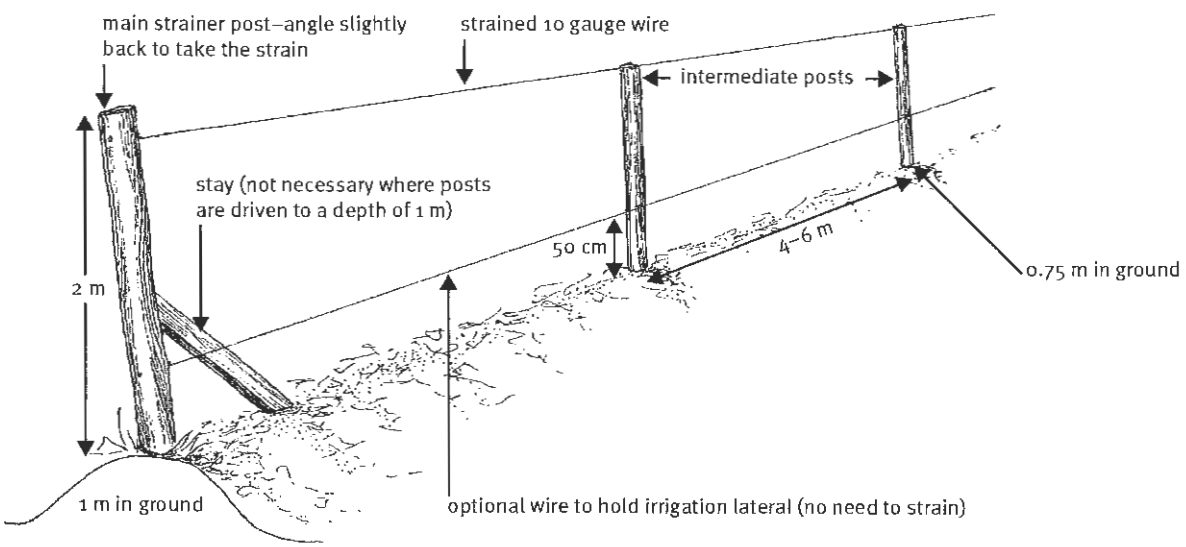


Figure 6.1 Specifications for a single-wire passionfruit trellis

Figure 6.2 (Left) A single-wire trellis where the first and second posts have been braced using a horizontal metal pipe and a diagonal tensioning wire

Figure 6.3 (Right) A single-wire trellis system where the irrigation laterals run along the ground and sprinklers are held on plastic stakes; strings are used for training the vines up to the wire

Some advantages and disadvantages of single-wire trellises are:

- They are relatively cheap to erect.
- They allow easy access between rows for tractors and equipment.
- It is easy to train vines to the single wire.
- It is easy to remove dead vines from trellises when replanting.
- Exposed fruit may be blemished by sunburn in hot weather.
- Vines can be sprayed from both sides but coverage of the internal stems, leaves and fruit is poor as vine foliage thickens with maturity.

Other trellis systems

A number of other trellis systems can be used to support the vines. Only limited information on the construction, merits and disadvantages of these systems is available. The notes that follow are general observations only and growers need to carefully consider how these may relate to their specific situation.

Important: Variety performance on a particular trellis system can vary significantly between sites depending on climate and management factors. Therefore it is not possible to make specific recommendations regarding which trellis system gives the best results for any particular variety or region. Growers *must* trial any alternative trellis system before adopting its use on a large scale.

Pergolas

A pergola system consists of an overhead grid constructed using timber or metal (or a combination of both) and wires supported on posts. The vines grow over the grid to form a complete overhead canopy. Some examples of pergolas are shown in Figures 6.4, 6.5, 6.7 and 6.9.

Growing passionfruit commercially on pergolas is a recent development and so tried and tested recommendations are not available. Designs vary considerably and construction materials, dimensions and planting distances depend on a grower's individual circumstances and preferences. The following points give some general guidelines:

- The structure of the pergola is based on a rectangular or square grid of posts. Dimensions vary, but 2.6 metre by 4.5 metre rectangular and 2.7 metre square layouts have been used. Depending on how much clearance is needed for machinery, 100 millimetre diameter CCA-treated pine posts can be 2.4 metres long with 1.8 metres out of the ground or 3.0 metres long with up to 2.2 metres out of the ground. Other materials can be used and combinations of wooden and steel posts have been used successfully.
- Wire runners 30–40 centimetres apart provide the support for overhead vine growth. These wires pass over the top of either wooden or metal support beams, which join the posts at right angles to the direction of the wires (see Figure 6.4). Economies can be gained by using wire instead of beams in alternate rows, but it may be difficult to tension these enough to prevent excessive sagging under the weight of a closed canopy.

Figure 6.4 Banks of wires resting on metal pipe supports will provide support for the vine canopy

- The end posts of rows must he reinforced with extra struts so that overhead wires can be tensioned enough to prevent excessive sagging when the weight of the full vine canopy is on them. Extra stability can be provided by using guy wires from the end posts to star pickets driven into the ground (see Figure 6.5).

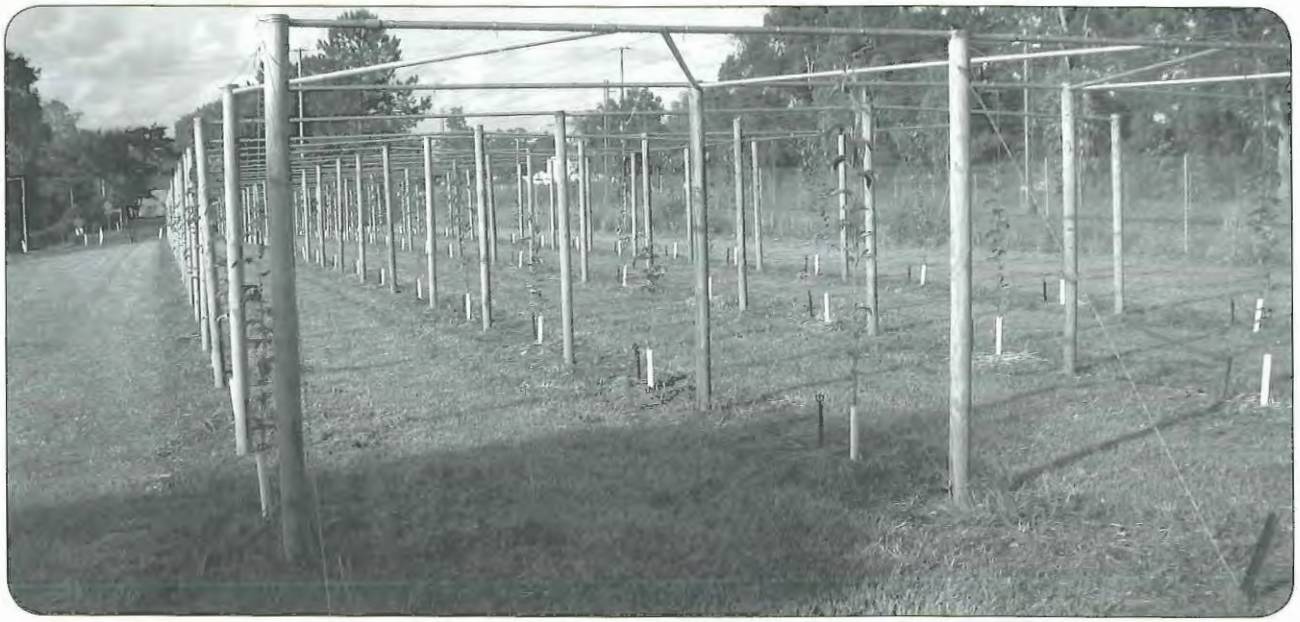


Figure 6.5 Metal pipes and guy wires to star picket anchors have been used to strengthen this pergola structure

Some advantages and disadvantages of the pergola system are:

- High production and fruit quality in the first year can be achieved for most varieties. More laterals can be carried on the vines, which can result in a quicker and larger volume of fruit production than would be the case on a single-wire trellis. Growers report that yield increases of 30–40% have been achieved using this system instead of single-wire trellises.
- The structure needs to be rigid in all directions and is expensive to construct.
- Fruit hanging down below the canopy is shaded and protected from sunburn (see Figure 6.9). Fruit that develops on the top of the canopy may get sunburnt.
- Extra training of vines is needed to run them onto all the wires.
- Ripe fruit can become hidden ('hung up') in thick canopies and be missed at harvest.
- 'Hung up' fruit eventually rots and can cause disease problems.
- Good spray coverage is possible for fruit hanging down away from leaves (as in Figure 6.9).
- With most pergolas, only the underside of the canopy can be sprayed. If the vine foliage becomes too thick, spray coverage is limited and pest and disease problems can become impossible to manage. Pergolas suit situations where vines are replanted each year and growth is not allowed to become too thick.
- Machinery needs to be compact enough to pass underneath the pergolas (see Figure 6.6).

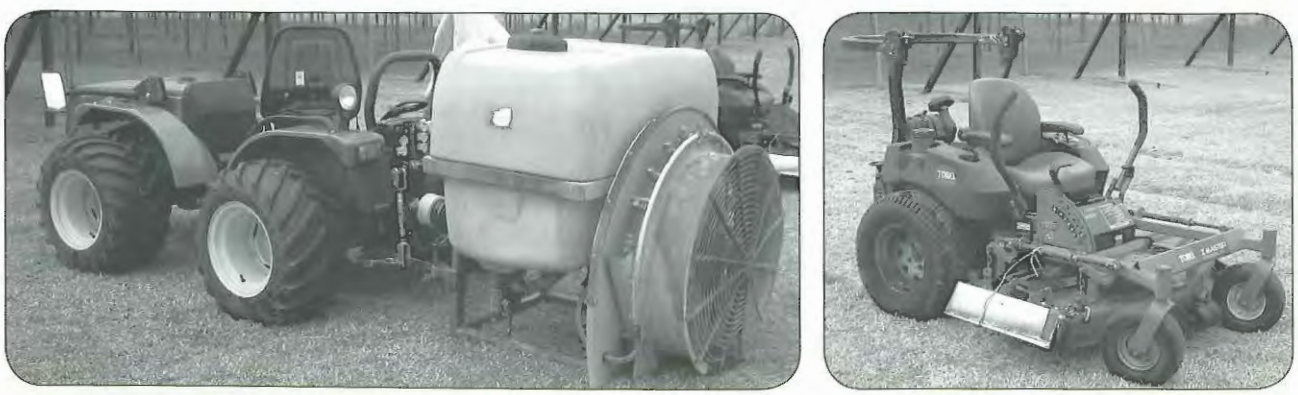


Figure 6.6 Compact machinery is needed to fit under some pergola and A-frame systems

- If pergolas are established on a block system with strategically spaced avenues between the blocks (see Figure 6.7), a large tractor complete with cab and sprayer (such as the one shown in Figure 6.8) can be used to apply pesticides and fungicides both above and below the canopy. Although vine canopy area is sacrificed, spray machinery can be used during wet weather periods without compacting the soil around the vine rooting zone. This allows timely pesticide applications and so improves the productivity and quality of the vines. The sprayer shown in Figure 6.8 gave good coverage into the middle of 13 metre wide blocks. Observations indicate that a venturi effect created by the two lines of airflow (above and below the canopy) draws the pesticides through the canopy, improving coverage.

- A good ground cover of a shade-tolerant grass (such as sweet smother grass) must be established to cushion falling fruit and minimise skin damage. The higher the pergola canopy, the more critical good ground cover is. Chapter 16 provides some information on sweet smother grass.

- Removal of vines from the structure prior to replanting is more difficult than for a single-wire trellis.

Figure 6.7 Pergolas established in blocks with avenues every 13 metres (6 rows of posts giving 5 × 2.6 metre gaps) to allow the passage of machinery

Figure 6.8 An air-blast sprayer adapted for use in a pergola with avenues for passage of machinery; the ducting provides two channels of air to deliver pesticides above and below the vine canopy

Pergola systems have worked well in northern Queensland on farms where vines are replanted each year as part of a management system developed to produce crops during the September to December period, when prices are often very high. In wet tropical climates there are added advantages of using pergolas:

- Hanging fruit dries quickly.
- Fruit that falls to the ground is protected from the sun and does not need to be collected as frequently.
- Fruit are well displayed (see Figure 6.9) and Panama fruit can be easily harvested from the vine.
- Less mowing is needed because the inter-row areas are shaded (but the erosion risk will be higher if there is no ground cover under the pergola).
- Strong pergola structures may stand up to strong winds better than other trellis systems do.

Figure 6.9 A pergola constructed using alternating wooden and steel posts with irrigation sprinkler droppers hanging down below the canopy; most fruit hangs below the canopy

A-frame trellises

A-frame trellising (see Figures 6.10 and 6.11) has been used successfully in Australia. A-frames are constructed from treated timber and are designed for enhanced productivity. Some general points on construction are:

- The wires are 40 centimetres apart and start about a third of the way up the frames.
- A horizontal strut about 1 metre below the apex of the frame with 2 or 3 wires running through it (see Figure 6.10) lowers the top of the canopy and achieves faster overhead cover. On some sites with vigorously growing varieties, these crossbars may not be needed.
- Align rows north–south for even sunlight interception to give good growth and development of fruit on both sides of the A-frame.
- To maximise the use of space, the bases of A-frames in adjacent rows can be butted up to each other. If space is not a limiting factor, gaps can be left between the A-frame rows.
- Single-wire trellises can be converted to A-frames simply by bolting the frames to the trellis posts (see Figure 6.11). Some growers have installed A-frames higher on the posts than shown in Figure 6.11 to facilitate movement of equipment beneath the A-frames.
- The frames should be large enough for machinery for spraying, slashing and harvesting to pass beneath.

Figure 6.10 (Left) In a trial at Duranbah in northern New South Wales, the results from A-frames with crossbars below the apex were better than those from A-frames without crossbars

Figure 6.11 (Right) Frames bolted onto existing single-wire trellis posts

Some advantages and disadvantages of using A-frames are:

- More laterals can be carried on the vines, which may result in a quicker and larger volume of fruit production than would be the case on a single-wire trellis. Growers report that yield increases of 200% have been achieved by changing from a single-wire system to an A-frame system.
- Foliage on the frame provides shade protection for fallen fruit. Once the canopy closes, sunburn damage to fruit is virtually eliminated. As a result, fruit can be collected on alternate days, and intervals of up to 3 days have proven satisfactory on some sites. This is a major benefit as it significantly reduces harvest labour costs.
- Pest and disease control is more effective. When vines are sprayed from underneath the A-frames, some pesticide blows through the vines onto the outside of the canopy on the neighbouring frame. Air-blast sprayers give good coverage of foliage and hanging fruit.
- The arrangement of the vine on the A-frame provides better sunlight interception than a single-wire trellis does.
- Hanging fruit dries quickly.
- The frames are more expensive than single-wire trellises.
- Extra training of vines is needed to run them onto all the wires.
- Extra work is needed to remove the vines prior to replanting.
- Tractors and equipment need to be compact enough to pass underneath the frames.

Pandora, McGuffies Red and Sweetheart have been successfully grown on A-frames, but individual growers should rigorously trial A-frames on their site prior to adopting them as their standard system.

A New Zealand design uses wooden frames and steel hoops to make an inverted A-frame. The arms of the frame are 4 metres long and their angle to the ground is such that the top of the arm is 3.7 metres above the ground. The frames can be used to support protective shade material or nets, which can also provide protection from hail and frost (see Figure 6.12).

Figure 6.12 An inverted A-frame trellis system made of steel and incorporating shade material (which protects vines from sun, hail and frost)

Fence trellises

Fence trellises are used by some growers, especially in Western Australia. They are identical to single-wire trellises except that a second wire is strained at 70 centimetres below the top wire. Two laterals are trained onto the lower wire and two to the top wire.

Some advantages and disadvantages of fence trellises are:

- They help provide rapid development of the vine and coverage of the trellises, especially in cooler areas where vine growth may be slow.
- The second wire increases the rigidity of the wall of foliage and helps reduce wind-rub damage to fruit.
- Extra training of vines is needed to run them onto all the wires.
- Extra work is needed to remove the vines from the trellis prior to replanting.
- Low-hanging fruit from the vine laterals on the lower wire may be more prone to pest and disease damage.
- More laterals can be carried, which may result in a quicker and larger volume of fruit production than would be the case on a single-wire trellis.

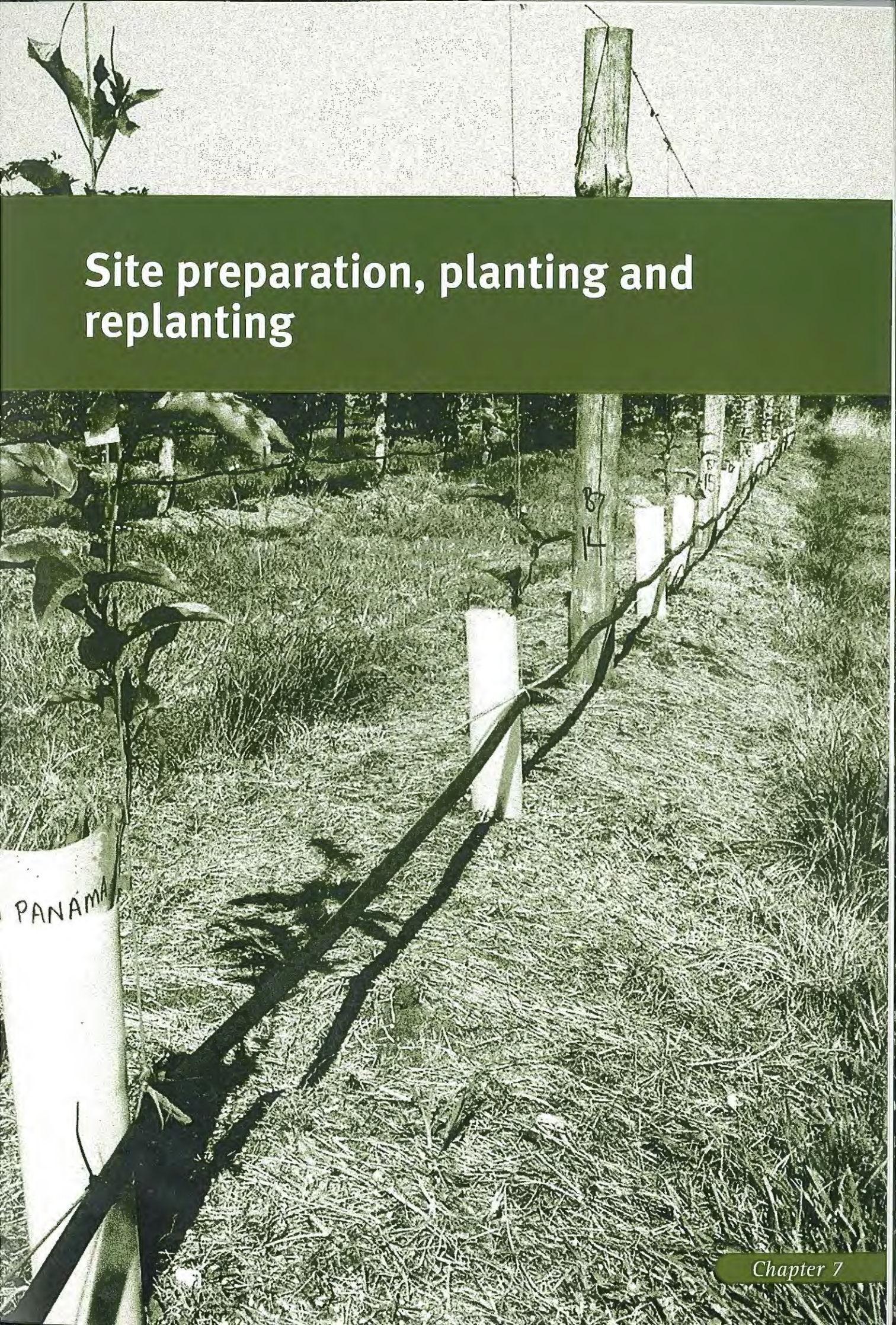
T-bar trellises

Another alternative is T-bar trellises. Here a short cross-member of timber across the top of each post holds 2 to 4 wires, along which the vines grow.

Some advantages and disadvantages of T-bar trellises are:

- Extra wires and timber are needed. This type of structure is more complicated and more expensive than a single-wire trellis.
- Rows may need to be further apart so that tractors and other equipment can pass between the T-bars.
- The vine foliage covering the structure provides some shade for fruit that hangs down below the canopy and thus protection from sunburn.
- There is a good spray coverage of fruit hanging down away from leaves.
- Hanging fruit dries quickly.
- Some fruit may not fall through the canopy for harvest.
- Vines may be thicker than on a single-wire trellis.
- Extra training of vines is needed to run them onto all the wires.
- More laterals can be carried, which may result in a quicker and larger volume of fruit production than would be the case on a single-wire trellis.
- Extra work is needed to remove the vines from the extra wire prior to replanting.

Site preparation, planting and replanting



This chapter outlines the basic order of operations for site preparation and planting of a new passionfruit plantation. Cross-references to other chapters indicate where more detailed information on specific topics can be found.

Some of the information in this chapter also applies to replanting (where old vines are being replaced with new ones). Passionfruit plantations are normally replanted every 1 to 4 years, depending upon the growing conditions and varieties grown. Replanting needs to be undertaken as part of a planned and structured process, not as an ad hoc decision, and is an essential aspect of maintaining the financial success of the plantation.

The main steps in planting are:

Order the vines

Once you have chosen your varieties and worked out your row and vine spacing, calculate the number of vines you need. Remember to buy a few extras, as it is likely that some will die from transplant shock.

Order your vines from a specialist passionfruit nursery at least 12 months before the intended planting. Follow these guidelines:

- Give preference to nurseries that use scion material taken from vines visually selected for their quality in autumn and winter.
- Remember that many of the more recently bred and widely planted purple varieties are propagated under licence from APIA, and these varieties are only available from APIA-licensed nurseries. (APIA uses the royalties it receives from the sale of these plants to fund further research.)*
- Specify that you want your vines grafted onto a strain of *P. edulis* f. *flavicarpa* that is resistant to fusarium wilt.
- Give preference to nurseries using non-soil potting mixes. These produce healthier planting material and minimise the risk of introducing soil-borne pests and diseases into your plantation.
- If you are growing Panama selections, you can propagate your own plants from seed and this may reduce costs. You can also select seeds from plants with superior fruit quality and yield attributes (see Chapter 18).

Nursery production of vines is a specialist job. However, some basic information on propagation is provided in Chapter 18.

Clear the land, leaving appropriate windbreak trees

Check with your local and state government authorities for any regulations about tree clearing.

Start any land clearing at least 12 months before planting. Identify and mark strategically placed existing stands of timber that can act as perimeter windbreaks (see Chapter 4). Then clear and stick rake the land where necessary. Stack the timber into windrows for burning. Do not push it into gullies and depressions. Leave gaps in the windrows every 30 metres to allow safe removal of run-off water.

At all times during land preparation and planting, avoid working the soil or using machinery in wet field conditions, as the soil may compact.

Mark out the rows

Mark rows that are to run across the slope parallel to a surveyed keyline. Cut a piece of wire to a length that is equal to the desired distance between rows. Tightly stretch the wire at right angles to the keyline and mark a point every 20 metres along the row. This method can be used either where rows are straight or where they follow contours, as shown in Figure 7.1.

Mark rows that are to run up and down the slope at right angles to the contour or parallel to the longest row.

* In 2011, APIA changed its name to Passionfruit Australia Incorporated. See Appendix B for contact details.

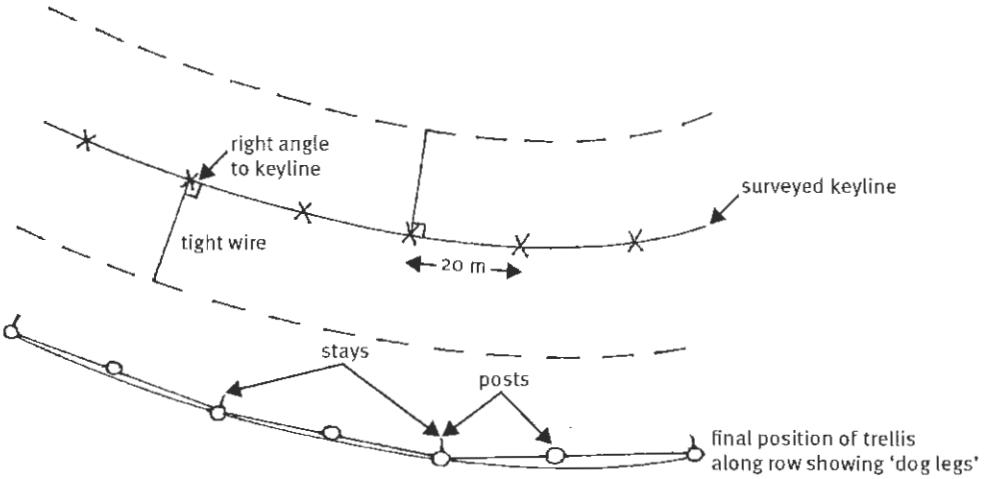


Figure 7.1 Marking out parallel rows across a slope

Deep rip along the rows

Where the land has been previously cultivated or grazed, deep rip to a depth of at least 60 centimetres along the rows. This will break up any hard layers of soil that have developed below the surface and may impede water penetration and passionfruit root development. Ripping will also help with the drainage of wet areas. If ripping downhill, lift the toolbar every 30 to 40 metres to avoid subsequent water scouring down the rip lines.

Install orchard infrastructure

Lay out and install any drainage and erosion-control measures that have been identified in the plantation plan (see Chapter 3). These may include:

- main diversion drains
- surface drains
- contour drains or U-drains
- all-weather on-farm access roads
- dams
- artificial waterways
- bench terracing.

Construct mounds

Where required, construct mounds along the planting rows (see Chapter 3).

Mounds (or raised beds) are beneficial to vine health. They help to prevent the soil around roots from becoming waterlogged during periods of heavy or extended rainfall and improve soil depth. Saturated soils have little or no oxygen in the pore spaces between the soil particles and the vine roots will die if they are deprived of oxygen. When the soil dries out, vines will take some time to recover (reducing yields) or may die, depending on the severity of the problem. In particular, base rot caused by the soil-borne fungus *Fusarium solani* is often associated with vines that have been stressed in this way (see Chapter 13). Base rot cannot

be controlled with fungicides, but it is a weak pathogen and does not infect healthy vines, so any measures taken to improve drainage will help to limit its occurrence. Both surface drainage and internal drainage are improved by mounds, even in well-drained soil types.

Figure 7.2 Mounds or raised beds help to improve drainage around the vine roots and increase soil depth

Plant windbreak trees

Establish planted windbreak trees where they are needed to supplement natural timber stands (see Chapter 4).

Analyse the soil and apply the required fertilisers

Have a soil analysis done at least 6 months before planting. This allows time to apply the required fertilisers and condition the soil so that it is ready for planting.

Buy a soil sampling kit from your local farm supply store. Follow the sampling instructions and send the sample away for analysis. The results should be back in about 2 weeks and will be interpreted by the laboratory analysing your sample.

More information about soil analysis and the nutrient requirements of passionfruit is given in Chapters 9 and 10.

Apply preplant fertiliser and cultivate strips along the vine rows

Apply preplant fertilisers that are recommended from the results of the soil analysis. It is very important to incorporate the less-soluble fertilisers (such as horticultural lime, dolomite, gypsum, phosphate, copper and zinc) before planting.

To incorporate the fertiliser, cultivate 1 metre wide strips along the vine rows using tined implements. Do not overuse a rotary hoe, as it can lead to soil compaction and soil structural problems. Also, it can cause settling of the soil in the vine row below ground level. This settling may cause water movement along the row, leading to soil erosion and wet spots (which can lead to disease problems). Minimise cultivation of other areas of the block to reduce soil erosion.

Cultivation along the vine rows also aids vine establishment and reduces initial weed competition.

Grow a green manure crop in the strips

Where possible, grow a green manure crop in the cultivated strips. Use hybrid forage sorghum for spring or summer plantings, and oats in autumn or winter. A side dressing of urea 2 weeks after crop emergence will promote good growth. Slash when the green manure crop is mature but before it seeds and disc into the soil.

Erect trellises

Chapter 6 gives information on constructing single-wire trellises and other trellising options.

Mark out the vine planting sites

Mark out the vine planting sites with a peg. If a green manure crop was not grown, apply to each planting site one of the following:

- 10 litres of poultry manure
- 2 litres of pelleted poultry manure
- 20 litres of aged filterpress (mill mud)
- 40 litres of an organic manure such as cow manure.

Spread this over a 2 square-metre area at each site at least 3 months before planting and immediately incorporate it into the soil. Spread a coarse mulch such as sorghum stubble 15 centimetres deep over each site. Do not place fertiliser or fresh manure or organic materials into the planting holes during or close to planting.

Install the irrigation system

Chapter 11 gives detailed information on irrigation systems, soil-moisture monitoring and irrigation scheduling.

Plant the vines

When you receive your vines, make sure they have good leaf colour, have a sound graft union (for grafted plants), are free from pests and diseases, and have been hardened to full sunlight. Do not accept vines that are stunted, root-bound or yellow.

Before planting, check the vines carefully for evidence of red scale. If you detect it, thoroughly spray the vines with an appropriate insecticide (see Appendix A).

When to plant

In tropical and subtropical climates, you can plant any time between September and March. However it is best, if at all possible, to avoid very hot weather periods during the summer months, as this is very stressful on the vines. Experience shows that September to early October is best in subtropical regions. In northern Queensland, planting in November or December may result in a crop during September to October the next year (when prices may be high).

In Western Australia, September or October is the recommended time for planting. After this, it begins to get too hot and dry, making establishment care more demanding. Autumn planting normally does not allow enough time for the plant to establish before cold weather sets in.

The planting procedure

If the vines are not sun-hardened before they leave the nursery, gradually move them into stronger light over 2 weeks before planting. Thoroughly water potted vines the night before planting.

Water the vine sites thoroughly 1 to 2 days before planting to wet them to a depth of 30 centimetres. Do not plant vines during the hottest part of the day.

For single-wire trellises, the planting site is normally midway between the posts. Where a pergola system is used and planting distances suit, the vines can be planted next to the posts to provide support. Planting on the leeward side of the post maximises protection from the prevailing wind (see Figure 7.3).

Figure 7.3 Plant vines on the leeward side of the pergola post to help protect early growth

1. Dig a hole slightly deeper and wider than the pot or bag. Do not use post-hole diggers or augers. Do not place fertilisers or organic materials into the hole or near the vine at planting time.
2. Remove the vine from the pot or bag (see Figure 7.4). Examine the root ball and gently loosen a little of the potting mix around the edge of the root ball. Check the root system for upturned roots at the base of the root ball (see Figure 7.5) and cut off any present just before the upturn. Treat the roots very gently.

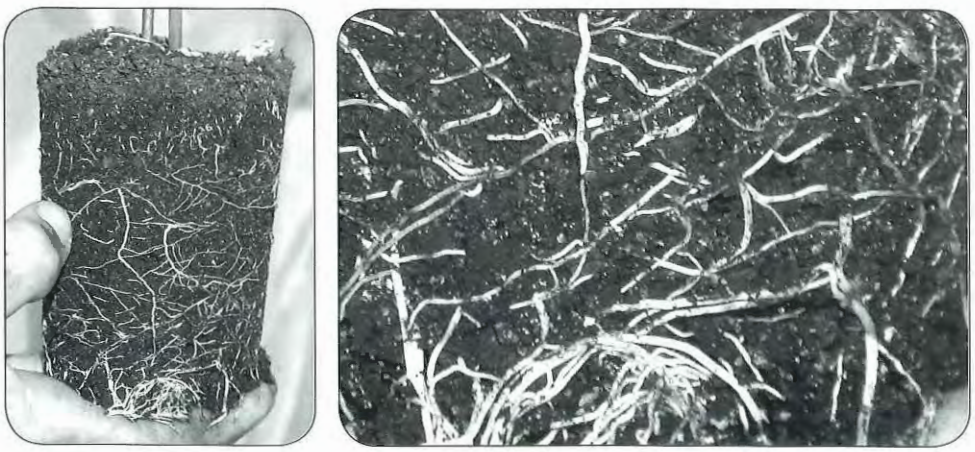


Figure 7.4 A healthy root system on a vine prior to planting

A This part of the root was bent when the rootstock seedling (right) was transplanted into a pot—do not cut the root at this point, as it is too high in the root ball

B This part of the main root twisted upwards when it grew into the bottom of the pot—before planting, cut the root off just above the upturn

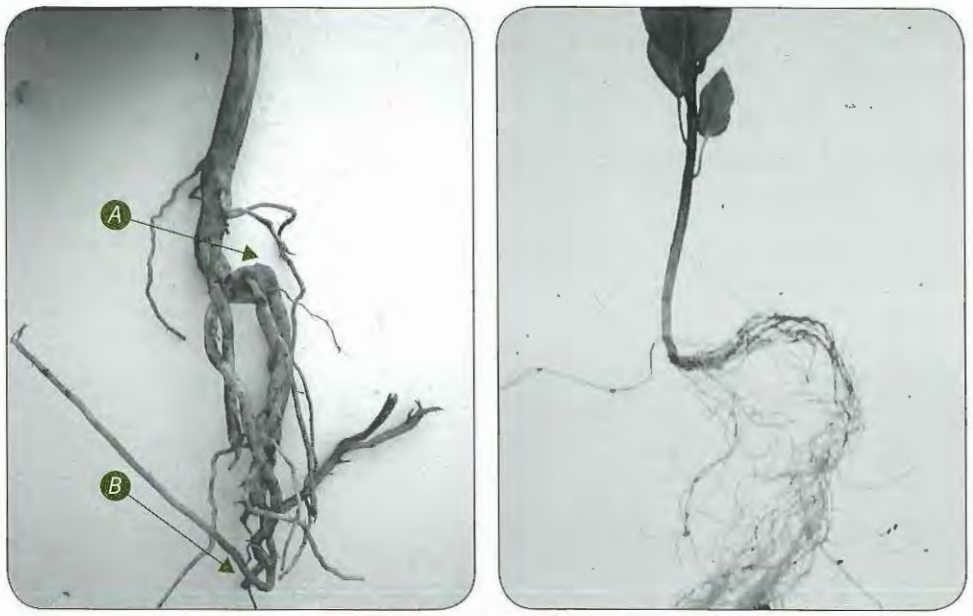


Figure 7.5 A twisted root system due to the root being bent during potting out in the nursery (A) and hitting the bottom of the pot (B)

3. Place the vine in the hole, positioning it so that the top of the potting mix is very slightly above ground level. (This will allow for soil settling and will ensure that the top of the potting mix does not end up below ground level.) Half-fill the hole with soil, gently pressing the soil into contact with the root ball. Fill the hole with water. (This helps to bring the soil into close contact with the root ball.) Allow the water to drain, then completely fill the hole with soil.
4. Firm the soil down gently with your hands (not your feet) and leave a basin around the vine to hold water (see Figure 7.6). Water the vine again.

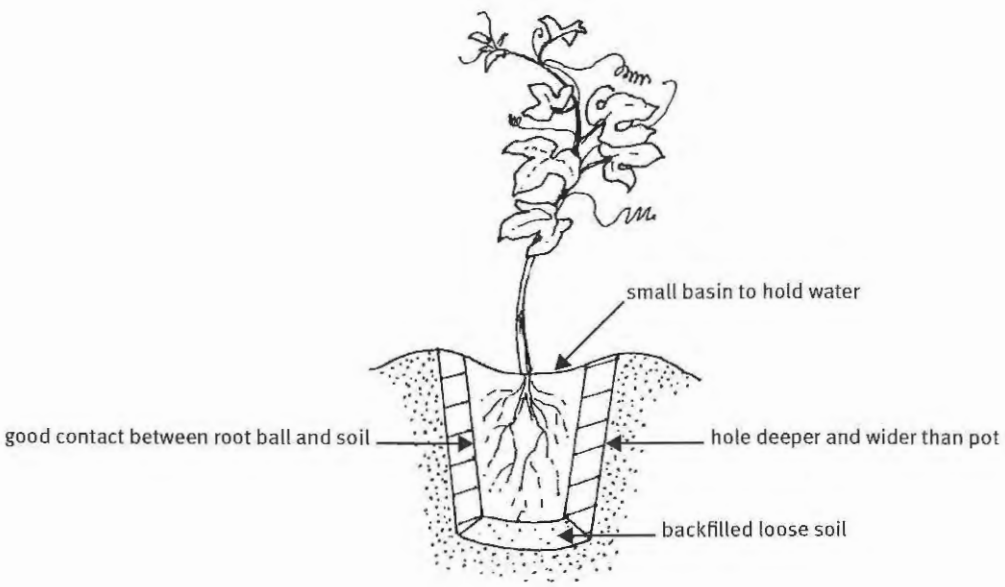


Figure 7.6 A correctly planted vine

5. Mulch the vine with a coarse mulch such as sorghum straw 10 to 15 centimetres deep. Keep the mulch 10 centimetres away from the stem to avoid collar rot.
6. Attach the vine to a long stake, or attach it to a short stake and tie a string from the stake to the top wire. Tape the vine to the stake or string at three or four places to hold it in place until it is established (see Figure 7.7).

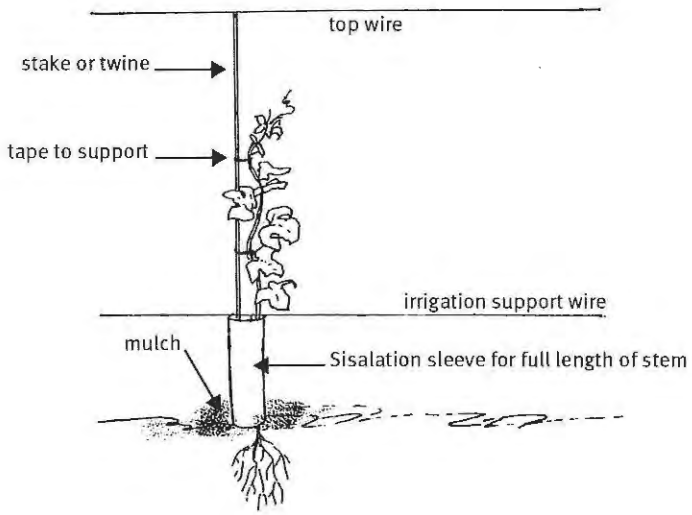


Figure 7.7 A planted vine showing staking and the Sisalation guard

7. Loosely wrap the base of the vine including the stake with one thickness of builders Sisalation with the silver side facing outwards (see Figure 7.7). Pieces 10 centimetres wide and 50 centimetres tall are generally suitable. Sisalation is cheap, easy to use, durable and reusable. White plastic paint is sometimes used as an alternative. Wrapping in Sisalation reduces suckering and protects the bark from sunburn and damage by animals and herbicides. Alternatively, ready-made stem guards (see Figure 7.8) can be purchased and are quick and easy to install. Translucent plastic vine guards (400 millimetre diameter, as used in the grape industry) help to prevent damage to young vines and provide an ideal microclimate for successful vine establishment. Regularly inspect inside the guards for ant nests and, where found, spray the nests with an appropriate insecticide (see Appendix A).

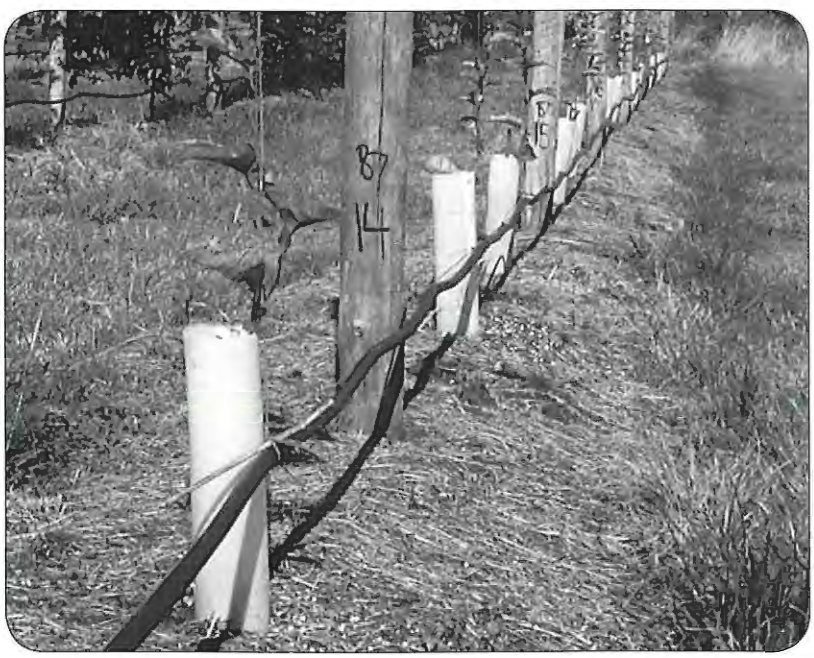


Figure 7.8 Plastic stem guards protect the stems of young vines

8. Depending on rainfall, water the vine twice a week for the next 4 weeks. In northern Queensland during very hot, dry weather, watering may be needed every second day or even daily because the small root system of newly planted vines makes them particularly vulnerable to heat stress.

Warning: The death or poor growth of young vines is often due to poor planting technique. Take care with each of these steps.

Manage young vines

During the first 6 months, the aim is to grow a strong, healthy vine that will produce well in the future. Refer to the relevant chapters for detailed information regarding the following critical aspects of management:

- fertilising (Chapter 10)
- watering (Chapter 11)
- training the vines to the trellis (Chapter 8)
- weed control and mulching (Chapter 16)
- pest and disease control (Chapters 12, 13, 14 and 15).

Replant

Passionfruit plantations are replanted on a regular basis. Vines have a limited productive life because pests and diseases will inevitably build up to a level where a high percentage of fruit becomes blemished and unsuitable for the fresh market and/or vines will die from pests and diseases. This happens even on plantations managed by experienced and skilled growers. Delaying replanting until it is too late is false economy; a planned approach to replanting is essential.

Frequency of replanting varies depending upon a number of factors, many of which are interdependent:

- **Pest and disease pressure.** High rainfall and humidity can mean that pests and diseases build up more quickly in hot, wet climates than in hot, dry climates. Viral disease is a major cause of premature vine decline (which will require replanting to be brought forward). The rate of vine decline is difficult to predict and depends on a number of factors (such as site, climatic factors, planting material and other pest and disease pressures), all of which may deplete the natural resistance of vines to viral infection.
- **Variety.** Panama selections normally grow much more vigorously than purple varieties do and can quickly develop dense foliage, which limits the coverage of pesticide sprays. As a result, some pest and disease problems are difficult to control in Panama selections at an earlier age. On the other hand, Panama selections are propagated from seed, and because viruses are not transmitted in seed, young vines are initially free from viral infection. The scion material used to produce grafted vines of the purple varieties (which cannot be propagated from seed) can transfer a virus directly into the new plant and as a result vine decline arising from viral infections can develop more rapidly in purple varieties.

  Traditionally Panama selections have been replanted every 12 to 18 months and purple varieties every 2 or 3 years. However, on some farms in recent years, vine decline in purple varieties (thought to be caused mainly by passionfruit woodiness virus) has reduced yields in the second or third year of production to such an extent that growers have found it necessary to replant after 12 or 24 months. It is important to assess plantation health and replant accordingly.
- **Climate.** Vines grow and form thick, dense foliage more quickly in tropical climates than in subtropical climates. As a result, pests and diseases are often difficult to control in tropical regions at an earlier vine age.
- **Management.** Growers who are careful and methodical with pest and disease control normally have healthier vines than those who are not. Growers need to develop the knowledge and skills to effectively identify pest and disease problems, decide on the appropriate management strategy and carry out that strategy effectively.
- **Equipment used to manage pests and diseases.** Some types of sprayers provide better coverage of vines than others and so improve the effectiveness of pesticides. For example, pests and diseases sprayed with a knapsack sprayer are unlikely to be as effectively controlled as they would be if sprayed with an air-blast sprayer.

There is a significant cost involved in replanting, but regular replanting has benefits. These include:

- It provides an opportunity to test and assess new varieties regularly on a trial basis and increase plantings of the best varieties at the next replant.
- It establishes disease-free and pest-free plants, which will be more productive than the old plants.
- It provides more financial certainty. Old plants may quickly become infested with pests (e.g. red scale) or diseases that are very difficult or impossible to control in thick vines. This can mean that a whole season's crop can be lost with little warning. While there is a significant cost involved in replanting more frequently, income from the plantation may be more secure when vines (even apparently healthy ones) are replanted every 2 or 3 years.
- It may be possible in tropical climates to time replants so that they produce an out-of-season crop (which will have a higher market value).

Replanting is carried out in a similar way to the method described under 'Plant the vines' earlier in this chapter. However, also note the following:

- The existing trellis is reused, but the old vines need to be cut out and removed before planting the new vines. This can be done by cutting the base of the stem near ground level, then cutting the vines away from the top trellis wire and letting the cut vine roll down into the inter-row space. The cut vines can then be mulched by reversing a slasher over them. This should be done when the vines are still green and fresh; if they are allowed to wilt, slashing may become difficult. The vine stump remaining in the ground and the main part of the root can then be lifted out with a spade.
- When replanting, avoid reusing the old planting point if the old vine had root disease—replant either side of the old planting point. How far you can move the planting point will depend upon the irrigation system and how easy it is to shift the minisprinklers. It may be necessary to realign the irrigation sprinklers, and this can be done either by blocking off the old points on the lateral using 'goof plugs' or alternatively by pulling the lateral to realign it with the new planting points. Where there are no root disease problems, the same planting points can be used.

Training, pruning and crop manipulation

Training is done to divert the vine's energy to achieve the best cultural outcome. On a single-wire trellis, the vines need to be trained to encourage rapid coverage of the top wire, as this will optimise the use of sunlight. For pergolas and A-frame trellises, vines need to be trained onto multiple wires. This chapter includes basic recommendations for:

Training young vines to the trellis

Training is required at least weekly during the first 3 months. It involves the following steps:

1. Drive a long stake (that reaches the top wire) into the ground alongside the vine. Alternatively, install a string line from a short stake to the top wire or from the bottom wire to the top wire if a lower wire is used (see Figure 8.1).

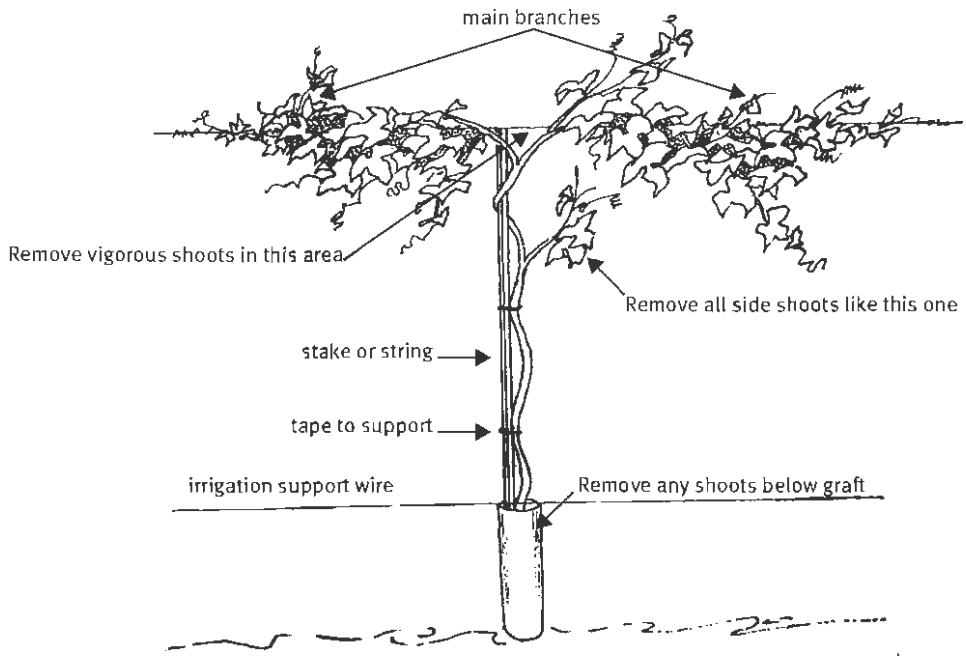


Figure 8.1 Training the young vine

2. Remove all side shoots above and below the graft, leaving a single leader, but retain any leaves on the leader (see Figures 8.1 and 8.2). On single-wire trellises and pergolas, continue to remove all side shoots (but not leaves) as they appear along the length of the leader until it reaches the top wire(s). On A-frame trellises, train suitably spaced side shoots onto and along the multiple wires on the sides of the A-frames.
3. If necessary, remove grafting tape to prevent strangulation of the vine. Most nurseries use degradable tape, which does not require removal. Check with your nursery.
4. Train the leader to the top wire by taping it to the string (see Figure 8.2, page 72).
5. When the leader is above the top wire, train it along the wire in the direction in which it is naturally growing (see Figure 8.1). Tape it at regular intervals (see Figure 8.3, page 72).
6. On single-wire trellises, select a side shoot near the junction of the leader and the wire and train it along the wire in the opposite direction (see Figure 8.1). Tape it at regular intervals. On A-frame trellises, pergolas and T-bar trellises, train more side shoots to the extra wires.
7. Cut back any vigorous shoots within 30 centimetres of the junction of the two main lateral branches (see Figure 8.1).

Figure 8.2 Tape the leader to the string (left) and remove all side shoots like this one (right)

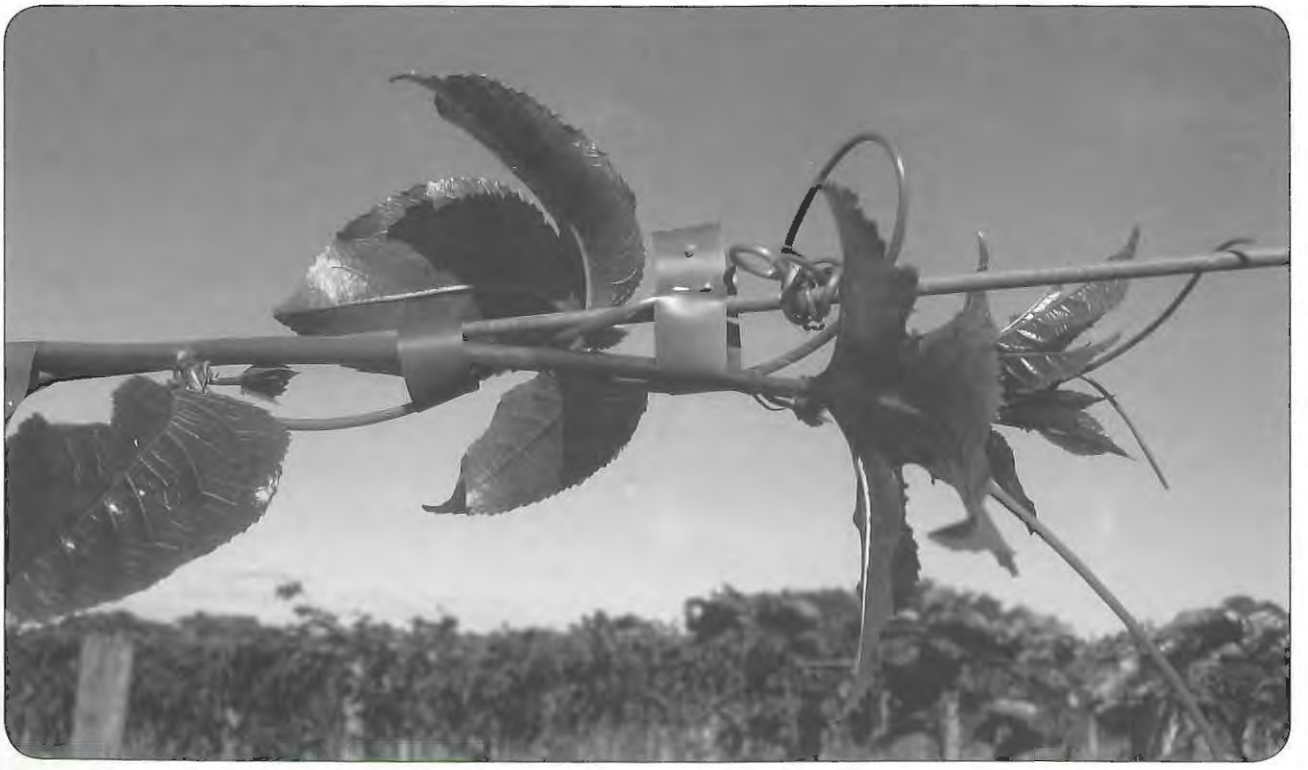


Figure 8.3 Tape the vine at regular intervals as it grows along the wire

Figure 8.4 Remove fruit within 30 centimetres of the junction

8. Remove any fruit on the stem and 30 centimetres either side of the junction, as these will limit the vine growth during the early stages of its development (see Figure 8.4). Do this until the neighbouring vine leaders meet on the top wire.

9. Clean the pruning secateurs with soapy water at regular intervals. This will reduce the possibility of virus transmission via sap on the secateurs.

Pruning mature vines

Pruning was practiced in the past to help control pests and diseases—it removed diseased and damaged laterals and opened up the foliage to allow better spray coverage. Now, however, most growers do not prune their vines. It is generally accepted that pest and disease problems are best dealt with by removing vines and replanting on a regular basis.

For single-wire trellises, the only routine pruning needed is to trim off any laterals hanging closer than 30 centimetres to the ground. This will help prevent the spread of soil-borne diseases onto the vine. Throwing long laterals back over the trellis is not recommended, as this can promote pest and disease problems.

On pergola systems, vines that fall down from the canopy need to be trimmed off after the fruit has been harvested, or lifted back into the canopy if there are gaps to be filled.

As before, clean all pruning secateurs with soapy water at regular intervals.

Crop manipulation

Prices for passionfruit fluctuate throughout the year according to supply and demand. Prices are usually highest from September to November, when supply is short because there is minimal flowering during the cooler months of June, July and August in southern Queensland and northern New South Wales.

It may be possible to encourage flowering at these times by:

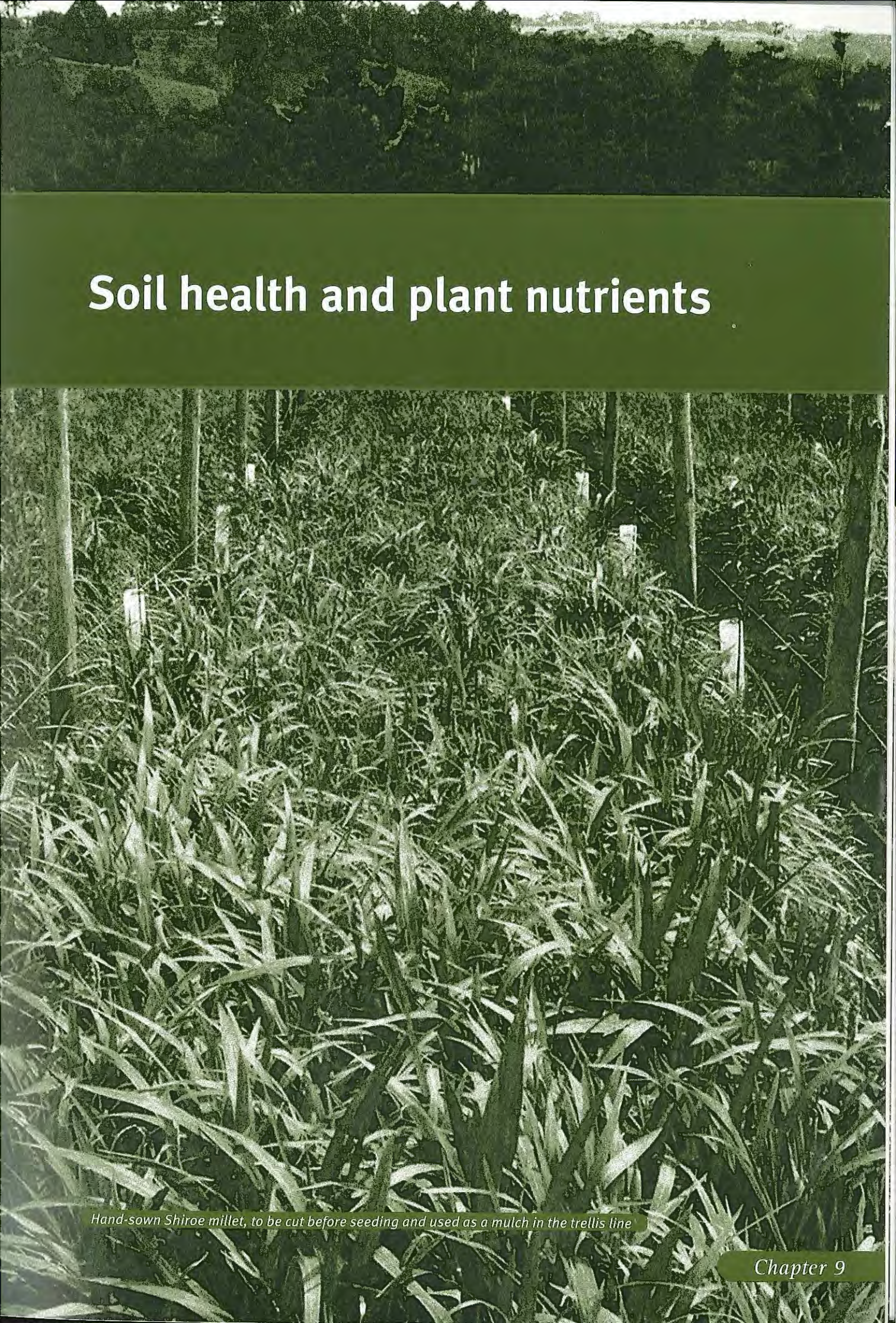
- pruning vines during summer to delay flowering
- replanting each year at a particular date to induce winter flowering (but take care with timing—trial different planting dates before using them on a large scale)
- selecting vines that produce an out-of-season crop.

There are no specific recommendations available for producing of out-of-season crops. You will need to work out your own system to suit your own plantation.

Some growers in tropical regions prune their vines to stimulate the timely production of vigorous new growth and so maximise fruit production to coincide with higher prices. Pruning is done with either secateurs or hedge trimmers. Timing appears to be site specific, and there are no tried and tested recommendations available. Other growers in tropical areas replant at specific times to target low production periods and high fruit prices.

Remember that if you do produce an out-of-season crop, it is likely to be much smaller than a main season crop—although the price per carton may be very high, you may only be able to produce a small number of cartons. It is probably better to view the out-of-season crop as a side issue producing a bonus income and not a core business issue that you rely on for financial viability.

Soil health and plant nutrients



Hand-sown Shiroe millet, to be cut before seeding and used as a mulch in the trellis line

A healthy, fertile soil is fundamental to productive and profitable passionfruit-growing. Soil health plays an important role in the long-term sustainability of the plantation and demonstrates good environmental stewardship. This chapter helps you understand soil fertility and the roles of the various plant nutrients:

Understanding soil health

Good soil health is a balance of physical properties, biological activity and chemical properties. A good balance optimises the soil's ability to:

- store and cycle water and nutrients
- decompose organic matter
- inactivate toxic compounds
- suppress pathogens
- enhance the efficacy of beneficial microbes (particularly at the root surface or rhizosphere)
- protect water quality.

Physical properties of soil

Physical properties of the soil (such as structure, texture, bulk density, porosity and plasticity) have a profound effect on soil health and on the health of the vine. Many of these properties are adversely affected by soil compaction. These properties influence the water infiltration rate, and consequently the effective use of rainfall and irrigation. They also influence susceptibility to erosion, soil aeration and the development of hardpan layers and surface crusting. Well-aerated soil with a low bulk density makes it easy for roots to grow, and encourages healthy root systems.

Biological soil health

The biological balance of healthy soils helps suppress the build-up of soil-borne pathogens such as phytophthora and maintains a stable ecological balance in the soil. There are many indicators of the biological health of the soil, including microbial biomass, microbial activity, bacterial and fungal biodiversity, the ratio of free-living to plant parasitic nematodes and earthworm density.

Enzymes produced by microorganisms play a key role in the oxidation and release of inorganic nutrients from organic matter, so it is important to provide a soil environment conducive to microbial activity.

Excessive use of copper pesticides in plantations can have a major and undesirable effect on the soil biota, so care should be taken to avoid excessive use of copper sprays and foliar run-off.

Chemical properties of soil

The pH of the soil is critical. Also, there must be adequate levels of essential nutrients and the correct nutrient ratios to support optimum plant growth.

Soil pH

Soil pH provides one of the most valuable indicators of soil health. Soil pH is a measure of soil acidity or alkalinity and is measured on a scale from 0 to 14. A pH of 7.0 is neutral; soil with a pH below this is acidic and soil with a pH above this is alkaline. The pH scale is a logarithmic scale; soil with a pH of 5.0 is 10 times as acidic as soil with a pH of 6.0.

Soil pH can be measured either in water or in calcium chloride. Tests using calcium chloride generally give results 0.5 to 0.8 pH units lower than results of equivalent tests in water. For passionfruit, soil pH is best kept in the range 5.5 to 6.5 (1:5 using a water test) or 5.0 to 5.5 (using a calcium chloride test).

The acidity or alkalinity of soil influences the quantity of essential mineral nutrients available for plant growth. Strongly acidic or alkaline soil pH levels limit the availability of most nutrients to the plant, as shown in Figure 9.1.

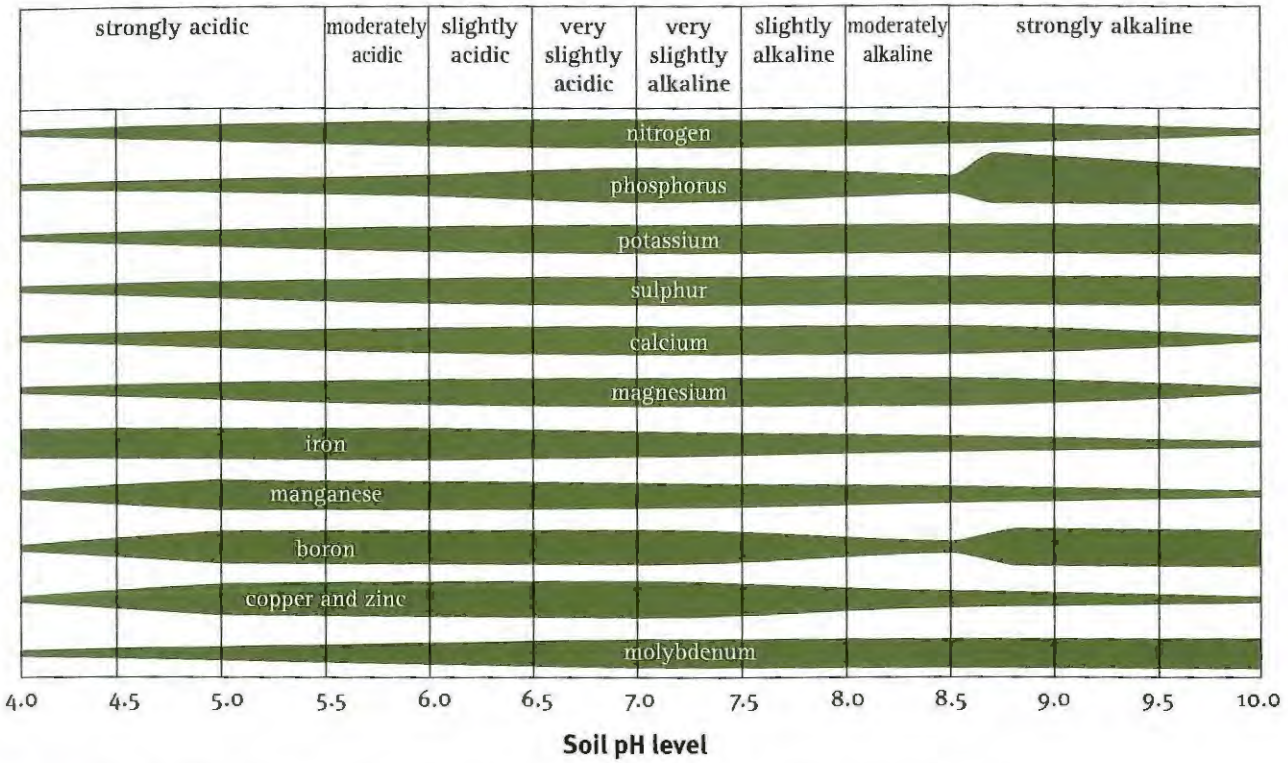


Figure 9.1 Effect of soil pH (water test) on nutrient availability (passionfruit optimum is 5.5 to 6.5)

If soil is too acidic, it can be treated with lime or dolomite. A complete soil analysis will show which one is most suitable. Dolomite contains calcium and magnesium, but lime contains calcium only. Lime and dolomite are highly insoluble; they should be applied at least 6 months before planting and must be properly incorporated into the topsoil. After planting, soil pH levels should be tested by soil analysis and corrected annually. In an established plantation, where it may not be possible to incorporate lime or dolomite, the fertiliser can be applied and left on the surface so that it slowly infiltrates the soil.

Lime

Lime and dolomite products are mined from natural deposits and therefore their purity varies. Because of this, some products will require higher application rates than others to achieve the same change in pH. Also, finer products will react in the soil and change the pH more quickly than coarser products will.

Different kinds of soil respond differently to lime. Table 9.1 shows the amounts of lime normally required to achieve pH correction based on soil types. These rates are a guide only and should be fine-tuned by soil analysis.

Table 9.1 Lime requirements to adjust pH levels into the desired 5.5 to 6.5 range

Original pH		Lime required (t/ha)		
Water test	Calcium chloride test	Sandy soil	Loam	Clay loam
4.5 to 5.0	4.0 to 4.5	4.0*	6.25*	7.5*
5.0 to 5.5	4.5 to 5.0	1.5	3.75*	5.0*
5.5 to 6.0	5.0 to 5.5	Not necessary to adjust pH in this range		

* Do not apply more than 2 tonnes per hectare per application. Split the applications if rates are higher than this and allow at least 6 months between applications.

Different lime and dolomite products may have different neutralising values and application rates will vary accordingly. The neutralising value indicates how much acidity the product will neutralise compared with pure lime (calcium carbonate), which has a neutralising value of 100. Pure dolomite (a mixture of calcium and magnesium carbonates) has a neutralising value of 109, so 0.92 kilograms of dolomite has the same neutralising value as 1 kilogram of lime.

Microfine Lime has 80% of its particles finer than 10 microns (micrometres) and 50% finer than 4 microns. It is more expensive than coarser products, but it reacts more quickly and can raise the pH deeper in the soil than other lime products can. Microfine Lime is often used for application as a suspension by fertigation, but extra agitation may be required to keep the powder in suspension in the fertigation tank. Rates are usually several times lower than for conventional lime rates. Seek an expert opinion on rates from your product supplier.

Very heavy applications of lime can lock up micronutrients such as zinc, iron and boron. Do not exceed 2.0 tonnes per hectare in any single application. For rates in excess of this, split the applications and allow 6 months between them so that the lime can be incorporated into the soil by irrigation and/or rainfall.

Causes of acid soil

Nitrogenous fertilisers containing ammonium acidify the soil and liming is required to balance this effect. The main causes of acidification are:

- The conversion of ammonium ions in fertiliser to nitrate ions (the form of nitrogen used by the plant) is an acidifying process.
- Nitrate leached from the soil is accompanied hy the loss of base cations (positively charged ions), such as calcium, magnesium and potassium. This depletes the surface soil of cations, resulting in an increase in soil acidity.

Cation exchange capacity

Cation exchange capacity (CEC) measures the ability of the soil to hold cations, including calcium, magnesium, potassium, sodium and aluminium. The CEC is the sum of these five cations. It is a valuable indicator of the chemical fertility of the soil and the availability of nutrients to the soil solution for plant growth.

Cations are held in the soil on the surfaces of clay colloids, organic matter and humus. The quantity held is determined by pH, clay content and soil type, as well as the organic matter and humus content. Typically, sands have CECs of 1 to 5, loams 4 to 10, clay loams 6 to 15, and clays 5 to 40. The CEC level in clay soils depends largely on soil pH.

The balance between cations should fall between certain limits:

- Calcium should always be present in the greatest amount and should constitute 60 to 70% of the CEC. As pH decreases, levels of calcium fall rapidly.
- Magnesium is normally the second most plentiful cation and should account for 10 to 20% of the CEC. Figures greater than 20% are normally only found in heavy black and grey soils formed on basalt. Many Australian soils have high subsoil magnesium levels. This is generally not detected in soil analyses, as soil samples are usually taken no deeper than 20 centimetres.
- Potassium should account for 2 to 5% of the CEC. The amount of potassium in sandy soils is generally quite low.
- Sodium is an undesirable cation normally present in small quantities. Larger amounts are only found in saline soils or those formed from marine sediments. Clay loams and clays with greater than 5% sodium have problems with water movement through the soil.
- Aluminium is also an undesirable cation and is only present in toxic forms where pH falls below 5.0 (1:5 water). Aluminium toxicity causes root damage and reduces growth.

Organic carbon and other indicators of soil chemical health

Organic carbon is a measure of soil organic matter. It is made up of any living or dead plant and animal material in the soil. Organic matter is a bighly desirable constituent of the soil. Benefits of increasing tbe level of organic matter in the soil include improving soil structure, drainage and water retention; providing nutrients such as nitrogen, phosphorus and sulphur; and increasing the CEC. Organic matter can be increased by promoting grass growth in the inter-row area. Organic carbon values of more than 4% are regarded as high, 2 to 4% as medium and 1 to 2% as low.

Understanding the important nutrients

The most important nutrients for plant health are nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulphur (S). They are often referred to as macronutrients because plants need them in large amounts. Their key features and uses are given in Tables 9.2 to 9.7.

Table 9.2 The key features and uses of nitrogen

Function	The key nutrient because of its predominant influence on the rate of vegetative growth. Productivity in passionfruit depends on the amount of vegetative growth; when vegetative growth is maximised, it provides the largest number of potential fruiting sites. Vigorous vegetative growth also helps to minimise the impact of passionfruit woodiness virus, particularly in winter, when vine growth naturally slows. A key component of chlorophyll (the green pigment in leaves), which is why nitrogen-deficient vines are light green or yellow. An essential requirement for the synthesis of plant hormones, which control vine growth.
Behaviour in soil and plant	Very mobile in the soil and leaches very readily, particularly in high-rainfall areas. May have to be topped up with small applications after extended periods of rain. Very mobile within the vine. New vegetative growth has a strong demand for nitrogen and it is moved from the old leaves to young leaves during periods of rapid growth. Too little reduces photosynthesis and hence leaf growth, causing reduced flowering and fruit set. On the other hand, too much is wasteful; it can lead to imbalances with other nutrients (such as potassium, calcium and magnesium) and creates the risk of excess nitrogen leaching into groundwater.
Fertiliser forms	Urea (46% N). This is normally the cheapest form of nitrogen. However, the nitrogen in this fertiliser will be lost as gas (ammonia) directly to the atmosphere (up to 30% in a week) if it is not washed into the soil by irrigation or rainfall immediately after application. Sulphate of ammonia (Gran-Am®, 21% N). Potassium nitrate (13% N and 38% K). Calcium nitrate (15% N and 18–19% Ca). Calcium ammonium nitrate (CAN, 27% N and 8% Ca).
Management	In young vines, apply about every fortnight so that the leaf canopy will grow as quickly as possible. In bearing vines, apply at least monthly with rates based on leaf analysis, crop removal and a visual assessment of vigour. Sufficient nitrogen must be available during the main flowering peaks. Avoid excessive applications (particularly in the ammonium form), as this can increase soil acidity. Because nitrogen is readily leached out of the soil in high-rainfall areas (which is both wasteful and damaging to the environment), apply small amounts regularly, such as by fertigation every 2 to 4 weeks.

Table 9.3 The key features and uses of phosphorus

Function	Essential for energy metabolism in cell maintenance and growth. Particularly important for root growth.
Behaviour in soil and plant	Only a small proportion is generally available for vine uptake. Very immobile in the soil and not readily leached; can be fixed in heavy soils, rendering it only slowly available to plants. The fixing process varies with soil type, and is most pronounced on krasnozems (red volcanic loams). Tends to be fixed in the top few millimetres of soil and is thus easily lost by erosion; when the soil is dry, is inaccessible to plant roots. Excessive soil levels may induce iron and zinc deficiencies. The iron to phosphorus ratio in leaves (Fe:P) is a reliable indicator of vine health. A ratio of less than 0.07 is often associated with phosphorus-induced iron deficiency (chlorosis). Very mobile in the plant, moving readily both upwards and downwards.
Fertiliser forms	Superphosphate (9% P, 11% S, 20% Ca). Triple superphosphate (19% P, 2% S, 18.5% Ca). Diammonium phosphate (DAP, 18% N, 20% P, 2% S). Monoammonium phosphate (MAP, 12% N, 22% P, 3% S). Rock phosphate (P content varies according to source; check content before calculating rates; very slow release).
Management	Passionfruit has a low requirement for phosphorus, particularly in the sandy loam soils where much of the crop is grown. As phosphorus is readily available in these soils, deficiencies are rare. Regular application may be necessary is in heavier clay soils, where phosphorus becomes fixed and unavailable to the vine. Here, banding of phosphorus fertiliser in a strip along the row will generally meet the vine's needs for several years. Base the calculation of rates on leaf and soil analyses. Apply in late summer. Although soil tests indicate the phosphorus status of the soil, they do not specify exactly how much of the soil phosphorus is available to the plant. Experience with horticultural crops in the subtropics has shown very poor relations between soil tests for phosphorus and plant response. If compound fertilisers containing a high proportion of phosphorus are used regularly, phosphorus levels may become excessive, resulting in an induced deficiency of some trace elements, especially zinc. Phosphorus is also important for growing a good green manure crop during land preparation and maintaining a healthy grass cover between the rows after vine establishment. Extractable soil phosphorus levels between 75 and 100 milligrams per kilogram (using the Colwell soil test) are required for optimum fruit production. Preplant application and incorporation will place phosphorus in the root zone and minimise erosion losses (which can lead to high phosphorus levels in waterways).

Table 9.4 The key features and uses of potassium

Function	After nitrogen, is the next most important nutrient for passionfruit. Is a major component of fruit and, if deficient, can have a significant impact on fruit size and quality. Influences water balance and movement in the plant. Synthesises starch and sugars with a direct effect on fruit quality. Increases the vigour and disease resistance of plants.
Behaviour in soil and plant	Very mobile in the soil and readily leached, particularly in sandy soils. Very mobile in the plant, readily moving in all directions. However, because it is not required to a great extent by leaves, new growth flushes do not draw large amounts of potassium away from the fruit. Peak requirements occur during fruit growth. Excess may lead to imbalances with calcium and magnesium.
Fertiliser forms	Potassium sulphate (sulphate of potash, 41% K, 16.5% S). Potassium chloride (muriate of potash, 50% K, 50% Cl); not often used as it can cause chloride burn. Potassium nitrate (38% K, 13% N).
Management	Generally apply monthly, with higher rates during the peaks of fruit growth (in spring and summer) and lower rates during late autumn and winter. Base rates on leaf and soil analyses and crop removal. Consider the availability of potassium in relation to that of other nutrients, such as calcium and magnesium. An excess of one of these nutrients can reduce the availability of others. For example, excessive applications of potassium fertilisers can induce a magnesium deficiency. Because potassium is readily leached out of the soil in high-rainfall areas (which is both wasteful and damaging to the environment), apply small amounts regularly, such as by fertigation every 2 to 4 weeks.

Table 9.5 The key features and uses of calcium

Function	Important for cell division and cell development in new leaves, fruit and root tips. Has a role in fruit ripening and fruit quality.
Behaviour in soil and plant	Relatively immobile in the soil. Mobile within the vine in an 'upward' direction towards the leaf tips with little remobilisation downwards. Levels in the leaf are important, and reflect not only the absolute amount of calcium in the soil but also its balance with magnesium and potassium. Low leaf calcium values can result from an excess of these other two elements. High soil levels may reduce uptake of manganese, zinc, boron, copper and phosphorus. While the need for calcium is high, calcium deficiency is rare. Problems develop only where soil pH is low or where excessive nitrogen reduces calcium uptake. Although coarse lime on the soil surface may show up in soil tests, it is largely unavailable to the plant.
Fertiliser forms	Calcium sulphate (gypsum, 18–20% Ca, 14–18% S). Calcium nitrate (18–19% Ca; 15% N). Calcium carbonate (lime, 35–40% Ca). Calcium magnesium carbonate (dolomite, 12–15% Ca, 8–12.5% Mg). Calcium ammonium nitrate (CAN, 8% Ca, 27% N).
Management	Timing and application rates for calcium, magnesium and potassium should be based on leaf and soil analyses because of the links between these nutrients and pH. Corrective application is only necessary once every few years. Aim to keep the soil pH (1:5 soil:water) around 5.5 to 6.5 (5.0 to 5.5 for krasnozem soils). Consider the availability of calcium in relation to that of other nutrients, such as potassium and magnesium. An excess of one of these nutrients can reduce the availability of others. Choose a calcium product according to the effect required. Lime (calcium carbonate) is normally used to raise soil pH where only calcium levels are low. Use dolomite (calcium magnesium carhonate) when soil pH needs to be raised and both calcium and magnesium levels are low. Use gypsum (calcium sulphate) when pH is within the desired range and the soil calcium level is low. Since lime and dolomite are insoluhle, and gypsum is relatively insoluble in water, apply them before the wet season to help with incorporation. Before buying any liming material, check the neutralising value, fineness and calcium and magnesium content. Finer particles of lime react more quickly. Fine agricultural lime with 98–100% of particles less than 0.25 millimetres in diameter is recommended.

Table 9.6 The key features and uses of magnesium

Function	An essential component of chlorophyll, which traps light energy, converting it to chemical energy used to produce sugars (photosynthesis). Also regulates the uptake of other plant nutrients and is essential for many biochemical cellular functions.
Behaviour in soil and plant	Relatively mobile in the soil and is absorbed by roots, mainly through passive diffusion. May compete with high soil concentrations of ammonium, potassium and calcium for uptake, leading to magnesium deficiency. Very mobile within the vine, moving readily from old leaves to new leaves under deficient conditions. Not required in large amounts, but deficiencies can occur in leached, acidic, sandy soils. High levels can interfere with the uptake of calcium and potassium and make the soil 'tighter'.
Fertiliser forms	Calcium magnesium carbonate (dolomite, 8–12.5% Mg, 12–15% Ca). Granomag® (magnesium oxide, 54% Mg); may be most cost-effective source because of its concentrated nature and ease of handling. Magnesium sulphate (Epsom salts, 9.5% Mg).
Management	Consider the availability of magnesium in relation to that of other nutrients, such as calcium and potassium. An excess of one of these nutrients can reduce the availability of others. Because of the links between pH, CEC, calcium, magnesium and potassium, base the calculation of rates and timing of these nutrients on leaf and soil analyses, and on the halance of cations. Choose a magnesium product according to the effect required. Use dolomite when soil pH, calcium and magnesium levels are all low and the ratio of calcium to magnesium is greater than 6:1. Make sure the dolomite used has a high neutralising value and a high degree of fineness. Use Granomag® (magnesium oxide) or magnesium sulphate when soil pH is within the desired range but the soil magnesium level is low.

Table 9.7 The key features and uses of sulphur

Function	An important component in proteins and chlorophyll.
Behaviour in soil and plant	Relatively mobile in the soil. Absorbed by roots with little impact from other nutrients on uptake and movement. Movement in the vine is mainly upwards. Once incorporated in proteins, cannot be remobilised for use in other parts of the plant in times of deficiency.
Fertiliser forms	Sulphate of ammonia (24% S). Superphosphate (11% S). Single superphosphate with sulphur (26.1% S). Gypsum (14–18% S). Elemental sulphur (98–100% S).
Management	There are no specific management strategies for sulphur fertilising in passionfruit. Under normal circumstances, fertilisers commonly used (superphosphate, sulphate of ammonia, sulphate of potash and gypsum) generally contain enough sulphur to meet vine requirements. If leaf sulphur levels are low, use these fertilisers in the fertiliser program.

Trace elements

Trace elements (also known as micronutrients) are extremely important, although only small quantities are usually required. Trace elements most likely to be deficient are boron (B), zinc (Zn), copper (Cu) and iron (Fe). Key features and uses of these are provided in Tables 9.8 to 9.11.

Table 9.8 The key features and uses of boron

Function	Important for cell division and cell growth, especially in areas of the plant where growth is occuring (e.g. flowers, fruit, shoot and root tips). Important for root health. Is the main trace element affecting fruit yield and quality. Too little reduces fruit set and affects fruit development, causing deformed fruit.
Behaviour in soil and plant	Very mobile in the soil. Easily leached from acidic soils, and rendered unavailable in calcareous (alkaline) soils and in very dry soils. Not very mobile within the plant, with any movement occurring upwards and little remobilisation downwards. Consequently, in most Australian growing environments, vines require a constant supply of boron throughout the year from small, regular applications.
Fertiliser forms	Borax (11% B). Solubor® (21% B); while Solubor costs more per bag than borax, the price per unit of boron is similar and Solubor is easier to mix. Boric acid (17% B).
Management	Many soils are naturally deficient in boron, but because the range between boron deficiency and toxicity is narrow, careful management is required. Use leaf and soil analyses to monitor levels. As boron is not easily translocated within the vine, there must be a ready supply from the soil. To apply boron evenly and to avoid toxicity, mix it with water and spray it on the ground. Alternatively, apply soluble forms (Solubor, boric acid) by fertigation. To treat boron deficiency in the short term, apply foliar boron sprays (100 grams per 100 litres of water) to the developing flush and flowers. However, follow-up soil applications will be needed. If a scheduled application is due but the plantation has received very little rain or irrigation since the last application, postpone the application until substantial rain or irrigation is received to avoid toxicity. Apply boron only if soil and leaf analyses indicate a requirement; boron toxicity can easily be produced by overdosing, especially on light soils. In the Carnarvon area in Western Australia, soil and water boron is high. This is generally countered by the naturally high pH of these soils, but can become a problem if the soil pH falls.

Table 9.9 The key features and uses of zinc

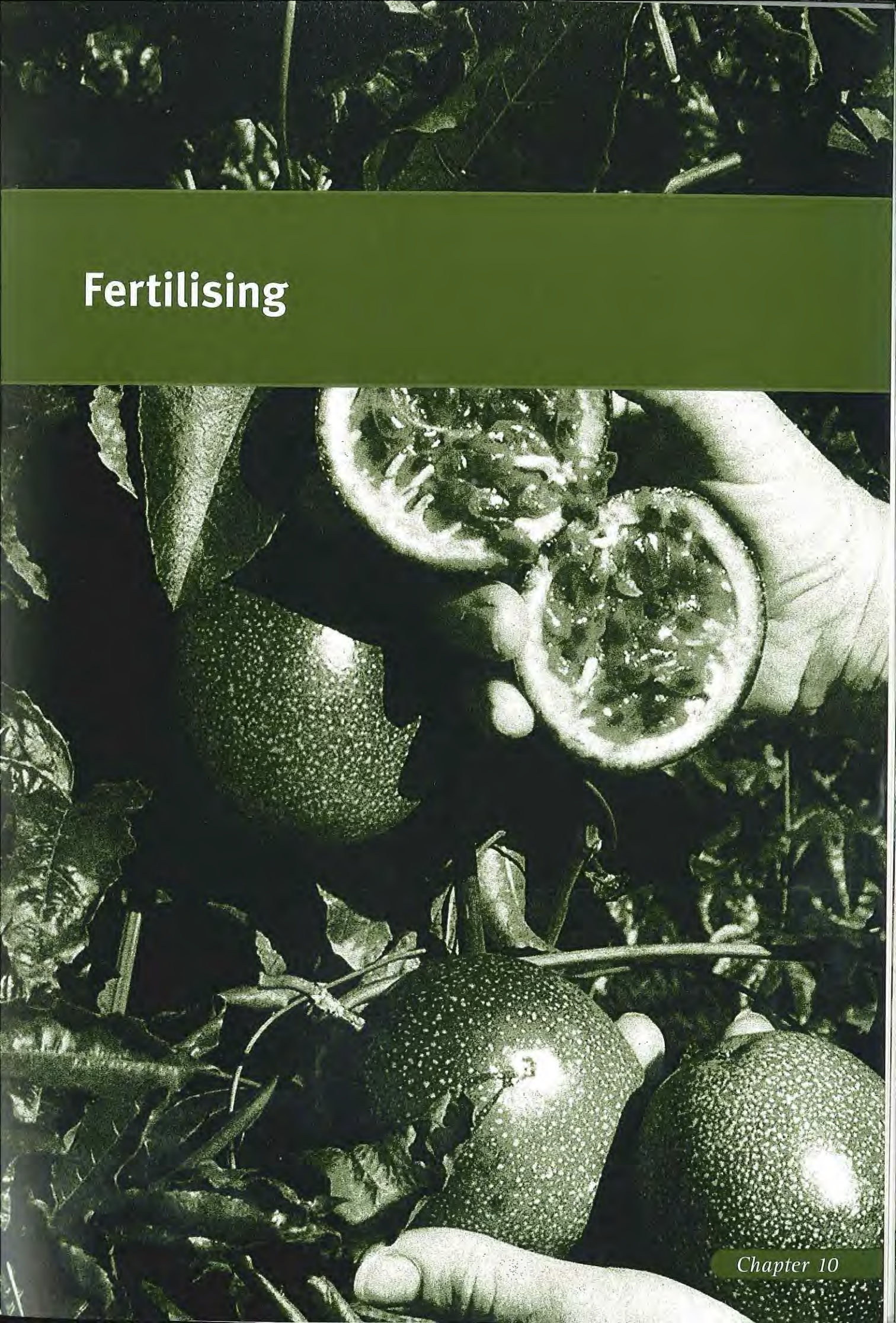
Function	Essential in the production of enzymes and plant hormones, so is required for new growth, which is distorted when deficiency occurs. Has a regulatory role in the uptake of water. Necessary for normal chlorophyll formation.
Behaviour in soil and plant	Not very mobile in the soil. Mycorrhizas assist with the root uptake of zinc in some plants. Research with other species indicates low mobility in plants and a tendency to accumulate in roots. Deficiency is reasonably common, particularly on soils with high pH or where heavy applications of lime have been made. High soil phosphorus levels also inhibit uptake. There is evidence in red krasnozem soils that plants have trouble with uptake.
Fertiliser forms	Zinc sulphate heptahydrate (23% Zn). Zinc sulphate monohydrate (36% Zn). Zinc oxide (80% Zn).
Management	In most soils, there should be sufficient uptake from soil-applied zinc to overcome a deficiency. However, in red kraznosem soils, concentrate the zinc in a band along the dripline of the vines. Where necessary, use foliar sprays as a supplement (100 grams of zinc sulphate heptahydrate per 100 litres of water). Zinc becomes less available under high pH or high soil phosphate conditions and can often be deficient. In the coastal silicate sands of south-western Western Australia, zinc fixation can be an issue and levels need to be monitored carefully. Banding of zinc fertilisers in the root zone and mulching to increase soil organic matter can help.

Table 9.10 The key features and uses of copper

Function	Involved in various plant processes such as photosynthesis and nitrogen metabolism. Also important in the production of lignin, which provides strength to the growth of lateral branches.
Behaviour in soil and plant	One of the least mobile elements in the soil and not easily leached. Not readily mobile within the plant, though if present in sufficient quantities, will be translocated from older to younger leaves. Deficiency is normally only a problem in leached, sandy soils receiving high nitrogen, or where soil phosphorus is very high. High levels in soil may induce an iron deficiency.
Fertiliser forms	Bluestone (copper sulphate pentahydrate, 25% Cu). Copper is also available in several fungicides, including copper oxychloride and copper hydroxide. If copper fungicides are regularly used for control of diseases, there is generally no need to use copper fertilisers.
Management	Routine sprays of copper-based fungicides for disease control generally prevent copper deficiency from developing. Remember that excessive use of copper pesticides in plantations can have an undesirable effect on the soil's biological health; avoid excessive use of copper fungicide sprays.

Table 9.11 The key features and uses of iron

Function	Critical in the production of chlorophyll.
Behaviour in soil and plant	Generally abundant in the soil, where it is relatively mobile. Not very mobile within the vine. Deficiency is generally associated with either a soil pH greater than 7.0 (1:5 water test), or high levels of soil phosphorus, or high levels of soil manganese.
Fertiliser forms	Iron sulphate (23% Fe), for use in most situations. Iron chelate (iron EDDHA, 5–15% Fe), for use in soils with a very high pH or very high calcium levels.
Management	Iron deficiency can be corrected by lowering the pH with sulphur or by using sulphate of ammonia instead of urea for nitrogen requirements. However, where high soil calcium and phosphorus levels cause the iron deficiency, applications of iron sulphate are unlikely to he effective. In these situations, use iron chelate instead.



Fertilising

Chapter 10

An unmanaged approach to fertilising passionfruit can lead to excessively low or high levels of some nutrients in both the soil and vines, which may cause several problems:

- *reduced yields and poor fruit quality*
- *nutrient run-off (from excessive applications) into watercourses, causing environmental damage both within and outside the property*
- *financial loss, either from fertiliser being applied where it is not needed or yield loss through inadequate nutrition.*

Blanket fertiliser applications fail to recognise that different varieties and different blocks of vines may have different fertiliser needs. To maximise profits, it is important to develop and implement a fertilising program that maximises vine growth and quality fruit production. The following information will help you do this:

Preplant soil analysis and fertilising

Preplant soil analysis is the only accurate way of determining the fertiliser needs of the plantation during the 6 to 12 month establishment period, because the plants are not old enough for leaf-tissue analysis.

Use chemical soil analysis to ensure that the soil pH and nutrients are within the adequate range before planting. Have a soil analysis done at least 6 months before planting; this allows plenty of time to apply the required fertilisers and condition the soil. This is particularly important for insoluble nutrients (such as calcium and magnesium) and those with limited mobility (such as phosphorus, zinc and copper), which must be worked into the root zone. It is difficult to do this after the vines have been planted. In phosphorus-fixing soils, concentrate phosphorus fertiliser in a narrow band along the intended row to reduce the rate of fixation.

Buy a soil sampling kit from a reputable laboratory at your local farm supply store. Follow the sampling instructions and send the sample away for analysis. Results should be back in about 2 weeks and will usually be interpreted by the laboratory analysing your sample. They will recommend appropriate fertilisers and rates to bring the pH and levels of all nutrients within the desired ranges.

Also consider the physical properties of the soil, since they can have a profound effect on root development, soil aeration and infiltration of water. Before planting, take corrective measures such as deep ripping to break up hardpans, applying gypsum to improve soil structure and incorporating organic matter.

Consider using natural mineral fertilisers such as Alroc™ and Natra-Min™.

Fertilising young vines

Young vines have a high requirement for nitrogen and (depending on soil type) phosphorus, but have a relatively low requirement for potassium until bearing commences. If nutrient levels were adjusted properly before planting, only small amounts of nitrogen and phosphorous need to be applied to promote vegetative growth and root development during the first 6 months of growth.

Do not start fertilising until the newly planted vines have started to put on new growth. This normally takes about 2 weeks. Then fertilise little and often, about once every fortnight. For each application, use about 50 grams of diammonium phosphate (DAP) per vine. Gradually increase this to about 100 grams per vine at 6 months after planting.

DAP is considered the safest form of nitrogen to apply to young vines. Avoid using urea or other highly soluble forms of nitrogen, as the risk of fertiliser burn is too great. If preplant soil analysis was not done, alternate DAP with a complete fertiliser such as Nitrophoska Blue™ or Rustica Plus™.

Spread the fertiliser in a broad doughnut-shaped ring around the vine out to about 50 centimetres from its base. Keep the fertiliser 10 centimetres away from the stem. Alternatively, apply the fertiliser through the irrigation system (by fertigation).

Refer to your preplant soil analysis for details of other fertilisers that may need to be reapplied at this point.

Fertilising bearing vines

Plant nutrition and fertilising is a complex subject. Developing a balanced and efficient fertiliser program for your plantation may take several years. Fertiliser rates are not indicated by just a single soil or leaf analysis. Building up data and gaining experience in interpreting data over several years is essential for good nutrition management.

If you have addressed any deficiencies and imbalances before planting, most of the fertiliser requirements for the next 2 to 3 years are going to be regular maintenance dressings of nitrogen and potassium. These are required in larger amounts than the other nutrients (see Table 10.1) and they leach from the root zone readily. Maintenance dressings of boron may also be required in small amounts.

Once vines reach bearing age (from about 6 months onwards), nitrogen and potassium fertiliser application should be based on the following principles:

1. **Nutrient replacement.** This is an allowance for nutrients that:
   - have been removed by the harvested crop
   - have been lost through leaching and fixation
   - are locked up in the vine foliage, roots and stems and so are not available for fruit growth.
2. **Nutrient monitoring.** This is adjustment of fertiliser rates according to the results of soil and leaf analyses.

Nutrient replacement and basic fertiliser rates

A starting point for deciding how much fertiliser needs to be applied to vines is to replace the nutrients that are removed from the plantation in the harvested fruit. In very simple terms, the amount of a nutrient contained in the fruit is the minimum amount that will need to be replaced to maintain soil fertility at its original level.

A guide to nutrient removal was derived from preliminary research in New South Wales (see Table 10.1).

Table 10.1 Nutrient removal in fruit

Nutrient	Kilograms removed per tonne of fresh fruit
Nitrogen	3.32
Phosphorus	0.33
Potassium	4.30
Calcium	0.25
Magnesium	0.20
Sulphur	0.32

In addition to this, two other factors need to be taken into account:

1. **The amount of nutrient that is removed by leaves, roots and stems.** This amount is locked up in the vine's vegetative growth and therefore is not available for fruit production. The amount is estimated to be equal to that which is lost through harvested fruit (except for calcium, which is locked up in significantly greater amounts).
2. **Losses from leaching by heavy rainfall, excessive irrigation, soil fixation and soil erosion effects.** Expect the following losses and adjust the rates as specified:
   - 30–50% of nitrogen lost by leaching, with the higher levels occurring in sandy soils. Increase nitrogen rates by 40%.
   - 50–80% of phosphorus lost by fixation, with the higher levels occurring in red krasnozem soils. A further 5–20% of phosphorus may be lost by soil erosion in run-off, with the higher levels occurring in sandy soils prone to erosion. Increase phosphorus rates by 100%.
   - 20–30% of potassium lost by leaching, with the higher levels occurring in sandy soils. Increase potassium rates by 30%.
   - 5–20% of calcium lost by soil erosion in run-off, with the higher levels occurring in sandy soils prone to erosion. Increase calcium rates by 10%.

- 20–30% of magnesium lost by leaching, with the higher levels occurring in sandy soils. Increase magnesium rates by 25%.
- 5–20% of sulphur lost by soil erosion in run-off, with the higher levels occurring in sandy soils prone to erosion. Sulphur is also temporarily immobilised during breakdown of crop residues. Increase sulphur rates by 10%.

Because soil type and weather conditions vary so much, you may need to adjust these rates to suit your particular conditions.

These factors combined form the basis of the 'nutrient replacement concept' method of calculating fertiliser requirements. For example:

1 tonne of fruit removes 3.32 kilograms of nitrogen:	3.32
Double this to account for the nitrogen tied up in the vegetative growth:	6.64
Add 40% of this amount (2.656) to account for leaching loss:	9.296

The estimated amount of nitrogen needed to replace 1 tonne of fruit is therefore about 9.3 kilograms.

Using similar calculations gives the requirements for full nutrient replacement shown in Table 10.2.

Table 10.2 Annual nutrient requirements for full replacement (fruit and vine nutrient removal plus adjustment for leaching and other losses)

Crop yield (t/ha)	Nutrient requirement (kg/ha)					
	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Sulphur
5	46	6	56	3	2.5	4
10	92	14	112	6	5	8
15	138	20	168	9	7.5	12
20	184	26	224	12	10	16
25	230	32	280	15	12.5	20

A spreadsheet (in Excel format) to help calculate the amount of fertiliser needed for nutrient replacement is available from the New South Wales Department of Primary Industries website at www.dpi.nsw.gov.au

An example of annual basic rates for nitrogen and potassium calculated using the nutrient replacement concept is shown in Table 10.3 (page 94). This example is for a plantation yielding a crop of 20 tonnes per hectare and is based on annual nutrient removal rates of 184 kilograms per hectare for nitrogen and 224 kilograms per hectare for potassium (see Table 10.2). The annual requirement for nitrogen and potassium is broken up into 10 applications throughout the year with rates varying according to seasonal demands.

The rates given in Table 10.3 are not intended for use as a general recipe for fertilising passionfruit. They are the basic starting points for the two main nutrients, nitrogen and potassium, which are generally the only nutrients requiring regular application. You will need to use leaf and soil analysis data as well as production records and forecasts to adjust these rates for your plantation. Information on how to do this is given in this chapter under 'Interpretation of soil analysis results' and 'Interpretation of leaf-tissue analysis results'.

Replacement rates for nutrients other than nitrogen and potassium are determined by monitoring the levels of the nutrients in soil and leaf analysis results (see Table 10.4, page 96 and Table 10.5, page 98).

Table 10.3 Recommended starting point rates for nitrogen and potassium, for a plantation yielding 20 tonnes per hectare

Month	Nitrogen (g/vine)	Potassium (g/vine)
July–August (total)	22	28
September	32	39
October	23	28
November	22	28
December	22	28
January	22	28
February	32	39
March	12	12
April	12	12
May–June (total)	22	27
Total per vine	221	269
Total per hectare*	184 000	224 000

* Assuming 833 vines per hectare

Nutrient monitoring

As well as calculating approximate fertiliser rates based on *nutrient replacement*, you should use *nutrient monitoring* to modify these rates where analysis results indicate the need.

Monitoring the nutrient status of your plantation is valuable for fertiliser management. Soil and leaf analysis results help you objectively assess how the basic fertiliser rates should be amended to suit your situation. The potential savings and the gains in yield are considerably greater than the cost of these analyses. This is because the analyses provide valuable information that allows you to treat nutrient deficiencies and imbalances before they significantly affect crop yield and quality. In addition, where an environmental management system (EMS) process is used to manage and monitor the impact of growing passionfruit on the environment (see Chapter 19), you can use plant and soil nutrient data to endorse and justify your fertiliser program.

Two monitoring tools will help you develop and maintain the best fertiliser program for your plantation:

- **Soil analysis in bearing vines.** This ensures that soil pH is kept within the desired range and checks the important balance between pH, calcium, magnesium and potassium. Soil analysis results can also assist greatly with interpretation of leaf analysis data if soil and leaf sampling are done at the same time. Soil analysis should be done at least every 2 years.
- **Leaf-tissue analysis in bearing vines.** This annual analysis allows the fertiliser program to be fine-tuned each year to keep all nutrients within the optimum range. It allows you to consider variables such as the season, the crop load and the condition of the vine.

Samples should be taken at the same time each year. This allows you to easily compare current analysis results with those of previous years, because you will know that any differences are not due to different seasons or different stages in the annual growth cycle of the plant.

The changes in soil and leaf nutrient levels are just as important as the levels themselves. You can interpret any changes in the nutrient analysis levels in the light of the fertiliser applications and growing conditions (e.g. heavy rainfall causing leaching of nutrients) since the previous analysis. It is therefore important to keep accurate records of analysis results and fertiliser applications for your plantation blocks. For example, if analysis results show a decline in a particular nutrient's levels in the leaf tissue, you should increase the amount of fertiliser containing that nutrient in future. Conversely, if a nutrient level increases, you should decrease the amount of fertiliser containing that nutrient.

Soil sampling

Samples can be taken at any time, but it is best to take them at the same time as the leaf analysis to help with interpretation. Make sure the maximum possible time has elapsed since the last fertiliser application to reduce the chance of residual fertiliser distorting the analysis.

Buy a soil sampling kit from your farm supply store and follow the instructions. Take samples of soil from the top 20 centimetres. It is best to take separate samples from areas in the plantation that are different from each other (e.g. are of different age, history or soil type). Each sample should comprise about 15 subsamples taken across the area to be represented. Take the subsamples from under the vine canopy but no closer than 30 centimetres to the stem, and within the wetted area of the irrigation system. Use a plastic or stainless steel sampling tool to take the subsamples. If one of these is not available, use a clean and non-rusty soil auger or spade. Place the subsamples in a clean plastic bucket.

When you have collected all 15 subsamples, thoroughly mix the soil and remove about a cupful for analysis. Do this by taking pinches of soil periodically during the mixing process. Place the cupful portion on clean paper or plastic sheeting in the shade for a few hours to air-dry. Place the air-dried soil in the plastic sample bag provided with your test kit. Send it to the laboratory as soon as possible.

Request a full soil test, including pH, electrical conductivity, phosphorus, potassium, calcium, magnesium, sodium, aluminium and trace elements. Most soil tests do not measure total nutrient content, but rather use various procedures to extract 'available' fractions of the nutrient from the soil.

Interpretation of soil analysis results

The laboratory analysing your samples will usually interpret the results and provide recommendations of appropriate fertilisers and rates to bring the levels of all nutrients within the desired range.

If you want to do this yourself, or at least understand how it is done, read the broad guidelines for interpreting soil analysis results given in Table 10.4. Soil nutrient levels from analyses vary from laboratory to laboratory depending on extraction procedures used, so it is important to relate the result to the extraction procedure. The most commonly used extraction methods and matching desired ranges for these methods are shown in Table 10.4, but they will not apply to every laboratory.

To work out what fertilisers you need to apply, compare your soil analysis results with the optimum ranges given in Table 10.4. Only apply more than the maintenance dressings of nitrogen, potassium and boron when your soil levels need to be adjusted upwards to bring them into the optimum range. Where the analysis results indicate that levels are too high, reduce the amount of nutrient applied or abstain from applying any. In most soils, nitrogen, potassium and boron are probably the only nutrients that need to be added. In less-fertile, sandy soils, phosphorus, calcium and magnesium as well as nitrogen, potassium and boron may need regular adjustment.

Table 10.4 Optimum soil nutrient levels from commonly used extraction methods and suggested interpretations of results

Element/scale and extraction method	Optimum range	Interpretation—suggested adjustments to the basic rates indicated in Table 10.3 or Table 10.2
pH (1:5 water)	5.5–6.5 (5.0–5.5 for krasnozems)	5.5 is about ideal. If below 5.5 and if the calcium-to-magnesium ratio (see below) is between 3:1 and 5:1, apply dolomite. Otherwise, use lime. Normally apply once a year, but in a high-rainfall region apply every 6 months to reduce the amount of fertiliser lost in rainwater run-off.
pH (1:5 $CaCl_2$)	5.0–5.5	5.0 is about ideal. If below 5.0, and if the calcium-to-magnesium ratio (see below) is between 3:1 and 5:1, apply dolomite. Otherwise, use lime.
Organic carbon (Walkley–Black)	2.0–5.0%	If less than 2%, use green manure crops, mulches or organic manures.
Nitrate nitrogen (1:5 aqueous extract)	More than 20 milligrams per kilogram	If less than 20, apply at basic rates plus 30–50% if losses expected. If 20–40, apply at basic rates. If more than 60, apply at less than basic rates.
Phosphorus (Colwell)	75–100 milligrams per kilogram	If less than 75, apply at 30 kilograms per hectare; more if losses expected. If 75–100, apply at 20–30 kilograms per hectare. If more than 100, no application is necessary. Note: For phosphorus-fixing soil types, an extra allowance is needed. For karri loams, podzols and red earths, add an extra 50% to the above rates; for krasnozems, increase by 100%.
Potassium (exchangeable)	More than 0.5 milliequivalents per 100 grams	If less than 0.5, apply at basic rates plus 20–30% if losses expected. If 0.5–1, apply at less than basic rates. If more than 1, no application is necessary.
Calcium (exchangeable)	More than 7.5 milliequivalents per 100 grams	If less than 7.5, apply lime, dolomite or gypsum, depending on pH and the calcium-to-magnesium ratio. If more than 7.5 and pH (1:5 water) is more than 5.5, no application is necessary.
Magnesium (exchangeable)	More than 1.6 milliequivalents per 100 grams	If more than 1.6 and pH (1:5 water) is more than 5.5 and the calcium-to-magnesium ratio is between 3:1 and 5:1, no application is necessary. If less than 1.6 and pH (1:5 water) is more than 5.5 and the calcium-to-magnesium ratio is greater than 5:1, apply magnesium oxide at 100–200 kilograms per hectare.
Sodium (exchangeable)	Less than 2 milliequivalents per 100 grams	If more than 2, check quality of irrigation water and height of water table.
Chloride (1:5 aqueous extract)	Less than 300 milligrams per kilogram	If more than 300, check quality of irrigation water and height of water table and do not use any chloride-based fertiliser (such as muriate of potash).
Conductivity (1:5 aqueous extract)	Less than 2 decisiemens per metre	If more than 2, check quality of irrigation water, fertiliser rates and height of water table.

Element/scale and extraction method	Optimum range	Interpretation–suggested adjustments to the basic rates indicated in Table 10.3 or Table 10.2
Copper (DTPA)	0.3–10 milligrams per kilogram	Rarely out of adequate range.
Zinc (DTPA)	2–10 milligrams per kilogram	If less than 2, check leaf analysis level to see if overall deficiency is confirmed. Follow recommendations there.
Manganese (DTPA)	4–45 milligrams per kilogram	Rarely out of adequate range. If more than 45, aim for a pH (1:5 water) of 6.5.
Iron (DTPA)	More than 2 milligrams per kilogram	Rarely out of adequate range.
Boron (hot calcium chloride)	0.5–1 milligrams per kilogram	If less than 0.5, check leaf analysis level to see if overall deficiency is confirmed. Follow recommendations there.
Calcium-to-magnesium ratio	3:1–5:1	See pH, calcium and magnesium above.
Total CEC	More than 7	See pH, calcium, magnesium and potassium above.
Cation balance (%)	Calcium 60–70% Magnesium 10–20% Potassium 2–5% Sodium less than 5%	See pH, calcium, magnesium and potassium above.

Leaf-tissue sampling

The level of nutrients in leaves varies naturally with the seasonal growth of the vine throughout the year (the phenological cycle). Sampling should take place at the same time each year to eliminate the effects of seasonal variations. Leaf sampling should be done during July or August when the vines have slowed in growth. The optimum levels given in Table 10.5 are for this time of the year.

Buy a leaf sampling kit from your farm supply store and follow the instructions. Take leaf samples from vines representative of the plantation, not from vines on the perimeter, diseased vines or vines under stress. It is best to match the areas to be represented by the sample to those of the soil sample blocks. Subsample 20 vines, taking a leaf from six laterals on each vine. Take leaves from hoth sides of the vine. Select the last fully expanded leaf from a strong-growing lateral (see Figure 10.1). This is generally about the fourth to eighth leaf from the growing tip. After sampling, keep the leaves cool and send them to the laboratory as soon as possible.

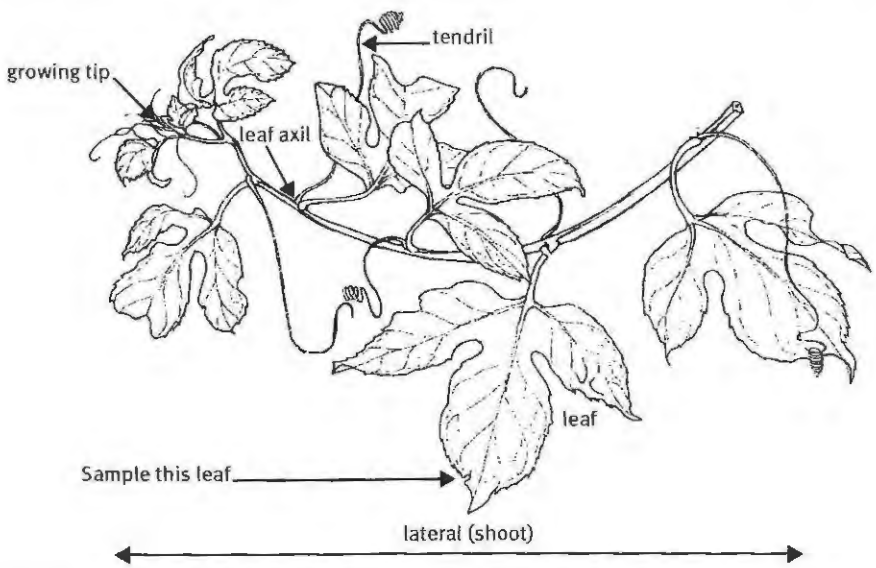


Figure 10.1 Correct leaves to sample for leaf analysis

Interpretation of leaf-tissue analysis results

The laboratory analysing your samples will usually interpret the results and provide recommendations of appropriate fertilisers and rates to bring the levels of all nutrients within the desired range.

If you want to do this yourself, or at least understand how it is done, read the broad guidelines in Table 10.5. Unlike soil analysis results, leaf-tissue test results from all reputable laboratories should give the same results for the same sample. The leaf nutrient ranges shown in Table 10.5 apply to leaves analysed by the dried-tissue technique; they do not apply to results obtained from sap analysis.

To work out what fertilisers you need to apply, compare your leaf-tissue analysis results with the optimum ranges shown in Table 10.5. Only apply more than the maintenance dressings of nitrogen, potassium and boron when your leaf levels need to be adjusted upwards to bring them into line with the optimum range. Where the analysis results indicate that levels are too high, reduce the amount of nutrient applied or do not apply any.

Table 10.5 Optimum leaf nutrient ranges for passionfruit and suggested interpretation of results

Nutrient	Optimum range	Interpretation*
Nitrogen	4.25–5.25%	If below desired levels, may indicate insufficient fertiliser, high leaching rates or root damage.
Sulphur	0.2–0.4%	Rarely out of range, but if low use sulphur-based fertilisers in the fertiliser program.
Phosphorus	0.25–0.35%	If within desired range, no action is necessary. If below desired range, may indicate insufficient fertiliser, soil fixation or low pH.
Potassium	2.0–3.0%	If below desired levels, may indicate insufficient fertiliser or competition for uptake with high levels of calcium and/or magnesium.
Calcium	1.0–2.5%	If below desired range, may indicate low soil pH, insufficient calcium fertiliser or an imbalance with potassium and/or magnesium. Use soil analysis results for potassium, calcium, magnesium and pH to determine type of fertiliser and rates of application. If within or above desired range, no action is necessary.
Magnesium	0.3–0.5%	If below desired range, may indicate low soil pH, insufficient magnesium fertiliser or an imbalance with potassium and/or calcium. Use soil analysis results for potassium, calcium, magnesium and pH to determine type of fertiliser and rates of application. If within or above desired range, no action is necessary. Note: Magnesium deficiency symptoms are often seen in cooler weather, particularly on older leaves, and are often known as 'winter yellows'. These symptoms normally disappear as conditions improve.
Zinc	50–80 parts per million	If below desired range, may indicate high soil pH or high rates of applied phosphorus or nitrogen fertiliser. Low levels are more common in sandy soils. If soil levels are also low, apply zinc sulphate monohydrate to soil under vines at a rate of 2–3 grams per square metre. Apply foliar sprays of zinc sulphate heptahydrate in spring for short-term assistance. If within or above desired range, no action is necessary.
Copper	5–20 parts per million	Rarely out of range if copper sprays are used for disease control.
Sodium	Less than 0.15%	If more than desired level, check quality of irrigation water and soil analysis results.
Chloride	Less than 1.5%	If more than desired range, check quality of irrigation water and soil analysis results. Do not use chloride-based fertilisers.

Nutrient	Optimum range	Interpretation*
Iron	100–200 parts per million	Rarely out of range except where heavy applications of phosphorus, lime or dolomite have been made, or where manganese levels are very high.
Boron	40–60 parts per million	If below desired range, evenly apply 10 grams of borax or 5 grams of Solubor to soil around each vine. As boron leaches easily, repeat 6 months later. On sandy soils, split each application and apply 1 month apart. Note that it is easy to overapply boron and cause boron toxicity. If within or above desired range, no action is necessary.
Manganese	50–350 parts per million	Rarely out of range, especially where mancozeb is regularly used for disease control. If below desired range, apply a foliar spray of manganese sulphate at 100 grams per 100 litres of water. If very high, check soil manganese levels and soil pH. If soil manganese is above 45 parts per million, aim for a soil pH (1:5 water) of 6.5 to reduce level of manganese in soil solution.

* If soil analysis has also been done, take into account soil analysis results.

Fertiliser application methods

Several methods of applying fertiliser are commonly used and there are many different types of fertiliser from which to choose. The following notes will help you decide which application method and fertiliser suits your situation.

Basal application

This is the application of a solid fertiliser to the soil around the vine. Set up the fertiliser spreader to place most of the fertiliser under the vine canopy.

Three types of fertiliser can be used:

- straight inorganic (mined or manufactured) or mixed inorganic fertilisers
- organic fertilisers
- non-artificial mineral fertilisers.

Inorganic (mined or manufactured) fertilisers

Inorganic fertilisers are available as straight nutrient sources or as mixtures (also known as blends). Straight fertilisers are usually preferred, as they allow each nutrient requirement to be addressed accurately and are cheaper per unit of nutrient than mixed fertilisers.

Note that urea (a commonly used straight fertiliser containing nitrogen) is readily converted to ammonia in the soil, often within a couple days of application. If the urea is not washed into the soil by rain or irrigation, large losses of nitrogen can occur through volatilisation (where the ammonia changes to a gas and is then lost into the atmosphere).

Mixed fertilisers (often called N:P:K) are convenient to use but may cause a nutrient imbalance by oversupplying one nutrient and undersupplying another. For example, continued use of these fertilisers may result in a build-up of phosphorus.

The nutrient content of a fertiliser is displayed on its label. Mixed fertilisers are usually described by the percentages of nitrogen, phosphorus and potassium (N:P:K) contained in the fertiliser and there is a wide range

available. Some mixed fertilisers also contain trace elements (such as copper, zinc and boron), but the amounts are often insufficient to correct deficiencies.

Another important issue in the selection of fertilisers is how much they will contribute to soil acidity (see Table 10.6). Most mixed fertilisers are based on sulphate of ammonia and will acidify the soil.

Table 10.6 Acidifying effects of common fertilisers

Fertiliser	Acidifying effect
MAP	Highly acidifying
Sulphate of ammonia	Highly acidifying
DAP	Acidifying
Urea	Acidifying (neutral if no leaching)
Potassium nitrate	Non-acidifying
Superphosphate	Non-acidifying
Muriate of potash	Non-acidifying

If you have a salinity problem, choose fertilisers with low salt indexes. Salt indexes of common fertilisers are given in Table 10.7.

Table 10.7 Salt indexes of common fertilisers

Fertiliser	Salt index*
Muriate of potash	114
Urea	75
Potassium nitrate	74
Sulphate of ammonia	69
Sulphate of potash	46
DAP	34
MAP	30
Gypsum	8
Superphosphate	8
Lime	5
Dolomite	1

* For comparison, common table salt has a salt index of 154.

Organic fertilisers

Organic fertilisers are useful in improving soil structure, organic matter levels and microbial activity. Their chemical composition, however, is variable and often low in some nutrients (such as potassium). They are recommended as supplements to the manufactured fertilisers. Do not apply raw animal manures to fruiting vines, because this creates a significant risk of microbial contamination of fallen fruit.

The use of organic fertilisers is encouraged during orchard establishment to:

- increase soil organic matter levels
- improve soil physical structure
- increase water storage

- increase nutrient availability
- suppress disease organisms through increased microbial activity.

Where organic matter is applied as a nutrient improvement, nutrient release rates are lower than for manufactured fertilisers. Deep-litter fowl manure should be stored for 1 to 2 months before spreading, to allow some decomposition. Ideally, it should be stored under cover to prevent wetting and leaching of valuable nutrients such as nitrogen and potassium. Caged-fowl manure may be an alternative, but it is stronger than the deep-litter manure, so use lower rates.

Mill mud (a by-product of sugarcane milling) is sometimes available in tropical and subtropical coastal districts. Be aware that weed seeds may be moved into plantations with this material.

Volatilisation of ammonia can be high from any fertilisers that contain nitrogen in the ammonium form. These include natural organic fertilisers, particularly those derived from fowl manure, urea and ammonium nitrate. These fertilisers should be rapidly incorporated into the soil, where they can be transformed to nitrate. The greatest losses occur when organic fertiliser is applied to the top of the soil and periodic light rain wets the fertiliser, but is insufficient to wash the soluble nitrogen into the soil. In such cases, a high proportion of nitrogen will be lost to the atmosphere as ammonia.

Organic fertilisers generally have low levels of nutrients and application rates should be adjusted for this. Extra nitrogen and potassium will often be required. The compositions of some commonly used organic fertilisers are shown in Table 10.8.

Table 10.8 Compositions of commonly used organic fertilisers

Source	Nitrogen (%)	Phosphorus (%)	Potassium (%)
Fowl manure (caged)	2.0–9.0	2.0–3.0	0.5–2.7
Fowl manure (deep-litter)	2.0–7.0	2.5–3.5	1.5–2.5
Poultry pellets	3.5	2.5	1.7
Blood and bone	4.0	4.0	–
Cow manure	0.5–1.0	0.1–0.3	0.4–0.5
Sheep manure	0.9–1.8	0.3–0.4	0.3
Horse manure	0.6–0.7	0.1–0.3	0.4–0.6
Pig manure	0.5–0.6	0.1–0.6	0.3–0.4
Mill mud	0.5	0.2	0.04

Non-artificial mineral fertilisers

In recent years there has been a movement away from reliance on high-analysis artificial fertilisers with high salt content. Many growers use natural mineral-based fertilisers with biological soil activators. These fertilisers should not be regarded as a substitute for other fertilisers, since they are unlikely to contribute the quantity of macronutrients required to sustain high yields. However, they may be included in a planned fertiliser program and have the following benefits:

- They are slow-release and do not leach or volatilise as much as some chemical fertilisers do.
- They improve soil structure.
- They improve soil health and increase soil microbial activity.
- They are soil microflora and microfauna friendly and encourage the build-up of populations of beneficial organisms.

Fertigation

Fertigation is a method of applying fertiliser through the irrigation water. Because passionfruit need regular applications of fertiliser, fertigation is recommended and has many advantages over the manual application of solid fertilisers. These include:

- Fertigation uses less labour.
- It gives more efficient nutrient uptake and allows fertilisers to be applied more regularly and conveniently.
- Nutrients are always readily available to the plant because of regular applications.
- Nutrients are readily accessed by the plant because fertiliser in irrigation water is applied exactly where it is needed, in the rooting zone.
- Erosion and leaching losses of fertilisers are minimised.
- Urea fertiliser can be used without gaseous losses.

Fertigation is more efficient than basal application, so the quantity of nutrients applied can be reduced by up to 25%. Fertiliser can be added during every irrigation if desired, but fertigation every 2 to 4 weeks is generally most practical.

The effectiveness of fertigation depends on the effectiveness of the irrigation system. Seek professional advice from an experienced irrigation designer on planning and operating the system. The full advantages of irrigation and fertigation only become evident if the irrigation system is designed correctly to meet vine requirements and to distribute water and fertiliser evenly. Irrigation output must be uniform across the block to fertigate accurately. Where fertigation is used on sloping land, use pressure-compensating emitters (either minisprinkler or drip). Avoid application at the end of an irrigation because there will be uneven drainage of lines. A good filtration system is essential.

Before starting, have a water-testing laboratory analyse the irrigation water. Make sure an iron test is included to assess the potential risk of blockages from iron bacteria.

Fertilisers used in fertigation must be highly soluble to avoid pump damage and pipe blockages. Mixtures of fertiliser must also be compatible to avoid precipitation, which can block sprinklers and cause root damage. For example, calcium and phosphate fertilisers mixed at high concentrations often form precipitates. The most suitable fertilisers for fertigation are urea, calcium nitrate, potassium nitrate and technical grade monoammonium phosphate (MAP). Some fertilisers suitable for fertigation are listed in Table 10.9. Several commercial soluble fertilisers that supply a range of nutrients are also available.

Table 10.9 Soluble fertilisers for fertigation

Fertiliser	Main nutrient supplied	Percantage of elements
Urea	Nitrogen	46% N
Calcium nitrate	Calcium, nitrogen	18.8% Ca, 15.5% N
Potassium nitrate	Potassium, nitrogen	38.3% K, 13% N
MAP (monoammonium phosphate technical grade)	Phosphorus, nitrogen	12% N, 26.6% P
MKP (monopotassium phosphate)	Potassium, phosphorus	28.6% K, 22.8% P

Fertigation is limited to highly soluble fertilisers, and is effective in applying fertiliser to the irrigated zone only. Therefore some ground applications of fertilisers (such as lime and phosphorus) may also be necessary.

Because of the corrosive nature of many fertilisers, the components of the irrigation system that come into contact with the solutions should consist of stainless steel, plastic or other non-corrosive materials. Concentrations of total nutrients in the main line should not exceed 5 grams per litre. Always mix fertilisers in a sufficient volume of water. If fertilisers are not completely dissolved and mixed prior to injection into the system, varying concentrations will be applied and/or blockages may occur within the system.

Modern fertigation systems use injectors to inject preset quantities of fertiliser into the irrigation system. They also incorporate electronic devices that ensure the injection rate is kept relative to the flow rate of the irrigation system. Injection rates can also be controlled by flow regulators, ball valves or electronic or hydraulic control units and computers.

Older systems rely on either:

- venturi suction from a tank with the flow rate controlled by a gate valve
- direct injection into the suction line of the irrigation pump (but beware of impeller corrosion)
- pressure differential (PD) drums, where some main-line flow is bled off through a pressure drum containing a concentrated fertiliser solution before being injected back into the main line as a diluted fertiliser solution.

Injection can start any time after the system is fully operational (that is, it has reached operating pressures and is flowing, and all air is out of the irrigation lines). It is best, however, to irrigate for a while at the start to wet the root zone and then fertigate during the latter part of the irrigation cycle. Merck™ nitrate test strips can be used to follow a dose of potassium nitrate through a system. This will give a direct and visual indication of the time it takes to inject and then flush the system. Alternatively, potassium permanganate (Condy's crystals) can be used to dye the irrigation water to make the same measurements. After injection is completed, continue irrigating for at least the measured flushing time to wash any fertiliser residues out of the irrigation system.

Install anti-siphoning valves or non-return valves where necessary to prevent backflow or siphoning of water or the fertiliser solution into fertiliser tanks, irrigation supply, household supply or stock supply.

During the irrigation season, it is important to monitor:

- pH effects in the root zone
- the effects of soil temperature on nutrient availability
- corrosion and blockages of outlets
- reactions with salts in the soil or water.

Fertigation increases the quantity of nutrients present in an irrigation system and this can lead to a build-up of bacteria, algae and slime. Remove this build-up at regular intervals by flushing chlorine or acid through the system. Do not inject chlorine at the same time as fertiliser, as the chlorine may tie up nutrients and make them unavailable to the vines.

It is very unlikely that the amount of chlorine used to clean the system will be toxic to the vines. However, should this occur, the chlorine in the soil may be leached out from the root zone using a large application of irrigation water, or by high rainfall. If applying irrigation water, do so before fertigating to avoid leaching all the nutrients as well!

The Queensland horticulture industry's peak body, Growcom, provides a number of fact sheets on fertigation at www.growcom.com.au

Foliar fertilisers

The normal approach to fertilising passionfruit is to apply the required fertiliser to the soil for uptake by the roots; this is the most efficient way of meeting the nutritional needs of the vine. Only small amounts of nutrients can be absorbed by the leaves and often these cannot be redistributed from the leaves to other parts of the plant. In some instances, a foliar fertiliser supplement may be beneficial as a short-term treatment for deficiencies at critical times, such as when the uptake of nutrients by the roots may be restricted during wet or cold conditions. Foliar fertilisers cannot be used as a replacement for basal or fertigation applications.

Examples of situations where foliar fertiliser may help are:

- application of potassium during peak periods of fruit growth (helps with fruit colouring and growth)
- application of potassium and/or magnesium if soil nitrogen levels are high or there is an imbalance between potassium, calcium and magnesium
- application of boron in early spring when winter and early spring conditions are unusually cool and root uptake is reduced.

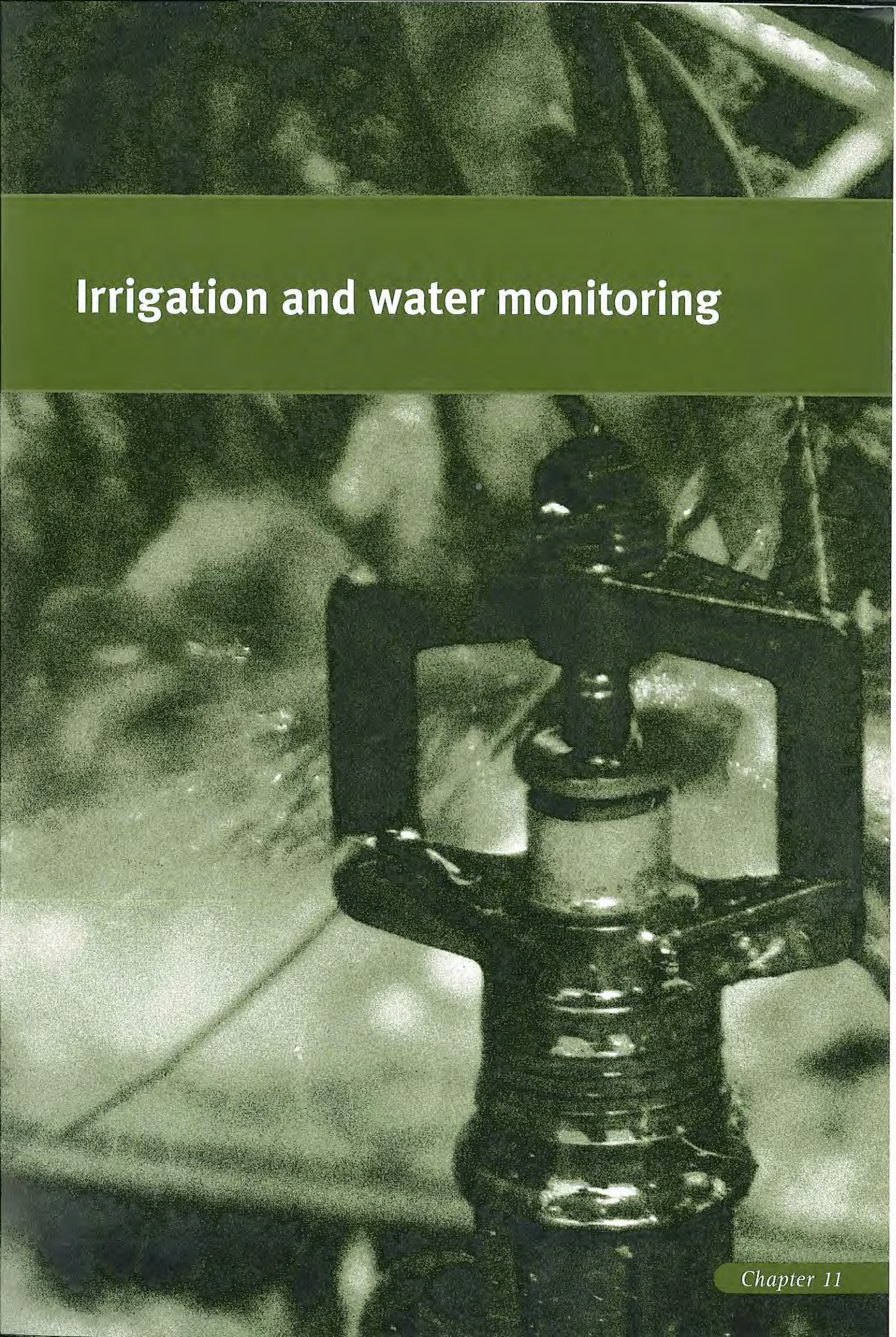
Where foliar fertilisers are required for specific nutrients, use those listed in Table 10.10. Complete foliar fertilisers that contain a range of nutrients (such as the Liquifert™ range) are also available.

Table 10.10 Foliar fertilisers for use in passionfruit

Nutrient	Fertiliser	Amount per 100 L of water
Potassium	Potassium nitrate	2 kg
Magnesium	Magnesium sulphate (Epsom salts)	1 kg
Boron	Solubor	100 g

Avoid using foliar fertiliser in the 2 months prior to leaf analysis sampling because residues on the leaves will distort the results. If the concentration of the solution is too strong, burn damage to fruit or leaves may occur.

Irrigation and water monitoring



Chapter 11

Irrigation is essential for growing high-quality passionfruit. Wilting is an obvious sign of stress from lack of water, but productivity is reduced long before the vines wilt. Too much water also stresses the vines and wastes a valuable resource. Water stress at critical times in the development of the crop can dramatically affect fruit yield and quality.

Careful management of irrigation is key to good plantation performance. The main things you need to know are:

The importance of getting irrigation right

Passionfruit vines need finely balanced water management. Too little water causes:

- reduced vegetative growth and hence reduced flowering and fruit production
- reduced flower bud initiation and flower opening
- smaller fruit with reduced pulp
- increased fruit drop
- reduced uptake of plant-immobile nutrients such as boron and calcium
- increased incidence of passionfruit woodiness virus through reduced vigour.

When guarding against under-watering, it is easy to go to the other extreme. Too much water causes:

- reduced vine vigour and fruit quality through reduced soil aeration
- increased incidence of base rot and rootrot
- increased risk of nutrient imbalances
- increased leaching of nutrients out of the root zone, which wastes fertiliser and pollutes groundwater.

Water supply and quality

A water reserve of 3 to 5 megalitres (1 megalitre = 1 million litres) per hectare of vines is generally sufficient to maintain production in plantations with summer rainfall, depending upon location and climate. Where passionfruit is grown in areas with very hot, dry summers (such as parts of Western Australia), 10 to 15 megalitres of irrigation water per hectare may be needed.

Passionfruit vines are sensitive to salinity. Water salinity or conductivity should preferably be less than 0.8 decisiemens per metre (800 microsiemens per centimetre). Test all new irrigation sources before use and test all existing sources regularly, especially if using bore water, since bores can become more saline under extended drought conditions.

Supply of and demand for water in the plantation

Only a small proportion of the vine's water requirement is used for growth of stems, leaves, roots and fruit. The majority is lost through transpiration through the stomata (small pores) on the leaf surface. This water movement through the vine is essential for carrying nutrients from the roots and for cooling sunlit leaves, which would otherwise get sunburnt.

Plant water use depends on supply and demand—the ability of the soil to supply sufficient water to the roots, and the demand for water determined by weather conditions, the size of the canopy and the resistance to water loss from the leaves. The stomata are able to close when water supplies are limiting, hence decreasing water loss.

The demand for water

Leaves comprise about 80% water and water evaporates from them into the relatively dry atmosphere. The demand for water is higher in sunlight when:

- humidity is low (that is, there is a drier atmosphere)
- temperature is high
- wind speed is high
- the leaf area (which provides the evaporative surface for water loss from the vine) is greater.

When less water is available in the leaves, the stomata close to reduce further loss of water to the atmosphere. The stomata also close at night, so the water status of vines that are under some water stress during the day will often improve at night.

As water is lost from the leaves via transpiration, tension develops between water molecules in the leaf, and this tension is transmitted through the xylem (the conduit linking leaves, through the stem, to the roots, where there is generally an abundance of water in well-managed plantations). This tension 'draws' water up from the roots to the leaves.

The supply of water

An optimum supply of water in the soil is needed for healthy and productive vines. Too much water will result in waterlogging and the vine will die from lack of oxygen to the roots. After rain or irrigation, excess water percolates down through the soil, allowing air to enter the large pores between soil particles. At this point, the soil is at field capacity and a large amount of water is held loosely in the smaller soil pores and around soil particles. Much of this water is available to the vine. However, some of the water is not available because it is held too tightly around the soil particles. When all the available soil water is used by the vine, and only the unavailable tightly held water is left, the soil is at wilting point. Theoretically, this is the point where plants would begin to wilt, but in practice they will wilt before this point is reached, particularly in hot, dry conditions.

Soil factors

Surface condition

An open, loose soil surface allows better water penetration from rainfall and irrigation. Such a soil surface is best achieved through mulching.

Soil texture

Soils of different texture (different particle sizes) and structure hold different amounts of available and unavailable water. In poorly structured soils, the amount of available soil water declines and root growth is impeded because soil particles tend to be more tightly packed together (compacted).

Root volume

The supply of water to the vine is determined by the amount of water in the soil, the extent and density of the root system and the movement of water through the soil (hydraulic conductivity). Plants with well-developed root systems have access to a larger reservoir of soil water and a dense mat of fibrous roots will more effectively exploit soil water reserves. Roots cannot grow in dry soil and tend to proliferate in moist soil. Root volume is reduced in compacted soil.

Infiltration

The amount of water that enters into the soil, as opposed to the amount that runs off the soil surface, depends on the infiltration rate (the rate at which water soaks into an already moist soil). This rate is different for different soils (see Table 11.1). Information on infiltration rate is important when planning the irrigation system—the precipitation rate of the irrigation system should not exceed the infiltration rate of the soil being irrigated. Have an experienced irrigation consultant perform an infiltration test on your soil before the irrigation system is designed and installed.

Table 11.1 Water infiltration rates for different soils

Soil type	Infiltration rate (mm/h) for uncompacted soils	
	Flat ground	Sloping ground
Deep sands, aggregated silts	More than 20	8
Deep, loamy sands	10–20	5
Loams, sandy loams and soils low in organic matter	5–10	3
Clay loams (including krasnozem soils)	5	2
Clays	Less than 5	Less than 2

Organic matter

Soils with higher organic matter levels can store more water.

Mounds

These are sometimes constructed where the depth of well-drained soil is marginally less than what is required for good soil drainage. However, mounds tend to dry out faster than flat ground and may require up to 20% extra water. Carefully monitor soil moisture in these situations.

On the other hand, mounds can be of benefit in wet regions because they help to prevent the root zone becoming completely saturated during periods of heavy rainfall.

Mounds may also affect infiltration rates because water is shed more readily from them than from a flat soil surface.

On some soils and in high-rainfall areas such as in the Northern Territory, mounds may slump. Regular replacement of organic mulches to maintain the soil structure will help prevent this.

Variability

Soil texture, soil depth and other factors affecting water availability can vary significantly within a plantation, and this should be taken into account when designing and operating an irrigation system. Vines on different soil types should be irrigated separately.

Develop a soil map of your plantation. This is a general map of the property that shows the main features and block boundaries, as well as soil texture and depth from several inspection holes (spaced on a grid pattern) across the plantation. On a small property, you can dig the inspection holes by hand with a soil auger or post-hole digger. For a larger property, hire a contractor with a motorised truck-mounted auger.

Mulch

Mulching provides significant benefit in managing water, rootrot diseases, weeds and nutrient uptake. Mulching helps reduce evaporation from the soil surface and reduces fluctuations in soil temperature. As a result, soil microflora and microfauna increase in number, organic matter builds up and a more open soil structure develops.

Higher organic-matter levels and a more open soil structure allow water to penetrate more easily. The soil can also store more moisture, which is particularly important during the critical periods of flowering, fruit set and early fruit growth. Substantial savings in irrigation water can be achieved by mulching.

Choice of mulch is critical and a coarse, open type of mulch is preferred. A fine mulch that packs down, sheds water and becomes non-wetting can reduce infiltration, particularly on a sloping or mounded site (see Chapter 16).

Compaction

Soil compaction reduces water infiltration and water storage and inhibits root penetration. Although machinery traffic will inevitably cause some inter-row compaction, you can minimise the problem by doing the following:

- Maintain an inter-row grass sward. This helps reduce surface soil erosion and the grass roots help keep the soil structure open, improving water penetration.
- Do not use machinery in the orchard unless necessary. Monitor pests to avoid unnecessary spraying, use fertigation to minimise the use of machinery to apply fertilisers and increase intervals between slashing.
- Avoid using machinery immediately after rain, as this often seals the soil surface.
- Limit the area subjected to compaction by using the same wheel track positions when travelling down the inter-row space.
- Consider using a soil renovator about once a year. Several types are available, but they all open up the soil surface without significantly damaging root systems or the inter-row plant cover.
- Use flotation or wider tyres on machinery.

Windbreaks

Windbreaks prevent excessive water loss from vine foliage under windy conditions by reducing evaporation. When installing irrigation, cater for the windbreak trees as well as the vines. This helps them to grow quickly so that they can provide protection earlier.

Developing a good irrigation system

The first essential requirement of efficient irrigation is a water supply with an irrigation system capable of delivering the required amounts of water when needed without wasting your scarce water resource.

When designing and building an effective irrigation system, there is no substitute for experience. The best way to do this is to have a qualified irrigation designer prepare an irrigation design plan. There are several irrigation systems that can be used:

- Microjets. These deflect water in an arc and have no moving parts. The best system has two 180° jets (one on each side of the vine stem) per vine.
- Minisprinklers. Small rotating sprinkler heads spray water in a circle under the vine. One sprinkler per vine positioned 30 to 50 centimetres to one side of the vine is the normal configuration.
- Trickle systems. This alternative has two drippers per vine located from 30 centimetres to 1 metre either side of the main stem. Trickle systems are unsuitable for sandy soils because the water tends to drain away quickly, wetting only a very small band of soil below the dripper. They also need to be well designed to operate effectively and must be properly maintained to prevent blockages.
- T-tape or inline drip systems. These have closely spaced holes and suit lighter soils. They must be carefully set up and intensely monitored and maintained because the restricted root zone provides less margin for error. The major advantage is their excellent economy of water use. A major problem is that they are susceptible to damage by birds, rats, hares and wallabies. In one trial, a system of this type was unusable after 12 months of continual repairs.

Good filtration is important for microjets and essential for trickle and T-tape systems. Emitters should be interchangeable so that the amount of water delivered can be varied. Colour coding of the emitters makes this easy.

Whatever system you use, it must be able to supply water to a depth of about 1 metre, the normal depth of roots in the soil. Remember to allow extra capacity in the design to water windbreak trees and to provide additional water to the rows of vines planted adjacent to the windbreak trees.

Potential pitfalls

There are several potential pitfalls to he aware of when using microjets or minisprinklers:

- **Incorrect operating pressure.** They only operate satisfactorily within a restricted pressure range. If the pressure is too low, water will be dumped at the end of the microjet/minisprinkler's throw, producing a doughnut effect. If the pressure is too high, misting will occur.
- **Pressure variation.** Ensure that pressure does not vary by more than about 10% across the block. Large pressure variations lead to uneven watering, with more water being delivered by the microjets/minisprinklers under high pressure and less by the ones under low pressure. Where pressure variation exceeds 10%, microjets/minisprinklers must be fitted with pressure compensators. A well-designed system using irrigation laterals that are appropriately tapered should not need pressure compensators, hut they may be necessary for blocks with significant variations in slope.
- **Waterlogging.** To avoid localised waterlogging, extend laterals beyond the vine rows and fit flushing valves. This ensures that any water remaining in the lines after irrigation drains away rapidly and harmlessly.
- **Uneven sprinkler distribution.** If microjets/minisprinklers distribute water unevenly, different parts of the root zone will receive too much water and others too little. Where fertigation is used, this will also cause uneven fertiliser application. Even application is particularly important where boron fertilisers are applied through the irrigation system—uneven watering can lead to boron toxicity. Where poor-quality water is used, uneven watering causes salt build-up in localised areas.
- **Incorrect height.** The optimum water distribution pattern is achieved when the microjet/minisprinkler is positioned at the manufacturer's recommended height above the ground.
- **Excessive wear.** Microjets and minisprinklers have a limited life and should be checked for the following signs of wear:
    - leaking from the base of the minisprinkler when the washers have worn, which will cause pooling on the ground
    - slow or uneven rotation
    - loss of diameter of throw.
- **Blockages.** Microjets and minisprinklers with low emitter rates have small apertures and are more easily blocked. Inadequate filtration, algae build-up, eggs laid by weevils or ants building nests can cause blockages. This generally occurs if the system has not been used for some time. Anti-ant sprinklers are available from some manufacturers. A good management practice is to take a quick run up each inter-row space on a motorbike and check minisprinkler operation at the start of the irrigation.
- **Animal interference.** Large birds (such as crows and cockatoos) or pigs may physically remove sprinkler heads. Pigs, rodents or dogs may chew laterals.

New irrigation developments

The pulse irrigation system (developed in Israel) uses short pulses of irrigation several times a day to keep the shallow feeder root zone continuously moist. In theory, it enables the vine to maintain active water and nutrient uptake for longer periods of the day, potentially increasing productivity and fruit quality. It is becoming popular in areas with hot, dry summers such as Western Australia's south-western region, the Riverland and Sunraysia.

Developing a soil-moisture monitoring system

The second essential requirement of efficient irrigation is a system to help decide when to water and how much to apply. This is known as a monitoring or scheduling system. Monitoring greatly improves the chance that water will be applied at the time and in the quantity that will maximise yield and fruit quality.

A range of equipment and techniques are available for monitoring soil moisture and scheduling irrigation. The most common are the soil-based systems using tensiometers, soil-moisture sensors such as gypsum blocks, or soil-capacitance probes. Another technique is a climate-based system that uses estimates of evapotranspiration.

The soil-based systems are preferred and recommended. Passionfruit has most of its roots in the top 50 centimetres of soil, and water-monitoring devices used for irrigation scheduling need to concentrate on this part of the soil profile. A brief comparison of the main systems is shown in Table 11.2. As soil-moisture monitoring can be complex, we recommend you seek expert advice, particularly when setting up the system.

Table 11.2 Comparison of the main soil-moisture monitoring systems

System	Advantages	Disadvantages
Tensiometers	Relatively cheap	Labour-intensive to collect and record data
	Easy to install yourself	Require regular maintenance
	Can be read by yourself	Can be inaccurate in extremely wet or dry soil
	Allow continuous monitoring	Less accurate in the top 10 centimetres of soil
		Not accurate in very sandy soils
Soil-moisture sensors (e.g. gypsum blocks)	Relatively cheap	Labour-intensive to collect and record data; requires a digital meter to be brought to each sensor site to take readings
	Easy to install yourself	Can be inaccurate in extremely wet or dry soil
	Can be read by yourself	Less accurate in the top 10 centimetres of soil
	Continuous monitoring possible	May only last up to 18 months because of the breakdown of the gypsum
Non-portable capacitance probes (e.g. C-Probe®, EnviroSCAN®)	Automatic continuous monitoring	Expensive
	Accurate at all depths and for all soils	Needs skill in interpreting data—training and support required
	Enables rapid reading and recording of results	Computer required
	Indicates both when to water and how much to apply	Not portable
Evaporation pan	Inexpensive	Less accurate as it ignores soil variability and the performance of the irrigation system
	No in-field measurement is needed, since the system uses weather data to predict irrigation needs	Cannot assess the effectiveness of rainfall or irrigation applied
	Regular schedules can be developed in advance	Requires evaporation and rainfall data
	Invaluable when planning the orchard to estimate annual requirements and peak demand needs	Error can build up; actual soil moisture needs to be checked periodically
	Can be used to provide a crosscheck with any soil-moisture monitoring devices used	

Many soil-moisture monitoring devices incorporate digital and visual displays to make them easier to read in the field (see Figure 11.1).

Figure 11.1 Digital and visual displays on soil-moisture monitoring devices make them easier to read

Tensiometers

Using tensiometers, provided they are well sited and maintained, is a relatively cheap and effective way of monitoring soil moisture. This is probably the most commonly used system.

A tensiometer consists of four basic parts—a hollow tube filled with water and algaecide, a ceramic tip, a water reservoir and a vacuum gauge (see Figure 11.2). The gauge reads water tension on a scale of 0 to 100 centibars (cb) or kilopascals (kPa).

Gaugeless tensiometers, which are read using a special handpiece, are also available. These tubes are cheaper, but the handpiece is expensive; however, these systems can be economical if you intend to purchase more than eight tensiometers. Some handpieces can save the readings, which can then be converted to graphs on a computer.

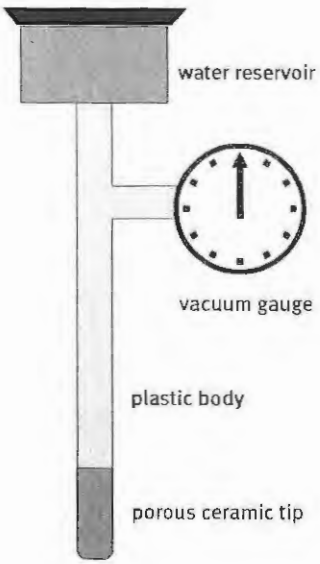


Figure 11.2 Parts of a standard tensiometer

In saturated soil, the vacuum gauge on the tensiometer displays 0 kilopascals. As the soil dries, water moves from inside the instrument, through the porous ceramic tip, into the soil, creating a vacuum inside the tube. The gauge measures this vacuum and will give readings as high as 90 kilopascals. When the soil becomes wet after rain or irrigation, water moves from the soil back into the tensiometer, the vacuum in the tube decreases and gauge readings fall.

Monitoring sites

Install tensiometers at monitoring sites throughout the plantation once vines are established, then leave them in place. Use at least one monitoring site for each block planted and soil type. At each site, install two tensiometers, one shallow (30 centimetres long) and the other deep (60 centimetres long). Position the shallow tensiometer in the major root zone with its tip 10 to 15 centimetres deep, and the deep tensiometer with its tip 30 to 40 centimetres deep (see Figure 11.3). Place tensiometers on the north-eastern side of healthy vines,

under the canopy on the edge of the row and where they will receive water from the microjets or trickle. Ensure tensiometers are installed at the same distance from the microjets/minisprinklers in all blocks. Where trickle systems are used, keep the tensiometers at least 15 centimetres from the trickle tube.

Installation of tensiometers

Assemble the tensiometers and fill them with boiled water (cooled) or demineralised water to which algaecide has been added. You can add a dye to the water to make it easier to observe the water level. It is important to remove any air from the pores of the ceramic tip, so leave tensiometers to stand in a bucket of water at least overnight, but preferably for 1 to 2 days.

Use a vacuum pump to remove any air from the tensiometer body and gauge. Make sure the pump fits snugly over the fill point on top of the tensiometer. Top up the tensiometers with more water if necessary and use the vacuum pump to remove any air bubbles. They are now ready to install.

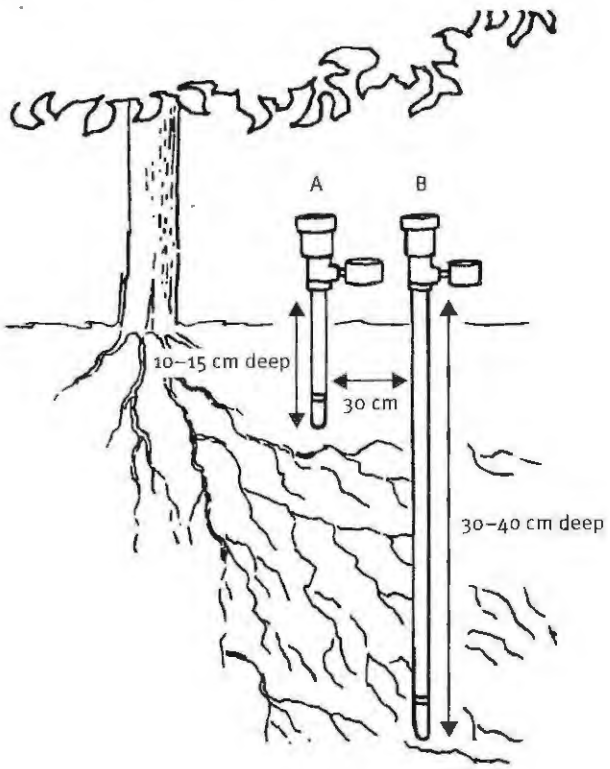


Figure 11.3 Tensiometer placement: (A) in major root zone and (B) below most roots

Carry the tensiometers to the installation site with the tips either in water or wrapped in wet rags. Do not touch the ceramic tips with your fingers, as grease from them can block the fine pores. Provided the ground is moist and well cultivated, you can push the shallow tensiometer 10 to 15 centimetres deep into the soil. Do not push too hard. The tips are strong, but can crack under excessive pressure; only experience teaches how hard is too hard. If you encounter a hard soil layer, either take the tensiometer out and try somewhere else, or use the deep tensiometer procedure.

To install the deep tensiometer:

- Use an old wooden auger (or similar) that is slightly narrower than the tensiometer tube to drill down to the desired depth.
- Slide the tensiometer (using only light force) into the hole until it is snug and all the way to the bottom. Alternatively, mix a soil slurry, fill the hole with it and then push the tensiometer through the slurry. You can mark the augered length on the tensiometer to help you judge when it is fully inserted.
- Use friable topsoil from a few metres away to create a slight mound around the tensiometer. This minimises the risk of water draining down beside the tensiometer, leading to false readings.

- If desired, place covers made from silver/blue insulation foil over the tensiometers to minimise temperature fluctuations and algal growth. Leave the gauge exposed for easy reading.
- Clearly mark tensiometer locations to avoid damage from tractors and other equipment.

The two main principles when installing tensiometers are:

- Maintain good contact between the soil and the ceramic tip.
- Ensure there are no easy pathways for water to flow directly from the soil surface to the tensiometer tip.

The tensiometers are now ready to operate. Use the vacuum pump to remove any air bubbles. Tensiometers may take a few irrigation cycles to settle down, so do not take too much notice of the readings for the first few days. During this period, air gaps may appear in the tensiometers. Simply refill them with algaecide-treated water. Within a week of installation, readings will respond to changes in soil moisture, falling with irrigation or rainfall and rising as the soil dries out.

Reading tensiometers

Read tensiometers at the same time each day before 8 am. At this time there is little water movement in the soil or plant. Read them at least twice a week but preferably every day. It is best to read the tensiometers daily for the first few weeks to get a feel for the system.

Lightly tap the gauge before reading the tensiometer. The shallow tensiometer indicates when to water. The deep tensiometer indicates when the right amount of water has been applied.

Irrigating using tensiometers

Start watering when the shallow tensiometer reads 10 to 20 kilopascals in sandy soils or 30 to 40 kilopascals in loam and clay loam soils. Stop watering when the reading on the deep tensiometer falls to 10 kilopascals. These readings are a guide only. You need to adjust your irrigation to suit your particular soil type and crop condition.

If the readings continue to rise immediately after irrigation, not enough water has been added. If its readings fall to less than 10 kilopascals soon after irrigation, too much water has been added.

In heavier soil, the deeper tensiometer may have a delayed response because of a slower infiltration rate. In this situation, irrigate for a set period when the shallow tensiometer indicates it is necessary and then wait overnight to see how the deep tensiometer has reacted. Adjust your irrigation length accordingly next time you irrigate. After a few irrigations, you will have established your reference irrigation length.

Once a week, remove any accumulated air using a vacuum pump and check that all gauges are working. Refill tensiometers with clean water as required.

Troubleshooting tensiometer problems

- No water in the tensiometer; gauge reads 0. There is either a crack in the ceramic tip or a faulty seal. Fill the tensiometer with water and apply suction with the vacuum pump. A stream of large bubbles will indicate the problem area; it is usually a cracked tip or a missing O-ring.
- Air entering over several days; gauge registering more than 5. There is either a hairline crack in the tip or a substantial air gap in the soil around the tip. Remove the tensiometer. If there are no obvious tip cracks, reinstall it in a different spot. If the problem persists, replace the tip.
- No change in readings over several days. The gauge may be faulty or blocked. Check the gauge is working by:
    - applying suction to the tensiometer with the vacuum pump or
    - removing the gauge, rinsing it with clean water and sucking it.

  If the needle does not move, the gauge is faulty and should be replaced.

- Tensiometer readings increase beyond 80 then fall to 0, accompanied by air in the tensiometer. The soil has become too dry for the tensiometer to operate. After irrigation, refill the tensiometer and treat it as if it had just been installed. If this happens frequently, consider whether you are under-watering. If you are happy with your irrigation scheduling, try installing the shallow tensiometer slightly deeper. This problem should never occur with the deep tensiometer.

Capacitance probes

Capacitance probes measure the dielectric constant of the soil and consequently its water content. They are available in two forms: portable versions (e.g. the Gopher® and the Diviner®) and non-portable versions (e.g. the EnviroSCAN® and the C-Probe®).

Portable versions

A portable version consists of a probe on the end of a rod. It is passed down 50 millimetre diameter PVC access tubes to determine the moisture content of the soil. Readings are taken at 10 centimetre intervals down the access tubes and recorded by a handheld logger. Soil-moisture readings can be measured on site or downloaded into a computer and calculated later. The logger can handle up to 99 sampling sites. The machine measures soil moisture in millimetres and can be used to estimate when to water and how much to apply.

Non-portable versions

These are continuous moisture-monitoring devices consisting of multiple snap-in sensors mounted on probes (see Figure 11.4). The probes are placed within vertical PVC access tubes installed semipermanently in the plantation. The probes are generally left in place for the season and then moved to another tube or site as required. However, a probe can he moved from tube to tube to record readings at several different sites. Measurements from the sensors are relayed at set times along a cable to a data logger for recording. Data from the logger are downloaded to a computer every few days to show water use and to provide recommendations for watering.

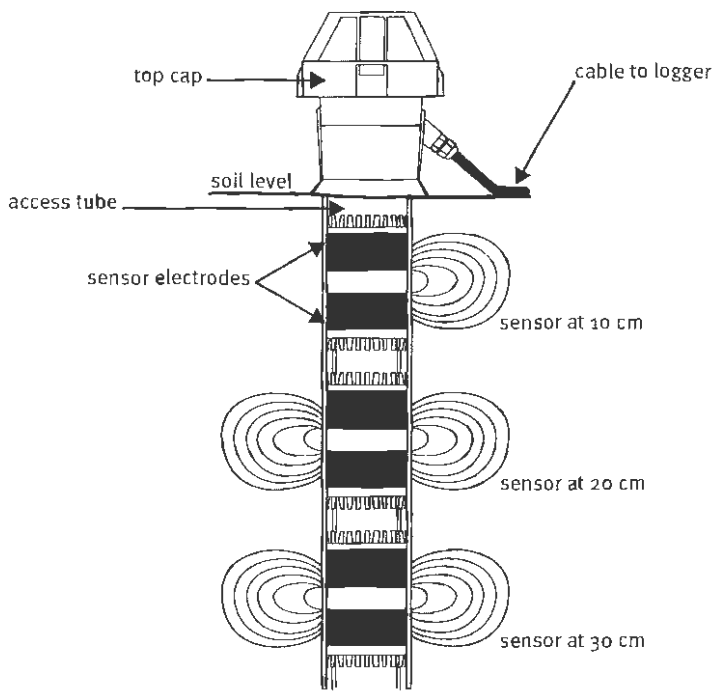


Figure 11.4 Diagrammatic representation of an Enviroscan® probe

For passionfruit, two probes are the minimum recommendation for a block, but the number of sites needed depends on the variability in soil and the varieties grown. The first probe should have sensors at 10, 30, 50 and 100 centimetres. The second probe should have sensors at 10, 30, 50, 100 and 150 centimetres to monitor losses from deep drainage. When setting up probe sites, consider the water distribution patterns from the irrigation system and position the probes appropriately. The equipment can be hired from some consultants.

As interpretation of the data requires some skill, we recommend you have consultants set up the system and provide at least the initial advice.

Evaporation replacement

Because the water requirement for vines is largely determined by atmospheric demand, a common way of determining irrigation needs is using evaporation replacement. You can calculate the irrigation required using the amount of evaporation from a Class A pan and an appropriate crop factor. This factor estimates the relationship between the pan evaporation and actual vine water use; it allows for canopy size and resistance by the canopy to transpiration. The water requirement calculated in this way is an estimate of the irrigation required for mature vines.

The evaporation replacement technique uses evaporation figures from a pan evaporimeter at a weather station to calculate water requirements at various times of the year. Evaporation figures for some districts are available from the Bureau of Meteorology. Alternatively, you can install a pan evaporimeter (or equivalent farm-made pan) and take regular readings.

The evaporation figures are used in a formula to calculate potential water use. The full formula is quite complex, so an abbreviated version is provided in Table 11.3. A worked example is shown in Table 11.4. Such a system is invaluable for estimating annual irrigation requirements, storage requirements and peak demands.

Table 11.3 Using readings from an evaporation pan to calculate the number of hours of watering per week

Step 1	Obtain the mean (average) evaporation figure (E_{pan}) for each month of the year.	E_{pan} (in millimetres)
Step 2	The evaporation figures are generally based on a US Class A evaporation pan, so multiply them by 0.85 to convert them to the equivalent evaporation from a free water surface. This gives the adjusted evaporation (ET_o).	$E_{pan} \times 0.85 = ET_o$ (in millimetres)
Step 3	To find the water use per month, multiply each ET_o by the crop factor representing the growth stage of the vine. The suggested crop factors vary from 0.6 in July to 0.9 in the peak of fruit production in summer (see Table 11.4).	$ET_o \times$ crop factor = water use per month (in millimetres)
Step 4	Divide the water use per month by 4 to calculate the approximate water use per week. This is roughly the amount of water required from rain or irrigation. (Ignore any rainfall of 5 millimetres or less.)	Water use per month ÷ 4 = water use per week (in millimetres)
Step 5	Calculate the output of your microjets (in millimetres per hour) by dividing their output (in litres per hour) by the area of effective coverage (in square metres).	Microjet output ÷ coverage = microjet output (in millimetres per hour)
Step 6	Divide the figure from step 4 by the figure from step 5 to obtain the number of hours of microjet watering per week.	Water use per week ÷ microjet output per square metre = microjet hours per week

Table 11.4 An example using the process in Table11.3 to determine the irrigation needs for bearing passionfruit vines at Nambour in south-eastern Queensland

Month	Step 1	Step 2	Step 3		Step 4	Step 5	Step 6
	Mean evaporation (E_{pan}) (mm)	Adjusted evaporation (ET_o) (mm)	Crop factor	Water use (mm)	Water use per week (mm)	Microjet output (mm/h)*	Watering required (h/week)†
January	186	158	0.9	142	36	10	3.5
February	151	128	0.9	115	29	10	3.0
March	146	124	0.8	99	25	10	2.5
April	123	105	0.7	74	18	10	2.0
May	87	74	0.7	52	13	10	1.5
June	69	59	0.7	41	10	10	1.0
July	78	66	0.6	40	10	10	1.0
August	102	87	0.7	61	15	10	1.5
September	135	115	0.7	81	20	10	2.0
October	164	140	0.8	112	28	10	3.0
November	186	158	0.9	142	36	10	3.5
December	208	177	0.9	159		10	4.0

* In this example, the microjets deliver 50 litres per hour (one at each vine) and cover 5 square metres (1.25 metre radius), giving 50 ÷ 5 = 10 millimetres per hour.

† Rounded to the nearest 0.5 hour and assuming no rainfall.

Useful conversions

Rainfall, evaporation and soil water storage are often expressed in millimetres (mm) but, since only a portion of the plantation (along the trellises, not between them) is irrigated, it is often useful to express water use and storage in litres. Irrigation emitter and dripper discharge is expressed in litres per hour (L/h) and, since the irrigation wetted pattern is restricted to the trellis line, it is more accurate to calculate the volume of the root zone wetted in cubic metres rather than in millimetres. You may find the following conversions helpful:

1000 cubic centimetres (cc or cm^3) = 1 litre (L)

1 cubic metre (m^3) = 1000 litres

1 millimetre (mm) = 1 litre per square metre (L/m^2)

1 millimetre = 10 000 litres per hectare (L/ha)

100 millimetres = 1 megalitre per hectare (ML/ha)

Tips for managing with limited water

Eliminate weed competition near vines, preferably by using a thick layer of mulch. Where necessary, use herbicides rather than cultivation to kill weeds, as cultivation damages surface feeder roots and increases evaporation losses. Take great care to avoid weedicide drift onto vines and to avoid the weedicide soaking into the soil and mulch near vine roots (see Chapter 16).

- Mulch vines, particularly during the drier spring months.
- Mow the inter-row plant cover to keep it from becoming too rank and competing with the vine.
- Choose sprinklers that wet the main root area only.

- Choose an irrigation system that minimises misting. This is usually achieved by using a high-output, low-pressure sprinkler.
- Irrigate at night. Remember to check sprinkler operation.
- Install a drip-hased or trickle system.

Irrigation requirements in Australian plantations

Table 11.5 provides useful data on the irrigation needs of the various regions in Australia where passionfruit are grown commercially.

Table 11.5 Useful information on irrigation requirements for regions

Production area	Climate	Average annual rainfall (mm)	Typical highest pan evaporation loss of the year (mm/week)	Key comments
Mareeba	Monsoonal summer rain; little rain at other times of year.	880	60	Sandy soils. Need regular irrigation. Water is bought from irrigation scheme.
Atherton	Mainly summer rainfall; some rain every month. Driest period in spring.	1300	35	Generally deep soils with good water-holding capacity. Irrigation mainly required as a supplement.
Bundaberg	Mainly summer rainfall; little rain at other times of year.	1000	70	Relatively dry. Much of annual rainfall is from short, intense storms.
Nambour, Tweed Valley, Richmond	Mainly summer rainfall; some rain every month. Driest period in spring.	1700–1800	40–45	Wetter climate with a relatively low irrigation demand. Irrigation required as supplement, particularly in spring.
Perth	Mediterranean (hot, dry summers and cool, wet winters).	820	60–75	Irrigation essential. On very sandy soils in this area, vines need to be irrigated several times a day in summer.
Darwin	Wet monsoonal tropics; distinct dry season.	1600–1800	75	Poor sandy soils. Irrigate daily during dry season. Use mounds to avoid waterlogging in wet season.

A rough guide to the amount of water required is 30 to 40 litres per vine per week in winter and 60 to 140 litres per vine per week in summer. The lower end of the range applies to cooler growing areas such as northern New South Wales and the higher end of the range to warmer tropical areas such as northern Queensland.

Water two or three times a week in spring and summer and once or twice a week in winter. Remember that these figures make no allowance for rainfall or very dry weather and the effect of these climatic conditions on soil moisture. Only soil-moisture monitoring devices can measure this.

Other information resources

A comprehensive range of fact sheets about irrigation are provided on the Queensland horticulture industry's Growcom website at www.growcom.com.au

Pest control

A passionvine bug on fruit (top)
Soft brown scale and associated sooty mould on a leaf (bottom)

Managing insect and animal pests is one of the most difficult aspects of growing passionfruit. There are a number of serious pests, and inevitably some will occur in your plantation. Several common passionfruit pests have the potential to significantly reduce fruit yield and quality, and some pests can kill vines.

It is now generally accepted that it is more economical and effective to use an integrated pest management method to control insect pests than to simply spray chemicals on a routine basis. Here are the important things you need to know:

Pest identification—the *Passionfruit problem solver field guide*

The first step in preventing pest problems in the plantation is to identify the cause of damage to the crop. The *Passionfruit problem solver field guide* can help you identify the pests and the damage they cause in passionfruit plantations.

This pocket-sized guide is illustrated with full-colour photographs and is printed on waterproof paper so that it can easily be carried around the plantation. It is available from the Queensland Government Bookshop at www.bookshop.qld.gov.au

Pest problems of passionfruit

Some pests are more common and more serious than others. The statuses of pests that are known to affect passionfruit in Australia are summarised in Table 12.1.

Table 12.1 Statuses of pests

Major and common pests requiring special attention	Potentially major and common pests requiring regular attention	Minor or uncommon pests rarely requiring treatment
Fruit flies, red scale	Ants (which encourage scales), green vegetable bugs, hemispherical scale, passionvine mealy bugs, passionvine bugs, passionvine mites, spotting bugs	Aphids, bandicoots, birds (especially cockatoos), borers, crickets, echidnas, green coffee scale, hares, lesser coffee bean weevils, mice, nematodes, pigs, rabbits, rats, Rutherglen bugs, snails, soft brown scale, swarming leaf beetles, termites, thrips, white grubs, white peach scale

Approaches to pest management

The traditional approach to pest management

The traditional approach to pest management was to apply pesticides at regular intervals throughout the year. This approach had a number of problems:

- It was a waste of money if the pests were absent.
- It disregarded the fact that small numbers of pests can be present in vines without significantly affecting yield and quality. In these cases, the cost of spraying was often much greater than the benefit gained by controlling the pest.
- It increased the risk of chemical damage to the fruit.
- It relied heavily on new chemicals being developed to replace those to which insects and mites developed resistance. This contradicts the modern reality, where fewer new chemicals are being discovered, developed and registered for use.
- It was severe on beneficial insects and mites and sometimes resulted in outbreaks of pests that were well controlled naturally.
- It unnecessarily increased the exposure of farm residents and workers to a range of toxic chemicals.
- It increased the amount of chemical residue in both the fruit and the environment.

The modern approach—integrated pest management

The modern approach to insect and mite pest management involves less reliance on chemicals. It uses all or a number of complementary control measures in an integrated program known as integrated pest management (IPM). The key elements of IPM are:

- Use cultural control measures such as growing less-susceptible varieties, crop hygiene and crop rotation.
- Use biological control measures such as naturally occurring or introduced parasites, predators and pathogens of the pests (often called 'beneficials').
- Use chemicals that have a minimal impact on beneficial parasites and predators, and are 'softer' on the environment.
- Use chemicals only when necessary.
- Apply chemicals carefully with well-calibrated spraying equipment to avoid crop damage, excess residues and off-site pollution.
- Use a monitoring system (see Chapter 14) to determine pest and beneficial levels. Use chemicals only when pest numbers exceed preset thresholds.

An IPM system that uses all of these elements can be used for passionfruit. However, even though in some situations mealy bugs and red scale can be well controlled, IPM is not without its risks. It works best:

- where pest consultants or skilled workers are available to monitor for pests and provide on-the-spot technical advice
- where a grower is dedicated to IPM ideals and is prepared to accept occasional higher damage levels that are inherent in a biological system, trading that off against the advantages of an IPM system.

The managed spraying alternative

If you are unable to employ a complete IPM system, you can still take advantage of the principal benefit offered (reduced chemical spraying) by using just some of the elements. The strategy for managed spraying is:

- Monitor pest populations as outlined in Chapter 14.
- Use chemicals only when action levels are reached; do not introduce biological control measures.
- If possible, use chemicals that are less toxic to naturally occurring parasites and predators so that you gain maximum benefit from their activity.
- Carefully apply chemicals with well-calibrated spraying equipment so that maximum impact is achieved with each spray.

Managed spraying is the recommended system for pest control in passionfruit.

Management and prevention of pest infestations

The information that follows is not intended as a guide to pest identification or diagnosis of the cause of damage. The *Passionfruit problem solver field guide* is recommended for this.

Note: A full list of chemicals registered (at the time of writing) for use on passionfruit is given in Appendix A. Registrations change from time to time; new ones are approved and existing ones are revoked. You *must* check that registrations are current for chemicals before using them and *always* follow label directions.

Major pests

Fruit flies and red scale are the most common and most serious pests of passionfruit. Recommended management and prevention strategies for them are given in the following sections.

Fruit flies

In passionfruit-growing areas of Queensland and northern New South Wales, Queensland fruit flies are active and pose a potential risk for most of the year. Activity slows during winter but often increases dramatically during August. It continues at varying levels during spring, summer and autumn. Young, developing fruit are most susceptible to attack.

In Western Australia, Queensland fruit flies are not present but Mediterranean fruit flies are and they have a similar level of activity. Their attempts to lay eggs on passionfruit are usually aborted but do result in obvious small sting spots on the skin, reducing marketability.

Monitor male fly numbers using pheromone traps (see Figure 12.1). This will indicate population changes. Cuelure traps are used for Queensland fruit flies. In Western Australia, Capilure® or trimedlure traps are used to monitor Mediterranean fruit flies. Fewer than 10 male flies caught per trap per week does not warrant control. A surge to 50 flies caught per trap per week indicates control action may be needed; confirm this by checking fruit for damage.

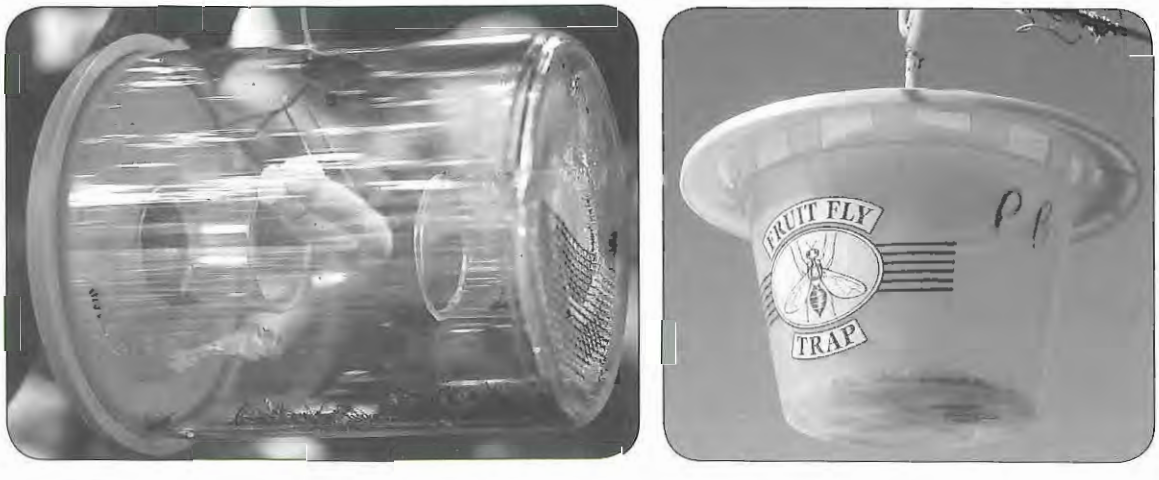


Figure 12.1 Two types of Cuelure traps used to monitor male Queensland fruit flies

Traps can attract fruit flies from a distance of 500 metres, which means that traps in a small plantation may attract flies from outside the plantation. This will provide a misleading indication of fly activity within the vines.

Female fruit flies are not strongly attracted to these lures, so the lures do not significantly control the population of egg-laying females.

Use the traps as broad indicators of fly activity only—the number of trap catches does not always relate to damage. In addition, monitor and assess damage to fruit and spray if 3% or more of fruit is damaged. If previous experience indicates they are necessary, use pre-emptive insecticide sprays when pest pressure is normally high.

Bait spraying is generally better than cover spraying because it is less disruptive to parasites and predators, it is quicker to apply and there is less drift (which reduces the risk of chemical exposure for the operator).

Bait sprays consist of a mixture of a registered insecticide and yeast autolysate. Those containing the insecticide maldison (Hy-Mal®) have given good control of fruit flies. Follow label directions for mixing and application. When the bait is applied to leaves, it encourages the growth of bacteria, a protein food source for adult female flies before egg laying. The flies are attracted to the protein, and while they feed they are killed by the insecticide. Because the bait attracts flies from some distance away, it does not need to be applied to the whole plant. It is best applied as a coarse spray to the bottom foliage of the vine.

Apply bait sprays weekly. When traps indicate high levels of fly activity (50 or more flies caught per week), apply bait sprays twice weekly. Also spray twice weekly during persistent wet weather and when flies are observed stinging the fruit. Pay particular attention to young fruit during peak periods of production.

Apply bait spray as a spot spray on every second or third vine in every second row. Apply 15 to 20 litres per hectare (approximately 75 to 100 millilitres per vine sprayed). Avoid contact with the fruit and apply bait to the lower foliage 30 centimetres above the ground. Spraying the boundary of the plantation is not sufficient to give effective control.

Amulet® baits can be used to deplete the population of male fruit flies in an area so that females are unable to mate or produce fertile eggs. Growers have reported good results using these in conjunction with weekly bait spraying using a Hy-Mal® and yeast autolysate mixture.

Alternatively, a cover spray of the whole plantation using an appropriate registered insecticide can be effective.

Some purple passionfruit varieties with hard skins are less susceptible to fruit fly attack.

Red scale

Red scale is a major and frequent pest, and is responsible for limiting the lives of vines to 3 years or less in most regions. It is a hard or armoured scale with a thin, circular, leathery covering over the soft, flattened, shield-shaped insect.

In Queensland and northern New South Wales, there are 4 to 6 generations per year (a generation every 6 to 8 weeks during spring, summer and autumn). Each adult female gives birth to about 150 young, which are called crawlers. The crawlers disperse over the vine looking for suitable feeding sites on leaves, stems and fruit. Until they settle, crawlers can be blown by wind to other vines. Populations can build up very quickly because of the large numbers of crawlers produced.

Once established, red scale is difficult to control with sprays, as the dense leaf canopy limits spray penetration. Red scale can be well controlled by natural parasites, provided they are not disrupted by broad-spectrum insecticides.

The scale is toxic to the vines and heavily infested vines usually do not recover. It is one of the major causes of poor growth and death of vines and a reason why plantations have to be replaced about every 3 years. Longevity of a plantation depends on keeping red scale out for as long as possible and then minimising its development. Management of red scale involves a number of important steps:

1. **Before planting.** Remove old scale-infested blocks, particularly any upwind of the planting site. Check vines to be planted carefully for scale. If any is present, thoroughly spray the vines with a registered insecticide.

2. **Young vines.** During the first 6 months after planting, monitor vines regularly for scale. Check the stems carefully, as that is often where the scale first shows. If a stem becomes infested, spray it thoroughly with a registered insecticide. Follow label directions. Do not use petroleum or paraffin oils when temperatures are above 30 °C. Try to slow the spread of scale in the first season and, since adult female scales do not move, apply insecticides as high-volume sprays to thoroughly wet infested areas.

3. **Bearing vines.** After vines reach 6 months of age and the main leaf canopy forms, continue to monitor the stems but also check the main branches and laterals for scale. If it is detected, examine it closely to see if there are signs of the main parasitoids, the small wasps *Aphytis lingnanensis* and *Comperiella bifasciata*. To do this, lift the covers off several scales to see if the yellow larvae and/or pupae of the parasitoid are present. Larvae and pupae can be readily recognised by the brown larval faecal pellets that surround them. If the parasitoid is not present, introduce commercially produced parasitoids. Some ladybirds (such as *Cryptolaemus montrouzieri* and *Chilocorus circumdatus*) and their larvae are predators of red scale.

   Unfortunately, natural control is usually insufficient to control this pest in passionfruit. Also, unnecessarily applying broad-spectrum pesticides that kill beneficials will only make control of the pest more difficult. If you detect scale on vines during their first year, introduce the commercially available parasitoid *Aphytis lingnanensis* and/or thoroughly spray the vines with an appropriate registered pesticide. If possible, use a paraffin mineral oil or an insect growth regulator, as these are less likely to disrupt any beneficial insects present. Follow the label directions and do not apply when temperatures are above 30 °C. Apply as high-volume sprays to thoroughly wet the vines.

   On older vines, introduce parasitoids or spray when 5% of vines are infested. Effective spray coverage is difficult in older vines and repetitive spraying of paraffin oil (at 3 to 4 week intervals) may be necessary to control a severe infestation. Check for any phytotoxic effects caused by excess oil. Identify heavily infested vines during picking and use coloured tape to mark them so that they can receive extra attention (such as individual spot sprays).

Minor pests

Other pests are less common and less serious. Recommended management and prevention strategies for these are given in Table 12.2.

Table 12.2 Minor pests of passionfruit

Pest	Management and prevention
Ants	Take action if ants associated with scales and/or mealy bugs are present on 30% or more of the shoots and leaves. Direct control of ants can be difficult; an alternative approach is to control the scales and mealy bugs. Spray the butts of vines and bases of trellis posts with an appropriate registered pesticide as necessary. Do not allow the spray to reach the upper vine, as it will disrupt natural enemies. Prune laterals away from the ground and control tall weeds (which allow ants to access the vines).
Birds	It may be possible to scare birds away using sound-making devices or by patrolling when they are more likely to be active (such as dawn and dusk). Not all birds will cause damage, and some will eat insect pests. Cockatoos may cause extensive damage, but in general birds are uncommon and intermittent pests. The frequency and severity of damage does not justify the large expenditure needed for nets. Control of native species requires approval from the relevant government wildlife authority in your state.
Crickets	Treatment is rarely warranted. Spraying the butts of the plants for the control of ants and mealy bugs may help deter crickets.
Green vegetable bugs	Check that the damage is serious enough to warrant treatment; generally, this is when at least 3% of fruit is freshly damaged. Two parasites attack these bugs: the small wasp *Trissolcus basalis* (attacks eggs) and the tachinid fly *Trichopoda giacomelli* (attacks adult bugs and nymphs). When required, spray with an appropriate registered chemical.
Lesser coffee bean weevils	Sprays applied for the control of other insects may provide incidental control.
Nematodes	Use a rootstock known to have resistance to nematode attack. The DEEDI rootstock selection has good resistance to root knot nematode.
Passionvine bugs	These bugs can cause significant damage to fruit. Check that the damage is serious enough to warrant treatment; generally, this is when at least 3% of fruit is freshly damaged. Eggs are laid in clusters and aggregations of young nymphs may sometimes be seen. When required, spray with an appropriate registered chemical.

(continued)

Table 12.2 Minor pests of passionfruit (continued)

Pest	Management and prevention
Passionvine mealy bugs	Before spraying, check that the infestation is serious enough to warrant treatment; generally, this is when at least 5% of fruit or 20% of vines are infested and only a small number of mealy bug predators are present. Introduce commercially available predators such as the ladybird *Cryptolaemus montrouzieri*. Ants tending the mealy bugs for honeydew interfere with natural control by attacking parasitoids and predators. Control ants by spraying the bases of vine stems and posts with an appropriate registered chemical. Where necessary, apply a cover spray of an appropriate registered chemical to the whole vine; however, good spray coverage can be difficult. The inappropriate use of some types of insecticides (e.g. pyrethroids) to control other insects can favour mealy bugs by killing off their natural enemies.
Passionvine mites	Each month examine 50 vines per hectare; choose vines that are scattered throughout the block. Check a 200 millimetre section of lateral along the wire and 5 attached leaves per vine for the mites (red eggs, nymphs and adults). Spray with an appropriate registered chemical if 10 or more vines (around 20%) are infested. Spraying thoroughly once or twice is usually sufficient. Phytoseiid mites (predatory mites) prey on the pest but cannot control severe infestations.
Rutherglen bugs	Regularly monitor the plantation for swarms, especially in spring, and spray with an appropriate registered chemical if necessary.
Scale insects (soft brown, green coffee, hemispherical and white peach)	Examine the vines every month. Control weeds and keep vines off the ground to help control ants. Control may be achieved by naturally occurring parasitoids. (Emergence holes in scales are evidence of parasitoid activity). If ants are present in association with the scales on 30% or more of the shoots and leaves, apply an appropriate registered pesticide to trellis posts and lower stems as necessary. If 20% of vines are still infested, natural enemies and ant control measures have not been effective. You may need to cover spray an appropriate registered pesticide. Choose a mineral oil if possible, as this is less likely to disrupt beneficial insects. Natural enemies, many of which are very small and rarely seen, are: • for soft brown scale: *Coccophagus*, *Metaphycus*, *Microterys* and *Diversinervus* spp. (wasps) • for green coffee scale: *Coccophagus* sp. (and other wasps) and *Verticillium lecanii* (fungus) • for hemispherical scale: *Scutellista caerulea* and *Encyrtus infelix* (wasps), *Verticillium lecanii* (fungus) • for white peach scale: *Chilocorus circumdatus* (orange ladybird). Spray the butt of the stem and bases of the trellis posts a couple of times a year to deter ants from tending the scales for their honeydew.

Pest	Management and prevention
Small animals	Hares, rabbits, rats and mice may all damage vines. Protective vine guards or frost wrapping around the stems (e.g. using builders Sisalation) will prevent damage. Spreading blood and hone around the stems is sometimes used as a deterrent, but it can attract dogs, bandicoots and pigs, which may dig up plants. Hares and rabhits are not protected species and may be eradicated. Keeping the plantation and headlands clean and well mown deters rats and mice. Bandicoots and echidnas are uncommon pests of minor importance. They may in fact be beneficial by eating cane grubs, although some root damage may occur as the animals dig in search of the grubs. Fill in holes as soon as you see them. Control of native species requires approval from the relevant state government wildlife authority.
Snails	They can be very difficult to treat once in the vines. Copper sprays to the trunks and trellis posts in the lead-up to wet weather will deter snails from moving into the vines.
Spotting bugs (fruitspotting bugs, banana spotting bugs)	Spotting hugs are elusive and difficult to see, so checking for fresh damage is more effective than looking for the insects. Damage to stems is usually only minor; of greater concern is the damage to fruit. Check that the damage is serious enough to warrant treatment; generally, this is when at least 3% of fruit is freshly damaged. When required, spray with an appropriate registered chemical.
Swarming leaf beetles	*Monolepta* and *Rhyparida* are mainly a problem in tropical regions. Sprays applied for the control of other insects may provide incidental control.
Termites	Discourage termites by removing all timber stumps, roots, sticks and other untreated timber. Termites may damage the roots of vines.
Thrips	Check leaves and flowers for thrips. Inspect 20 to 30 flowers and if there is an average of more than 10 thrips per flower, spray with an appropriate registered chemical. Fruit damage is unlikely to be serious enough to warrant treatment if the average is less than 5 per flower.
Wallabies	If wallabies are a recurring problem, consider fencing the block.
White grubs	These are the larvae of cane and African black beetles. Thoroughly cultivate soil prior to planting to disrupt their long life cycle. No chemicals are registered for white grub control in passionfruit.

Disease control

Stem canker (Phytophthora nicotianae) *can cause many vine deaths in a plantation when conditions are favourable*

Managing diseases is one of the most difficult aspects of growing passionfruit. There are a number of serious diseases, and some will inevitably occur during the life of the crop. Many have the potential to dramatically reduce fruit yield and quality. Here are the important things you need to know:

Disease identification—the *Passionfruit problem solver field guide*

The first step in treating disease problems in the plantation is to identify the cause of damage to the crop. The *Passionfruit problem solver field guide* can help you identify any diseases present in the plantation.

This pocket-sized guide is illustrated with full-colour photographs and is printed on waterproof paper so that it can easily be carried around the plantation. It is available from the Queensland Government Bookshop at www.bookshop.qld.gov.au

Disease problems of passionfruit

The statuses of diseases that affect passionfruit in Australia are summarised in Table 13.1.

Table 13.1 Statuses of diseases

Category	Major and common problems requiring special attention	Potentially major and common problems requiring regular attention	Minor or uncommon problems rarely requiring treatment
Fungal diseases	Alternata spot, fusarium wilt	Anthracnose, base rot (haematonectria canker), brown spot, cladosporium scab, phytophthora blight, phytophthora rootrot, septoria spot, stem canker	
Viral diseases	Passionfruit woodiness virus (PWV)		Cucumber mosaic virus (CMV)—mainly New South Wales

Disease management and prevention

Growers tend to rely on preventative measures to control most disease problems. These include:

- regular use of protective sprays for control of leaf and fruit diseases
- use of rootstocks resistant to fusarium wilt
- use of scion material taken from only healthy vines (to minimise viral diseases).

Monitoring

Diseases are difficult to monitor in the same way as insect and mite pests because they are caused by microscopic organisms, which cannot be seen with the naked eye. However, you can check vines for disease symptoms. With careful and regular monitoring, you can detect diseases before they are well established and difficult to control.

Regular monitoring also helps you evaluate your disease-management program (see Chapter 14). Look for and record any signs of disease when you are monitoring for pests.

Spraying programs

You can reduce the incidence of diseases such as alternata spot, anthracnose, brown spot, phytophthora blight and septoria spot by using a preventative spraying program. A protective fungicide sprayed every 3 to 4 weeks during dry weather and every 10 to 14 days during wet weather is recommended. If wet weather prevents scheduled spraying, you may need to close up the interval to 7 to 10 days for a short period. It is important to obtain full coverage of fruit and foliage.

Following severe disease outbreaks, incorporating other fungicides (such as iprodione or azoxystrobin) into the preventative program before, during and after extended wet periods may assist in control. Avoid the build-up of disease resistance when using either of these fungicides by following the resistance-management recommendations on the label.

Trials on 'plant defence activators' may lead to the registration of chemicals that provide control of certain diseases by stimulating the plant's own natural defences. In particular, certain compounds of silica may induce the development of stronger cell wall structures. Your chemical retailer will be able to advise you about registrations of these chemicals and their use when they become available.

Always check chemical registration details on the label and follow label directions.

Pruning and replanting

Pruning is also beneficial in disease control. It improves spray coverage and reduces disease inoculum in the canopy, especially when diseased parts of the vine are also removed. However, because pruning is expensive and there is a risk of diseases persisting and quickly reinfecting regrowth, it is generally accepted that a complete replanting is the most effective way of dealing with severe disease problems. Passionfruit vines are relatively cheap to replant, and a replanted plantation can come into production in 6 to 12 months (depending upon management and environmental conditions). Some growers replant every 1, 2 or 3 years (depending upon location) regardless of the condition of the vines to maintain plantation health and vigour.

Major and common diseases

The following information is not intended as a guide to disease identification or diagnosis of the cause of damage. The *Passionfruit problem solver field guide* is recommended for this.

Note: A full list of chemicals registered (at the time of writing) for use on passionfruit is given in Appendix A. Registrations change from time to time; new ones are approved and existing ones are revoked. You *must* check that registrations are current before using chemicals and *always* follow label directions.

Viral diseases

Viral diseases have a major factor effect on the productivity of passionfruit vines. 'Vine decline' has become an increasingly serious problem in recent years. The widespread presence of viral infections in vines in all of the growing areas of New South Wales and Queensland is thought to be the main cause of this problem.

The problem is generally worse in New South Wales and south-eastern and central Queensland than in northern Queensland. This does not mean that vines in northern Queensland are not infected; cultural practices such as growing Panama selections from seeds and replanting every year as well as the warm climate reduce expression levels. That is, there has not been enough time for the disease the symptoms to appear and/or the vines' vigorous growth masks the symptoms.

Growers usually refer to viral diseases as 'woodiness'. However, research has shown that most commercial plantings have one or more of the following viruses:

- passionfruit woodiness virus (PWV)–mild, severe or tip blight strains
- passiflora virus Y (PVY)
- clover yellow vein virus (CYVV)
- passiflora latent virus (PLV)

Two other (very rare) viral diseases have also been found in passionfruit:

- cucumber mosaic virus (CMV), which has only been found in one plantation
- badnavirus, which has been found only in Panama vines in northern Queensland and is associated with severe fruit and leaf distortion.

Virus symptoms are most pronounced in cool weather. During the remainder of the year, vine growth in well-managed plantations is sufficient to keep pace with PWV development, so that symptoms are masked and generally not a problem.

These viruses are spread via infected scion tips when grafting, in plant sap on pruning equipment and by feeding aphids. Once vines are infected, there is no cure. There is no evidence that any of the viruses are transmitted in seed. Viruses can also be transmitted in tissue culture, so propagation using tissue culture is not a solution.

Various aphid species are carriers of the viruses found in passionfruit; no other insects are able to transmit passionfruit viruses. Aphids are very common. When they settle on a passionfruit vine they will test-feed to check whether they are on a suitable host, and will transmit the virus to the vine during the initial few seconds of the test-feed. Because the infection occurs so quickly, using insecticides to control aphids is not a practical solution. On the contrary, there is evidence that insecticides increase the feeding activity of the aphids before they die and so more vines would be infected if insecticides were used.

Strategies that can be used to manage viruses in passionfruit include:

- Clean secateurs with soapy water at regular intervals when collecting tips for propagation. This will help to reduce the possibility of virus transmission via the sap.
- Check with your nursery that they only use scion material from healthy-looking vines, that they select fast-growing tips with long internodes and avoid tips that are hardening off. This will not remove viruses from the propagation cycle, but it will help to ensure that only the plants that are most tolerant to the viruses are used for propagation.
- Grow tolerant or resistant varieties. Current purple varieties have some tolerance and an industry breeding program is underway to improve resistance in future varieties. Tolerance and resistance are not the same: tolerance means that the plant is able to survive and grow even though it is infected with the virus; resistance means that the virus cannot establish in the plant.
- Panama selections such as McGuffies Red and Pandora should only be propagated from seed. Passionfruit viruses are not transmitted in seed and even though the vines will probably be infected by feeding aphids, there may be enough initial virus-free growth to help them better tolerate infection when it occurs.
- Where practical, replant whole blocks. Remove all old vines, as these are the main source of infection for new vines. If possible, replant upwind of other blocks in the plantation to slow the spread of the virus from the older vines.
- Aphids are not strong fliers and tend to drift with the prevailing wind. Use windbreaks to help minimise the movement of aphids through a plantation.
- Symptoms of the disease are often seen on vines that are stressed. Ensure windbreaks are established to minimise the impact of cold winds. Establish plantations in warm, sheltered locations and maintain vine vigour by fertilising and watering appropriately, especially during the winter months. This will help reduce the impact of viruses on productivity.
- Remove and destroy severely affected vines, as they will not recover. Vines mildly affected by PWV usually recover as growing conditions improve. Removing vines showing virus symptoms will not necessarily reduce overall infection levels in the block–the virus will almost certainly have been passed on to other vines during the lag time between infection and appearance of symptoms.
- If possible, eradicate wild and volunteer passionfruit growing near your plantation.
- If virus-free vines become available, 'barrier crops' planted around blocks may help keep aphids out of the vines and may 'clean' the aphids of viruses before they move into the vines. Barrier crops need to be attractive to aphids but not hosts of the passionfruit viruses; sorghum may be suitable.

Fungal diseases

Major and common fungal diseases of passionfruit and the recommended management and prevention strategies for these are given in Table 13.2.

Table 13.2 Management and prevention of fungal diseases

Disease	Management and prevention
Alternata spot	Alternata spot is the most serious of the fungal diseases that attack passionfruit. It may cause rapid and severe defoliation and fruit spotting during wet weather. Spores of the fungus are produced on leaves, fruit and dead flower remnants on fruit stalks. These are readily dispersed by wind and rain. Warm, wet weather favours development of the disease, which spreads readily. Some hybrids are more resistant to the disease than others (see Chapter 5). A layer of fungicide protection on leaves and fruit will prevent the germinating spores from penetrating the surface and so control the disease. Therefore, to manage this disease, you must maintain a protective spraying program throughout the period of risk. The only way to achieve this is hy regularly applying fungicide sprays using efficient and well-calibrated equipment. The recommended spraying interval ranges from 7 to 28 days. The choice of spraying interval depends on the following: • Rate of growth of leaves and fruit. When growth rate is high, use shorter intervals. • Incidence and frequency of rainfall. When there is rain, spray within 7 days of the last spray. Better still, incorporate a curative fungicide into the preventative program. • Temperature. Use a shorter interval when temperatures are above 20 °C. Otherwise, and when the temperature is below 16 °C, extend the interval to 28 days. Strategic sprays using strobilurin fungicides may help control outbreaks. Always follow the guidelines on the fungicide label when incorporating strobilurins into your spraying program; this will ensure effective control and minimise the risk of the disease becoming resistant to these types of fungicides.
Anthracnose	This pathogen has a very wide host range; it is spread by water splash and favoured by warm, wet weather. To prevent the build-up of the disease on both leaves and fruit, use a preventative fungicide spraying program. Use an appropriate registered chemical and ensure there is good spray penetration. The program used to control alternata spot, septoria spot and brown spot generally gives good control of anthracnose. Anthracnose is also a serious post-harvest disease, so it is essential to remove any affected fruit during packing. Some hybrids are more resistant to the disease than others (see Chapter 5).
Base rot (haematonectria canker)	This is caused by the fungus *Fusarium solani* and tends to develop in vines that have been stressed. Select free-draining soils and take care during transplanting in the nursery and planting out in the field not to damage or bend the root system (i.e. cause 'J' root). Vines that have been planted too deeply are very susceptible to infection, so make sure the base of the stem is level with the soil surface when planting. At all times avoid injury to the stems (e.g. from machinery, whipper snippers, stones, slashing), as this opens the vine up to infection.
Brown spot	Spores produced on lesions can be blown onto neighbouring vines by wind during dry weather. Warm, moist weather favours development of the disease. Reduce wind in the plantation, since wind rub can wound the vine and create entry sites for the disease. To prevent the build-up of the disease on both leaves and fruit, use a preventative fungicide spraying program. Strategic sprays using a systemic fungicide may help control outbreaks. Use appropriate registered chemicals.

Disease	Management and prevention
Cladosporium scab	Spores can be spread by wind and water splash. Infected seedlings and wild passionfruit can be sources of the disease. Spray with an appropriate registered chemical. For the best results, use a strobilurin fungicide in combination with a preventative fungicide program. Follow the guidelines on the fungicide label when incorporating strobilurins into your spraying program; this will ensure effective control and minimise the risk of the disease becoming resistant to these types of fungicides.
Fusarium wilt	This is caused by the fungus *Fusarium oxysporum* f. sp. *passiflorae* and was once a major disease of passionfruit in Queensland. It is now adequately controlled by the use of wilt-resistant rootstocks. *P. edulis* f. *flavicarpa* rootstock seed supplied by DEEDI has been selected for a very high degree of resistance to this disease and is recommended for rootstock seedlings for grafting purple varieties. It has the added advantage of having some resistance to phytophthora rootrot and nematodes. Some Panama selections with a high resistance to fusarium wilt (approximately 98%) can also be used as satisfactory rootstocks; consult your nursery. Panama selections are best propagated from seed to eliminate virus transmission. Being of *P. edulis* f. *flavicarpa* origin, they have some natural resistance to fusarium wilt. To maintain the high level of resistance, ensure vines that are sources of seed are protected from cross-pollination (see Chapter 18).
Phytophthora blight	The pathogen *Phytophthora nicotianae* has a wide host range and survives as tough resting spores in soil. Infection occurs when spores are splashed onto the plant by rain or irrigation water, especially during warm, wet, windy weather. High grafting on rootstocks will reduce soil splashing onto the stems of the more susceptible scion. To prevent the build-up of the disease on both leaves and fruit, use a preventative fungicide spraying program. Spray with an appropriate registered chemical and ensure there is good spray penetration during prolonged wet weather.
Phytophthora rootrot and stem canker	Select freely draining soils and use resistant rootstocks—the DEEDI rootstock is resistant to fusarium wilt and to *Phytophthora nicotianae*. High grafting on rootstocks (at least 30 centimetres) will reduce soil splashing onto the stems of the susceptible scion (see Figure 13.1, page 138). When there is a problem, use an appropriate registered systemic fungicide to control this disease. Use cultural control practices to prevent infected soil dispersing in water splash—plant sweet smother grass, use mulches and improve drainage. Avoid heavy applications of lime, as this increases phytophthora activity.
Septoria spot	These spores are thought to survive on leaf trash and are spread from infected material by rain and possibly by insects. This disease is favoured by prolonged rainy, mild weather. Use a preventative fungicide spraying program to prevent the build-up of the disease on both leaves and fruit. Some hybrids are more resistant to the disease than others (see Chapter 5).

The interaction between stem canker and base rot

The soil-borne fungi *Phytophthora nicotianae* and *Fusarium solani*, the pathogens that cause stem canker and base rot respectively, can interact to cause heavy vine losses. These fungi are very common in tropical and subtropical soils. Both fungi can be dispersed by the splashing of infested soil particles onto the stems of passionfruit vines. The two fungi then interact to cause an extensive and serious stem rot, which quickly kills the vine.

Phytophthora nicotanae will rapidly invade susceptible plant tissue. However, the DEEDI rootstock is resistant and the fungus can only infect stems above the graft union (see Figure 13.1).

Figure 13.1 Scion (above knife) infected by stem canker on a healthy, resistant rootstock (below knife)

Fusarium solani alone does not attack sound tissue or vigorous vines, but previous infection by *Phytophthora nicotanae* provides an ideal entry point for Fusarium solani. Plants subjected to stress as a result of other diseases, wounding, old age, poor growing conditions or insect attack are the most susceptible and develop base rot.

Exotic diseases

Exotic diseases of passionfruit currently not found in Australia are a significant biosecurity threat to the industry. One such disease is the bacterial blight *Xanthomonas axonopodis* pv. *Passiflorae*. This disease forms one or a few large necrotic lesions with translucent halos on leaf edges. The Pests and Disease Image Library (PaDIL) caries photographs and a detailed description of this disease at www.padil.gov.au (search for passionfruit).

Pest or disease

Vine	QFF	RS	MB	Alt	BS	SS	Pred	Para
10								
20	50%fruit					X		
30								
10		X						

Pest and disease monitoring, including biosecurity

To effectively control pests and diseases in horticulture, you need to carefully monitor the crop. Monitoring helps you gather the information you need to manage pest and disease problems.

Biosecurity planning, both at individual farm and industry-wide levels, will help prevent the establishment and spread of endemic and exotic diseases.

To find out more about how to monitor for pests and diseases and about biosecurity issues, read the following sections:

Monitoring

Whether you are using integrated pest management or following a managed spraying program (see Chapters 12 and 13), you need to regularly monitor your plantation for pests. Monitoring for endemic pests helps growers to decide:

- whether or not to spray (i.e. whether pest levels are serious enough to warrant spraying)
- which chemical to use should spraying be necessary
- whether or not to introduce beneficials.

In addition, by searching for exotic pests and noting their absence, you can assist the industry establish a record of 'evidence of absence' for exotic pests. More information on this is given in this chapter under 'The Passionfruit Industry Biosecurity Plan and evidence of absence'.

Monitoring requires skill in observing and identifying pests, parasites and predators. A good knowledge of the life cycles of the pests is also important, as many treatments require correct timing to give good control. This requires considerable training and experience. For this reason, we recommend you use a professional pest monitoring service. If you wish to do the monitoring yourself, we suggest that you first have some training with a pest consultant.

If you use professional pest monitoring services, a consultant will visit the plantation at regular intervals to monitor pest populations. After each visit, the consultant will provide a report on pest status and required sprays. The cost of using a pest consultant varies depending on distance travelled, number of blocks/varieties, planting density, and pest and disease status of the plantation. However, the advice provided by the consultant should save you money in the long run by avoiding both crop losses and expenditure on unnecessary pest treatments.

Monitoring works by first determining pest action levels—these are the pest populations at which damage is considered worth treating. (The action level for a pest is the point at which the damage it causes is roughly equivalent to the cost of control.) Next, pest populations are accurately monitored and control measures are applied only when pest populations approach or reach these action levels. Continued monitoring allows you to manage pest populations at or below these action levels. The parasites and predators that naturally attack the pests are also monitored, because in some cases they alone will be sufficient to keep the pest populations in check.

Monitoring of diseases is important for detecting obvious problems and for evaluating how well your disease management program is working. You should record any symptoms of diseases observed during pest monitoring.

Requirements for monitoring

Monitoring is a process of systematic observation and recording. The materials needed for monitoring are:

- a hand lens (× 10), magnifying glass or small microscope
- a notebook, prepared monitoring charts and a pen
- plastic bags or small bottles and a marking pen for samples
- a sharp pocket knife
- a roll of coloured plastic tape.

To do your own monitoring, you will need:

- the commitment and time to monitor at least once every 14 days (7 days for fruit flies)
- good eyesight
- a good knowledge of pests and beneficial insects and mites
- common sense.

The *Passionfruit problem solver field guide* can help growers identify pests and the damage they cause in passionfruit plantations. This pocket-sized guide is illustrated with full-colour photographs and is printed on waterproof paper so that it can easily be carried around the plantation. It is available from the Queensland Government Bookshop at www.bookshop.qld.gov.au

Chapters 12, 13 and 15 also give information on pests, diseases, spraying and registered chemicals. Appendix A includes details of chemicals currently registered for use on passionfruit.

How many vines to monitor

Divide your plantation into monitoring blocks, each consisting of vines of the same variety and of similar age. Monitor each block separately.

For most pests, closely examine 15 to 20 vines per hectare at random in each block. If you have less than one hectare in any block, check 20 vines in that block. Planting density does not affect the number of vines you need to monitor.

Many pests seem to attack particular 'hotspots' on a regular basis. Identify these areas and check them in addition to the random checks (unless they are already covered adequately in the random checks).

How often to monitor

Continue monitoring throughout the year. From September to April, monitor once every 2 weeks. For the remainder of the year, monitor every month or so to check that no new problems are emerging.

Monitoring procedure

Prepare some monitoring charts to record the results of your monitoring. An example of a monitoring chart and how it may be completed is shown in Figure 14.2. A blank chart (which you can photocopy) is given at the end of this chapter (page 145).

Monitor on foot rather than when driving, as you can inspect the vines more thoroughly when walking. Work through the plantation systematically. For example, you could check every 10th vine in every 4th row. At each selected vine, check 5 fruit, 5 leaves, 5 laterals and the stem for signs of damage caused by pests and for the presence of any pests or beneficial parasites and predators. Also check the vine for the symptoms of any passionfruit diseases. As you move between these vines, keep alert and visually scan other vines for problems. You must cover the whole plantation, as pests often develop in localised areas or 'hotspots'. Monitoring is a skilled operation and you will become more effective as you become more experienced.

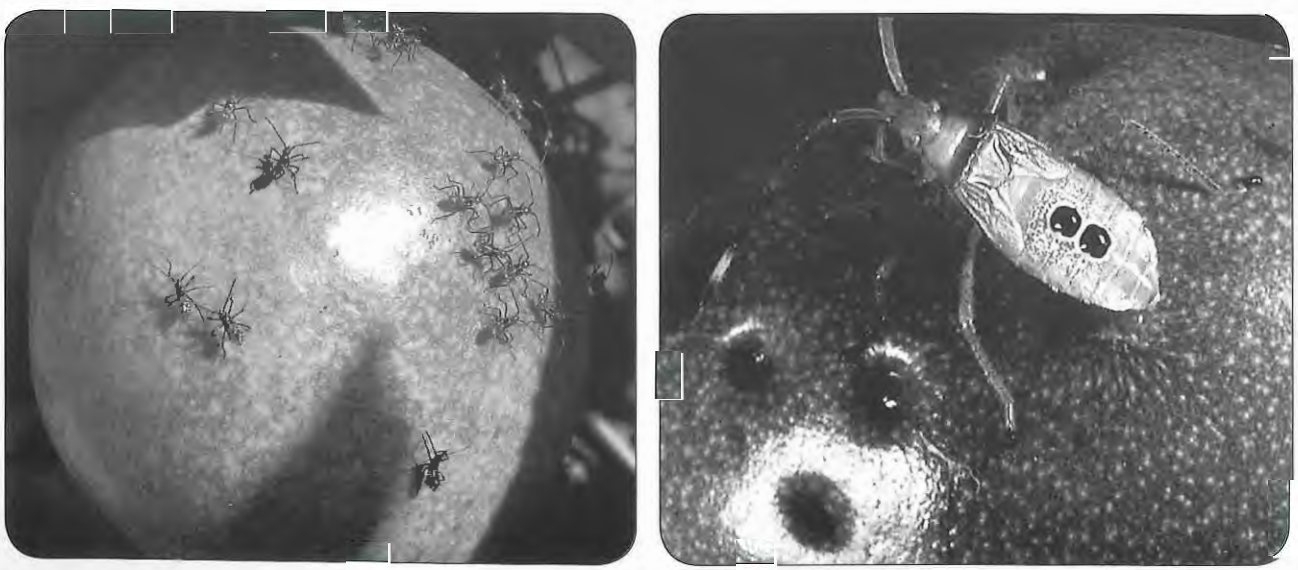


Figure 14.1 Passionvine bug nymphs (left) and fruitspotting bug nymphs (right)—two insect pests commonly found in passionfruit plantations

Monitor at fortnightly to monthly intervals depending upon the season. More frequent checking is needed in hot, humid weather. Regular, methodical monitoring allows you to assess if a particular pest problem is increasing or decreasing in severity.

After each monitoring round, transfer the results from your monitoring charts to a plantation record that will cover the full season. This will form a permanent record of the trend for each pest and parasite/predator over the season, and will be very valuable once recordings have been made over several years. This record will help you assess your action levels for the different pests (see Chapter 12 for action levels to use as a starting point) and adjust them if necessary.

Block:						Date:			
Row	Vine	Pest or disease*						Beneficials	
		QFF	RS	MB	Alt.	BS	SS	Predators	Parasites
1	10								
	20	50% fruit					×		
	30								
4	10		×						
	20								
	30			×	×			×	
	40			×					
	50								
etc.	etc.								

Exotic pests identified: Yes / No (circle) If 'Yes', give details: .....

.....

If you find something unusual in your plantation, call the Exotic Plant Pest Hotline on 1800 084 881.

Signed: ..... Date: .....

* Insert other appropriate column headings as required. Record the presence of pests, diseases and beneficials. Record an estimate of the percentage of leaves or fruit affected. For scales, record if a vine is infested. You will need to monitor the following pests and diseases, but monitor for others also if required:

QFF	Queensland fruit fly	Alt.	Alternata spot
RS	Red scale	BS	Brown spot
MB	Mealy bugs	SS	Septoria spot
M	Mites	PWV	Passionfruit woodiness virus
A	Ants	Phy.	Phytophthora
FSB	Fruitspotting bug	Anth.	Anthracnose
Predators	Mealy bug predators	Parasites	Red scale parasites

Figure 14.2 An example of a pest monitoring chart (partly completed)

On-farm biosecurity

Biosecurity can be defined as 'precautions taken to minimise the risk of introducing pests into an unaffected area'. In this definition, 'pest' means any unwanted insect, disease or weed. An 'exotic pest' is one that is not in Australia and an 'endemic pest' is one that is established in one or more of the passionfruit-growing regions in Australia. The 'unaffected area' may be a country, a state, an exclusion zone (such as a fruit fly exclusion zone) or a single farm.

Organisations such as the Australian Quarantine and Inspection Service enforce import restrictions that help to restrict the entry of exotic pests into Australia. However, the responsibility of on-farm quarantine is that of the grower, and individual growers are able to contribute to their own biosecurity and that of the industry.

Growers can protect their own farm by adopting these practices:

- Become knowledgeable about what endemic pests look like and immediately report any suspicious pests. Train plantation staff to know what to look for when they are working. **If you see anything unusual on your plantation, call Plant Health Australia's Exotic Plant Pest Hotline on 1800 084 881.** Plant Health Australia's website at www.planthealthaustralia.com.au provides details on all aspects of biosecurity, including industry biosecurity plans for numerous horticultural crops, the Emergency Plant Pest Response Deed and the strategies and policies that underpin Australia's plant health system. The Australian Government's Pests and Diseases Image Library (PaDIL) at www.padil.gov.au provides information on exotic pests and plant health issues concerning Australia.
- Monitor regularly for pests to allow early detection of anything unusual. Prompt treatment of any established pests can help prevent economically significant damage. Also, monitoring can provide evidence of absence of pests, which is invaluable for demonstrating 'pest freedom' in the Passionfruit Industry Biosecurity Plan (see below).
- When receiving vines for planting, check for any unusual pests and continue checking when training young vines. Talk to your supplier to find out where propagation material has been sourced.
- Control the access of visitors to your plantation. Clearly signpost the gate and ask visitors to check in at the shed or farmhouse. This is also important for workplace health and safety.
- Adopt a 'come clean, go clean' policy to prevent the spread of pests. Such policies are used in other industries (such as banana and cotton). Clean off machinery and vehicles before allowing them onto the property and before they leave.
- Use your own vehicle to transport visitors around the plantation rather than letting them drive theirs. Provide facilities for people to clean and disinfect their boots before entering the plantation.
- If you or staff return from overseas, ensure that you clean all footwear and clothing before entering the plantation.

The Passionfruit Industry Biosecurity Plan and evidence of absence

As part of the development of a Passionfruit Industry Biosecurity Plan, it will be necessary to establish that certain pests are not present in Australia.

In the future, overseas producers might apply to export passionfruit to Australia. As part of the assessment process for such an application, regulatory authorities will need evidence that any exotic pests present in the exporting country are not already present in Australia. Only a written record of 'evidence of absence' will satisfactorily show that exotic pests have not been found on passionfruit plantations in the past.

Growers' pest monitoring records will provide this key 'evidence of absence' should the need occur. You can assist in this process by recording your pest monitoring results on a chart each time you monitor and indicating if any exotic pests have been seen. A suitable pest monitoring chart that includes a statement confirming whether or not exotic pests were found during that round of monitoring is provided on the following page.

Biosecurity manuals have been developed for the apple and pear industry and the banana industry. These contain information that is applicable to any commodity and they are available from the Farm Biosecurity website at www.farmbiosecurity.com.au

Monitoring chart

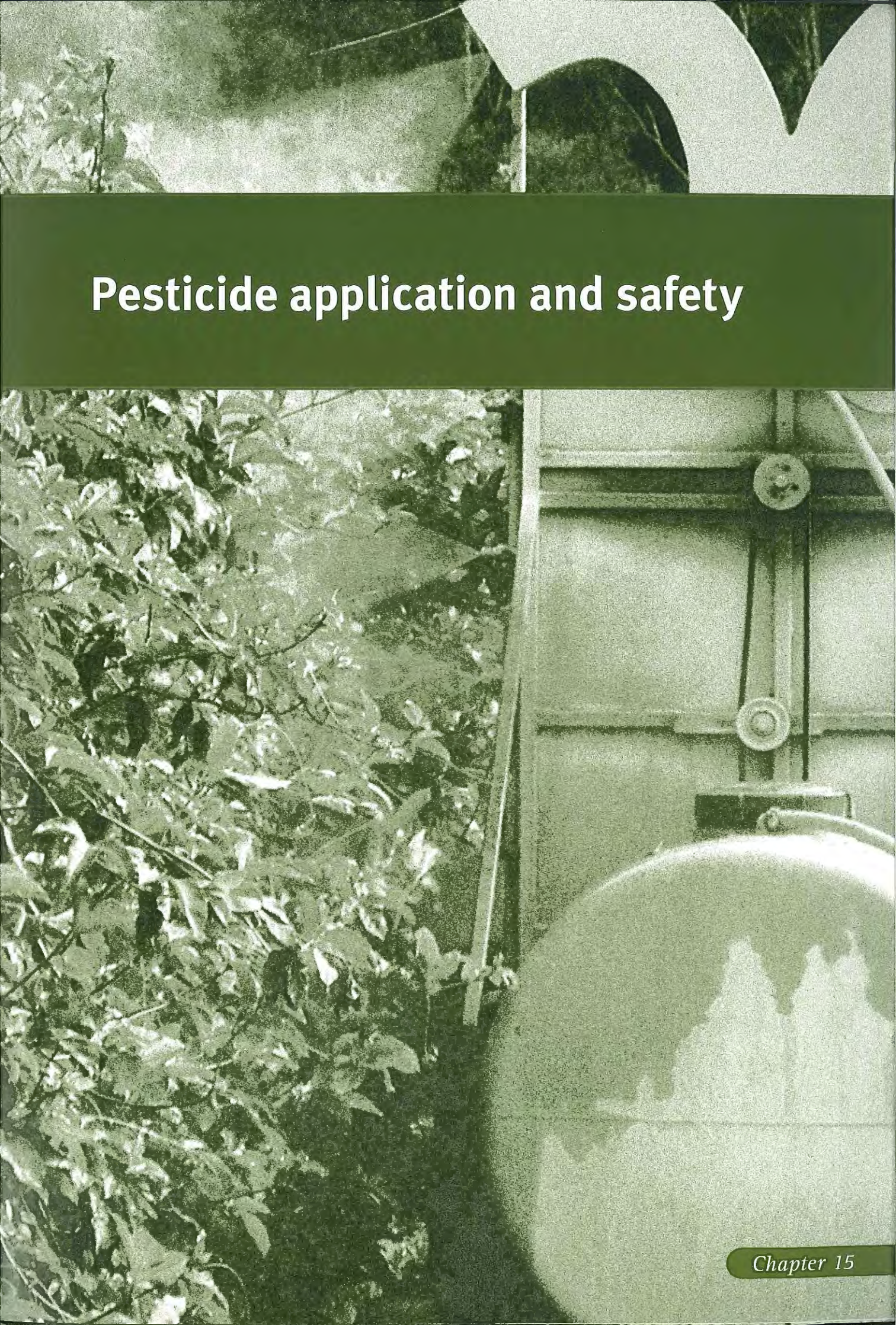
Block:						Date:			
Row	Vine	Pest or disease						Beneficials	
								Predators	Parasites

Exotic pests identified: Yes / No (circle) If 'Yes', give details: .....

.....

If you find something unusual in your plantation, call the Exotic Plant Pest Hotline on 1800 084 881.

Signed: ..... Date: .....



Pesticide application and safety

Chapter 15

If you decide to use an appropriate chemical for pest or disease control, follow these important guidelines:

- *Apply the chemical efficiently to maximise the effect of each spray on the target. This will reduce the number of sprays required.*
- *Use and apply the chemical safely so that any impact on operators, farm workers and the community is minimised.*

This chapter provides information on:

The basics

Before any spraying:

- Check that all equipment is in good working order.
- Make sure that all equipment has been properly calibrated to ensure the correct amount of chemical is applied to each vine at the optimum coverage.
- Check that operators fully understand the principles of spray application and know how to use the equipment to maximise efficiency and minimise spray drift.
- Read the label and follow its directions.
- Check that the weather conditions are suitable for spraying.
- Observe full safety precautions, including the use of safety equipment and protective clothing. These precautions are printed on the label.

When used under certain conditions, some pesticides are phytotoxic and can cause a spray burn on the vines you are trying to protect. To reduce the risk of this occurring:

- Do not spray on days when temperatures approach or exceed 30 °C.
- Avoid spraying when humidity is high, as this slows the drying of the chemical, and vine injury is more likely to occur.

Spray application equipment

Several types of sprayers are used in passionfruit plantations.

- For small plantations, pesticides can be applied using a hand gun. The gun is connected by a hose to a tank holding the pesticide. The tank is drawn behind a tractor or on a trailer.
- For larger plantations, a tractor-mounted (or trailer-mounted) air-assisted spray unit is recommended.
- A coarse-spray hand gun or tractor-mounted splatter sprayer is required when applying bait sprays for fruit flies.
- A separate smaller sprayer is needed for applying herbicides—simple hydraulic sprayers are the most suitable for this purpose (see Figure 15.1).
- *Never* apply insecticides and fungicides through a sprayer that has been used to apply herbicides; any herbicide residues in the tank will damage the vines.

Figure 15.1 A hydraulic sprayer that is dedicated to herbicide use

Air-assisted sprayers

Two types of air-assisted sprayers are commonly used in horticulture: air-blast machines and misting machines.

Air-blast machines (see Figures 15.2 and 15.3) are most commonly used in passionfruit plantations. Droplets produced by hydraulic nozzles are transported in an airstream produced by a large axial flow fan of diameter 800 to 900 millimetres. These machines produce high volumes (50 000 to 100 000 cubic metres per hour) of low-speed air. They are very versatile and can be operated at low spray volumes (250 to 1000 litres per hectare) or in higher volume mode (2000 to 4000 litres per hectare).

Pest and disease management is much more efficient when the spray application is correct. An effective spray reaches its target and provides good coverage of both leaf and fruit surfaces. The aim is to achieve about 70 to 100 droplets of spray per square centimetre with droplets ideally between 50 and 100 micrometres in diameter (1000 micrometres = 1 millimetre). The best deposition of droplets is generally obtained when they are carried to the target in a turbulent air stream.

High-volume applications are advantageous because they provide good coverage and spray penetration. This is essential when applying fungicides and those insecticides that target immobile pests such as scales and mealy bugs. Air-blast machines are therefore regarded as the most appropriate spraying equipment for pesticide application in passionfruit.

To operate efficiently, an air-blast machine should:

- produce small droplets
- produce a sufficient volume of air to replace the air within the vine
- direct the airstream towards the target
- create turbulence by converging the airstreams (to aid in deposition of droplets)
- have a slow operating speed (2 to 3 kilometres per hour) to ensure coverage is adequate.

A number of different air-blast machines are available. One effective set-up is shown on page 147 and in Figure 15.2. An alternative is to use a smaller machine like the one shown in Figure 15.3.

Misting machines are not usually used for spraying passionfruit. In these machines, droplets are produced from air-shear nozzles in an airstream produced by a small centrifugal flow fan that has low volume (10 000 to 25 000 cubic metres per hour) and high speed (250 to 350 kilometres per hour). These sprayers are suitable for low-volume spray applications of 300 to 600 litres per hectare (or less), which is not enough to achieve good coverage of mature passionfruit vines. Some air-shear machines also use electrostatic charges to improve coverage and reduce drift.

Figure 15.2 (Left) A trailer-mounted air-blast sprayer (a rear view of this machine is shown on page 147)

Figure 15.3 (Right) A three-point linkage-mounted air-blast machine

Bait sprayers

Bait sprays for fruit flies need to be applied with different equipment, usually a coarse-spray handgun or a tractor-mounted splatter sprayer. This is because small volumes of spray (15 to 20 litres per hectare) are being applied to multiple separate locations in the lower part of the canopy only, and the spray is best applied as a coarse spray containing large droplets.

A suitable sprayer (which can be fitted to a quad motorbike with coarse nozzles mounted either side) is shown in Figure 15.4. Alternatively, trailer-mounted sprayers can be used. The sprayer is best operated at a pressure of about 350 kilopascals, delivering between 75 and 100 millilitres per vine.

Figure 15.4 A bait sprayer like this can be fitted to a quad motorbike

Sprayer calibration

When using an air-blast machine, the effective coverage of a mature two-year-old vine requires up to 2 litres per vine. To achieve this coverage, the spraying machine needs to be calibrated.

Sprayer calibration is an essential but often misunderstood concept. It includes both spray volume and pesticide calculations. Calibration should be carried out every year, just like a service of the sprayer. The process of calibration is:

1. Check that your pressure gauge is working and that the pressure can be adjusted.
2. Check your spray jets for cracks and visible wear and replace them as necessary. Ceramic jets generally need changing every 3 to 4 years. Clean the filters and jets with a toothbrush and detergent, not with wire.
3. Calculate sprayer output in litres per minute by following these steps:
    a. Fill the tank with clean water, set the pressure at the 10, 15 or 20 bar and operate the sprayer for a minute or so in a level stationary position to fill all spray lines.
    b. Check all valves, hoses and nozzles for leaks.
    c. Stop the sprayer and refill the tank to the top or a predetermined mark.
    d. Operate the sprayer in a stationary position for 1 minute.
    e. Measure the amount of water required to refill the tank to the top or the mark. This is the sprayer output in litres per minute.
    f. Compare the output with the manufacturer's specifications for the jets at your chosen pressure. This will indicate whether your gauge is working correctly. If it is not, there could be blockages or wear in the nozzles. If there is a discrepancy, first check your gauge, then check for any blockages or wear in the valves, hoses and nozzles.

4. Check your ground speed. Don't rely on the tractor's speedometer. Mark out a distance of 100 metres. Select a gear to produce an operating speed of 2 to 3 kilometres per hour. With the sprayer operating, time the travel over the 100 metres. From this, calculate the actual speed in kilometres per hour using the following formula:

$$\text{Speed (km/h)} = \frac{\text{distance (m)} \times 3.6}{\text{time taken (s)}}$$

5. Calculate the application rate in litres per hectare using:

$$\text{Application rate (L/ha)} = \frac{600 \times \text{sprayer output (L/min)}}{\text{row spacing (m)} \times \text{speed (km/h)}}$$

   Note that this formula assumes that both sides are being sprayed; multiply the row spacing by 0.5 for a single-sided sprayer.

6. Divide the application rate by the number of vines per hectare to calculate the application rate per vine.
7. If the application rate is less than 1 litre per vine, travel more slowly. If it is more than 2 litres per vine, increase the speed.
8. Check your sprayer's coverage and uniformity by placing strips of water-sensitive paper in various positions on the vine.

Regularly check the nozzles, pressure gauge, spray volume and uniformity to ensure that the desired spray volume continues to be applied. If it increases or decreases, find out why and act accordingly.

Chemical accreditation

Growers must be able to demonstrate that they are meeting their duty of care and are using pesticides safely and responsibly. One way is to obtain user accreditation under the ChemCert training scheme (see Appendix B). ChemCert training in the use of farm chemicals is available throughout Australia. Participants are trained at a group workshop, then complete an assessment at the end of the course and, if they pass, are issued with a statement of accreditation that is valid for 5 years.

Though accreditation is not mandatory for the use of most pesticides, it is strongly recommended that all growers who use any pesticides at all complete the ChemCert training course. In Queensland, accreditation is provided by ChemCert Training Queensland, a wholly owned subsidiary of Farmsafe Queensland (www.farmsafe.com.au). In New South Wales, ChemCert Australia (www.chemcert.org.au) and SMARTtrain (www.smarttrain.com.au) provide accreditation training.

In some states, some pesticides (e.g. S7s) cannot be bought or used without current accreditation. Your customers (agents, merchants, retailers and processors) may require ChemCert accreditation as part of an on-farm quality-assurance program.

Records

All users of agricultural chemicals must keep comprehensive records. Calibration and individual spray records provide good evidence of each operation should a dispute arise. Records should include:

- date and time of application
- chemical used, rate and spray volume
- block, pest and area sprayed
- name and accreditation number of operator
- weather and other relevant operating conditions
- equipment used (for which there is a matching calibration record).

Under the *Pesticides Act 1999* (NSW), users of pesticides in New South Wales are obliged to keep written records of every application.

Spray compatibilities

It is often convenient to mix spray materials and apply them together in the one operation. However, mixing pesticides can result in the chemicals reacting with each other. This can reduce their effectiveness and can also produce a solution that will damage vines, even though the same chemicals sprayed separately will not cause damage. Follow the advice on the label regarding the options for mixing chemicals.

Pesticide safety

Essential precautions

Most pesticides are potentially hazardous. However, simple precautions can eliminate these hazards. Correct use, storage and disposal of pesticides will ensure the health and safety of yourself and others. Here are the main precautions:

- Always read the label first.
- Keep an up-to-date manifest or register that lists the pesticides currently on your property.
- Obtain, study and have on hand for emergencies the Material Safety Data Sheet (MSDS) for each chemical you use. (Suppliers of chemicals are legally required to provide these.)
- Use pesticides only as directed. Follow the label safety directions, including those for the use of safety equipment.
- Keep all pesticides in a secure, well-ventilated, well-lit room or separate storage area that has an impervious floor and impervious shelving. Store them away from foodstuffs and eating and packing facilities. (See further guidelines on storage in the following section.)
- Be aware of how poisons can enter the body.
- Store pesticides in original containers, with labels intact. Never store pesticides in food or drink containers. Relabel the container if a label comes off.
- Avoid storing excess quantities of pesticides. It is best to purchase only the amount needed for one season; this ensures the pesticides are fresh. It also reduces storage-space and spill-containment requirements.
- Dispose of empty containers immediately and correctly. Do not burn containers.
- Ensure that a suitable fire extinguisher and a fresh water supply are available close to where the pesticides are stored.
- Mix and measure in a level, well-ventilated area. Keep a spill kit (e.g. a bucket with a bag of lime and sawdust or other absorbent material) on hand where pesticides are stored or mixed. Do not dilute pesticide spills with water.
- Place a sign stating 'Danger: Agrochemicals' on the door of the pesticide storage room or shed.
- Keep a first aid kit on hand and make sure it is easily accessible.
- Do not store personal protective clothing and equipment in a pesticide storage area.
- Train employees so that they know how to use the pesticides on the farm correctly.

Storage

The Australian Dangerous Goods Code specifies the kinds of chemicals that cannot be stored together. For example, oxidisers and flammables must be separated by at least 5 metres.

- See the label for any specific requirements.
- Store pesticides in buildings that are secure, isolated, well ventilated, insulated, moisture-free and resistant to fire. The buildings must have impervious floors surrounded by bunds to contain spills. The Australian Standard AS 2507-1998, 'The storage and handling of agricultural and veterinary chemicals', specifies design criteria.

- Do not store pesticides in direct sunlight for prolonged periods. Overheated containers of volatile solvents may explode.
- Never store pesticides in containers that are (or look like) containers used for food, drink or non-toxic substances.
- Never store pesticides in an area prone to flooding.
- Keep pesticides out of reach of children.
- Never carry pesticides or spraying equipment in the passenger area of a car.
- If you find leaking or broken containers, dispose of them properly.

Measuring, mixing and spraying

- Read the label; heed the label.
- Wear protective clothing as detailed on the label. If clothing becomes contaminated with spray-strength solution, remove it immediately, rinse it, then launder it in hot, soapy water, separately from other washing. If clothing becomes contaminated with pesticide concentrate, dispose of it.
- Be especially careful when measuring and handling concentrates. Ensure these do not overheat. If they overheat, they may explode.
- Wear waterproof boots, overalls, washable hats, gloves, goggles and a respirator at all times when handling and spraying toxic concentrates, and when applying pesticides to crops.
- Remember to change the respirator cartridges at the recommended intervals. (Record the number of hours they have been in use.) Select the correct cartridge for the pesticide being used. This is especially important for fumigants.
- Change tractor cab filters regularly. Air-conditioned tractor cabs are not designed to filter pesticides. There is no Australian Standard to cover pesticide filtration by air-conditioners. Servicing and maintenance of air-conditioners are highly skilled operations and if they are not carried out properly, the risk to operator health is magnified. Inside air-conditioned cabs, use respirators and other protective clothing.
- In particular, avoid contaminating your skin, eyes and mouth. If your skin, eyes or mouth are contaminated by splashing or dust, wash them *immediately.*
- Keep clean water, soap and an uncontaminated towel near the mixing and filling area.
- *Never* clean nozzles with your mouth.
- Measure and mix in a well-ventilated area.
- Clean up spills and damaged containers immediately.
- Use a sharp knife to open hags containing pesticide. Do not tear them.
- Never pour pesticides into a spray tank while holding the container at or above eye level.
- Do not use matches or any other naked flames near pesticides, as the pesticide solvents could explode.
- *Never* eat, drink or smoke when handling or spraying pesticides. Doing so could result in oral poisoning or, in the case of smoking, explosions. Do not smoke anywhere near pesticides.
- Move upwind while spraying, and keep out of the sprayed area for several hours or for the length of time specified on the label as the re-entry period.
- Immediately after spraying, wash all exposed skin with soap and water, and clean all equipment.

Spills

- Confine pesticide spills quickly with sand, sawdust or soil dykes. Slowly sweep towards the centre of the spill.
- Use absorbent material (such as sawdust) to soak up a spill, then place this material in a container and dispose of it according to the instructions on the label.
- Never hose-down a spill, as the pesticide will be spread over a larger area and is more likely to reach a watercourse.
- After disposing of a pesticide spill, clean the equipment you have used. Launder your clothes in hot, soapy water, separately from other washing.

Poisoning

In the case of a pesticide emergency, call the Poisons Information Centre on 13 11 26 (national).

- Check the pesticide label and MSDS for the recommended actions or antidote and have this readily available.
- Learn to recognise the symptoms of pesticide poisoning. Read the MSDS and know what to look for. Acute poisoning symptoms start immediately or within a few hours of exposure. Mild symptoms can include nausea, anxiety, sweating and salivation; more severe symptoms can include vomiting, abdominal cramps, diarrhoea, urinary incontinence, vision impairment and respiratory difficulty. Chronic poisoning is much more insidious, as symptoms often do not show up until some time after exposure.
- If you are showing any symptoms of pesticide poisoning, see a doctor. Take the pesticide label and MSDS with you. Have someone else take you or accompany you to the doctor—do not go to the doctor alone.

Pesticides can enter the body in three ways:

1. **Dermal exposure** (direct contact with the skin and subsequent absorption). Liquids are particularly hazardous and can lead to acute poisoning, especially when pesticide concentrate is handled (i.e. when mixing). Long-term exposure to chemicals as a result of spray drift or contact with recently sprayed plants can lead to chronic poisoning. Dermal poisoning can occur when inadequate protective clothing is worn. Try not to re-enter sprayed areas for at least 12 hours (and preferably not for 24 hours) after spraying.
2. **Inhalation.** Inhaling chemicals—particularly dusts, powders, fumigation vapours and spray droplets—can lead to acute poisoning and chronic poisoning. Inhalation poisoning occurs when a suitable, properly maintained respirator is not worn, or where tractor cab filtration is not effective.
3. **Swallowing.** Children under the age of five are most at risk of swallowing poisons, usually as a result of inadequate storage security or improper disposal of empty containers. Never put pesticide into any type of drinking bottle. Another way that poison is ingested is by eating fruit too soon after pesticide application—over time, this can lead to chronic poisoning. This is a result of not reading or not following the label safety directions, in particular the withholding period. Appropriate handling procedures, as indicated on the pesticide label, must be followed. The MSDS available for each substance will also give details of what precautions are required when using that chemical.

Pesticides and the environment

Always consider the environment when you are applying pesticides. There are four main ways in which pesticides can pose a threat to the environment:

1. **Spray drift.** This is often the result of using an incorrect sprayer type, set-up or calibration. It can also result from spraying during inappropriate weather conditions, such as windy or inversion conditions. Make sure you calibrate your sprayer regularly.

2. **Excessive spray run-off.** This is caused by excessive spray volume or poor direction of nozzles, which is usually the result of using an incorrect sprayer type, set-up or calibration.

3. **Inappropriate disposal of excess pesticide (concentrated or diluted) and empty pesticide containers.** Ensure there is no risk of pesticides entering watercourses. Never leave pesticide drums or containers at water fill-up points, particularly when these are near watercourses or when there is a risk of flooding. There are documented methods for safely disposing of pesticides and their containers. These can vary from state to state and some are legal requirements. Be aware of your local disposal regulations. Do not use empty pesticide containers for any other purpose.

4. **Inappropriate location of pesticide storage sheds or fill-up and wash-down areas.** Consider the possibility of a spill occurring when locating these areas. For example, avoid locating these areas next to your water source, as it could become contaminated in the event of a spill. If you must store chemicals close to a water source, ensure that precautions are in place to contain and handle any spill.

Other information sources

A number of sources of information on the use of agricultural chemicals are available in printed and/or electronic format.

- ***Agricultural chemical users' manual.*** This comprehensive text for farmers, growers, trainers, spray contractors and operators is published by DEEDI. It provides expert advice on using agricultural chemicals safely and efficiently. The manual covers the use of insecticides, fungicides and herbicides. Topics include controlling agricultural pests, pest biology, product formulations and labels, product safety, transport, storage and disposal, managing agricultural chemical resistance, spray and other application technologies, spray application equipment, agricultural chemical drift management, and the law and agricultural chemicals. It is available as a free download at www.dpi.qld.gov.au or can be purchased as a hard copy from the Queensland Government Bookshop.

- Australian Pesticides and Veterinary Medicines Authority (APVMA). This Australian Government authority is responsible for assessing, registering and regulating pesticides and veterinary medicines up to and including the point of retail sale. The APVMA website (www.apvma.gov.au) includes:

    - the Public Chemical Registration Information System (PUBCRIS), a searchable database that gives details of all of the agricultural chemical products registered for use in Australia

    - a 'Permits' database that gives details of chemicals with temporary registrations for uses not shown on the label (off-label permits).

- drumMUSTER. This is the national program for the collection and recycling of empty, cleaned, non-returnable chemical containers. The program provides a defined route for safe disposal of your used chemical containers. Visit www.drummuster.com.au or call (02) 6230 6712.

- ChemClear®. This is a chemical waste disposal program for the safe management and disposal of unwanted rural agricultural chemicals. Visit www.chemclear.com.au or call (02) 6230 4799.

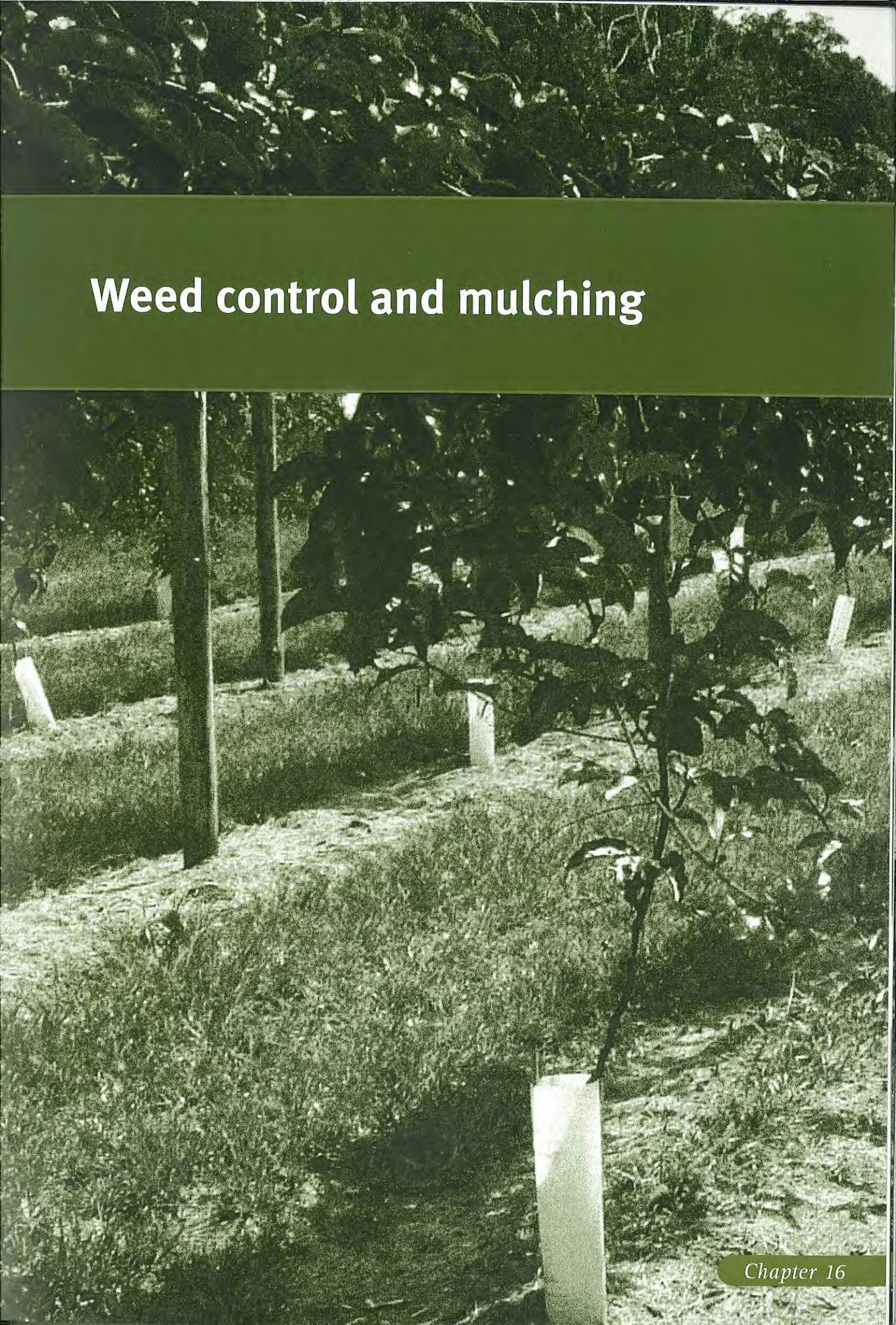
- Infopest Agvet. This contains details of all agricultural and veterinary (Agvet) chemicals registered in Australia. It includes chemical usage information, product labels, active ingredients and maximum residue limits (MRLs). This product is produced and sold by DEEDI. To order, call (07) 3239 3967 or visit www.biosecurity.qld.gov.au

- Infopest MSDS. This compilation is sourced directly from chemical companies and suppliers. This product is produced and sold by DEEDI. To order, call (07) 3239 3967 or visit www.biosecurity.qld.gov.au

- msds.com.au This Australian online MSDS database contains over 25 000 sheets that can be downloaded.

- Pest Genie. This online system is designed to support the effective and appropriate use of crop-protection and animal-health products. It contains free, comprehensive, up-to-date information on a broad range of products, as well as other information relating to their use. Visit www.pestgenie.com.au

Weed control and mulching



Chapter 16

Weeds compete with passionfruit vines for moisture and nutrients. Therefore, if vines are to grow and yield to their full potential, good weed control is essential. Mulching has many benefits; one is that it can suppress weeds. This chapter outlines the key elements of weed control and mulching:

Weed control

Newly planted vines are significantly disadvantaged if they need to compete with weeds for water and nutrients. Weed control immediately near young vines is vital. Weeds are best controlled by maintaining a grassed inter-row area and mulching about 50 centimetres on both sides of the vine row, as shown on page 157. Apply mulch 10 to 15 centimetres deep. Keep it well away from the stem to avoid collar rot.

Mulch may be brought in or grown on site. If you bring in mulch, try to use coarse hay or straw such as sorghum. Alternatively, you can use the grassed inter-row area to grow mulch. Rather than keeping the grass short, delay slashing until the grass is 15 to 20 centimetres high, but do not let any weeds present go to seed. Too frequent slashing is costly, contributes to compaction and favours unproductive grasses and weeds. Use side-delivery mowers to direct the slashings under the vines. It is also possihle to grow crops such as millet, sorghum, oats and lupins in the inter-row space to use as mulch materials (see Figure 16.1).

Figure 16.1 A living mulch crop of 2-month-old Shiroe millet; it was hand-sown during wet weather and will be cut before seeding using a side-throw mower to provide a mulch along the vine rows

Either hand weed or spot spray any weeds that grow through the mulch. Use one of the herbicides listed in Table 16.1 (page 161). Apply herbicides when the weeds are actively growing and take great care to prevent herbicide contact with any part of the vine (such as the stem, low-hanging leaves and exposed roots). To minimise spray drift, use a shielded, low-volume, low-pressure fan or flood-jet nozzle, or a rope wick applicator. Vine stem guards (see Figure 16.2, page 160) help to protect the vine from accidental spray drift.

Avoid using non-selective systemic herbicides such as glyphosate on sandy soils, especially in wet weather, since the chemical can be absorbed through the roots. To reduce the risk of herbicide penetrating the mulch and reaching the passionvine roots, use the minimum spray volume and apply only enough herbicide solution to wet the leaves without any run-off.

Figure 16.2 Vine stem guards provide protection from herbicide spray drift

Do not cultivate the soil closer than 1 metre to the vine, as passionfruit has a shallow root system that can be easily damaged. Do not use brush cutters because of the risk of damage to the stem.

Trials in New South Wales have shown that sprigs of shade-tolerant sweet smother grass (*Dactyloctenium australea*) planted on a regular pattern quickly spread to provide a carpet of foliage below the vines and in the inter-row area (see Figure 16.3). In subtropical areas it is easily established during summer when planted in moist soil and watered in; however, in tropical regions it grows less vigorously and is more difficult to establish. Once the grass is established, any that spreads too close to the stems of the vines can be sprayed off as required using a selective grass herbicide (see Table 16.1).

Figure 16.3 Fallen fruit on a cushion of sweet smother grass

Establishing sweet smother grass in the inter-row area provides the following benefits:

- It prevents erosion.
- It outcompetes other grasses and weeds and reduces weed-control costs.
- It needs less mowing than other grasses because of its low-growing habit.
- It is easily controlled by selective herbicides and does not compete with vines.
- It has soft foliage that cushions the landing of mature fruit falling from the vine, thus helping to prevent skin damage.

Appendix B includes contact details of suppliers of sweet smother grass turf (which can be split into sprigs for planting).

Table 16.1 Herbicides registered for weed control in passionfruit

Chemical	Trade names	Weeds controlled
Diquat (registered for orchard use)	Diquat 200, Reglone, Sanction 200	Broadleaf weeds and some annual grasses
Fluazifop-P as butyl	Flazz 212 EC, Fluazifop, Fusilade Forte, Fuzilier	Grasses
Glufosinate ammonium	Basta	Broadleaf weeds and grasses
Glyphosate as ipa (360 grams per litre)	APVMA permit 10954	Broadleaf weeds and grasses
Haloxyfop-R methyl ester	Asset, Convict, Exert 520, Firepower, Gallant West, Halomac 520, Halox 520, Haloxyfop 520 EC, Haloxyken 520 Hermes, Harpoon 520, Inquest, Judgement 130, Recon 520, Verdict 520	Grasses
Oryzalin (for use on non-bearing passionfruit only)	Cameo 500, Oryzalin 500, Prolan, Sharp Shooter 500 SC, Surflan 500	Some broadleaf weeds
Oxyfluorfen	Cavalier, Convert 240 EC, Encore 240, Goal, Govern, Oxen, Oxyfan, Oxyfluorfen, Ox 240, Oxxel 240 EC, Oxy 240 EC, Oxyfluorfen 240 EC, Point, Striker	Some broadleaf weeds and some grasses
Paraquat as dichloride (registered for orchard use)	Explode 250, Gramoxone 250, Inferno, Nuquat 250, Para-Ken 250, Paraquat 250, Quash 250, Shirquat 250, Sprayquat 250 Herbicide, Spraytop, Spraytop 250 SL, Scorpion 250, Uniquat 250	Most grasses and some broadleaf weeds
Paraquat plus diquat (registered for orchard use)	Blowout, Brown Out 250, Di-Par 250, Eos, Paradat, Paradym 250, Paraquat/ Diquat, Premier 250, Pre-Seed 250, Revolver, Scorcher 250, Speedy 250, Spray Seed 250, Spraykill 250, Spray & Sow, Wildfire 250, Uni-Spray 250	Grasses and broadleaf weeds

Warning: Take great care with all herbicides, and avoid spray drift onto the vines. Read labels carefully and observe all safety precautions.

Mulching

The passionfruit vine has a relatively shallow root system that has adapted to feeding near the soil surface. This makes vines susceptible to moisture stress. Mulching helps to prevent this and provides many other benefits. It is vital for long-term plantation health and productivity.

The benefits of mulching

The benefits of mulching include:

- It insulates the soil from the sun and wind, reducing evaporation and moderating temperatures in the root zone. Water and heat stress are reduced.
- It improves the physical characteristics of the soil—its structure, porosity and aeration. It builds up the organic-matter level in the soil, producing a more open soil structure. This enhances water penetration (which reduces water run-off and soil erosion) and soil water storage. Improved soil structure also reduces the potential for soil compaction and provides a better physical environment for root growth.
- It improves the chemical characteristics of the soil. High organic-matter levels enhance the capacity of the soil to store and release nutrients.
- It improves the biological characteristics of the soil by providing food for beneficial soil organisms as well as a better physical environment for their development. As a result, the soil microflora becomes more diverse and more abundant. This helps suppress harmful disease organisms (such as rootrot fungi) and significantly improves nutrient recycling and root health.
- It suppresses or prevents weed growth, which reduces competition for nutrients and water as well as the cost and risk of herbicide spraying.

Figure 16.4 Well-mulched mounds beneath vines grown on a pergola

Potential pitfalls of mulching

Mulching has potential problems that must be considered:

- Weed seeds can be introduced in the mulch material if it is not selected carefully.
- Mulching increases frost hazard. This is because loose mulch prevents the soil from absorbing and storing heat from the sun during the day. This heat would be released at night to help prevent frost damage.
- Mulching can be a fire hazard. Under hot, dry conditions, dry mulch burns well and the vine has little or no resistance to heat.
- Nitrogen levels can become too high or too low if unsuitable mulching materials are used.
- Extra microbial activity associated with freshly applied mulch can tie up some nitrogen, causing a short-term or medium-term deficiency in the vine. Increased amounts of nitrogen may need to be applied to prevent this. Approximately 1 kilogram of urea (or equivalent) is needed per cubic metre of mulch applied.
- Collar rot or stem canker may develop if mulching material is placed against the stem.

Suitable mulching materials

Not every type of mulch is suitable for passionfruit. The two most important properties are coarseness and the carbon:nitrogen (C:N) ratio:

- Coarseness. The mulch should be coarse enough to break down slowly and allow free drainage of water. These properties are generally found in materials that are fibrous, stalky, strawlike or chunky. Materials that are too fine (such as sawdust, bagasse and lawn clippings) tend to form a barrier that initially prevents water penetration. However, once wet, they become soggy, dry slowly and keep the underlying soil excessively wet. Fresh hardwood sawdust may be toxic because of its resin and phenol content, so it needs to be aged before use. In wetter environments, coarser materials should be used, as these take longer to break down.
- Carbon:nitrogen (C:N) ratio. Ideally, the C:N ratio should range from about 100:1 to 20:1 (see Table 16.2). Materials with a C:N ratio significantly lower than the recommended range (e.g. lucerne hay) tend to decompose too rapidly and raise nitrogen levels too much. Materials with a C:N ratio that is too high can cause a nitrogen drawdown effect unless extra nitrogen fertiliser is applied. (The drawdown effect occurs when the material takes nitrogen from the soil during decomposition, thus starving the vine.)

Table 16.2 Carbon:nitrogen (C:N) ratios in a range of dried materials

Material	Carbon:nitrogen (C:N) ratio
Pinus radiata sawdust	550:1
Cardboard	500:1
Pinus radiata bark	500:1
Eucalyptus sawdust	500:1
Eucalyptus bark	250:1
Bagasse	120:1
Woody prunings	100:1
Composted *Pinus radiata* bark	100:1
Wheat or oats straw	100:1
Sugarcane tops	80:1 to 100:1
Mature leaves	60:1
Spent mushroom compost	31:1
Composted pine bark	30:1 to 40:1
Corn stalks	33:1
Mill mud (filter press)*	23:1
Grasses	22:1
Mixed weeds	19:1
Cow manure	15:1
Lucerne hay	13:1
Peanut shells	12:1
Poultry litter	10:1
Poultry droppings	7:1
Pig manure	5:1

* This figure is for mill mud only. Some sugar mills blend fly ash with mill mud, and this mixture will have a different C:N ratio. In wetter areas, mill mud may not be suitable for mulching. However, it is suitable for drier areas and is also beneficial as an organic fertiliser for young vines, provided it is used sparingly.

Source: Handreck, KA & Black, ND 1994, *Growing media for ornamental plants and turf*, Revised edn, University of New South Wales Press, Sydney.

A combination of different materials can often be used to achieve the desired C:N ratio and coarseness.

If you are using materials with high C:N ratios (e.g. 100:1 and higher), either compost the material before applying or apply extra nitrogen to the vines to offset the drawdown effect. This is not as critical if the material used is very coarse (e.g. loose branches), because the rate of breakdown is very slow.

Locally available mulching materials should always be investigated. Sugarcane tops are popular, but they have a reputation for lowering soil pH more than other materials do. This is not a problem as long as pH is monitored and lime or dolomite is applied as required. Mill mud (filter press) from sugar mills is a popular mulch where it is available and studies have shown excellent results in terms of yield and fruit size improvement. This is thought to be due to its nutritional properties and its water-holding capacity. Mill mud releases its nitrogen slowly (about one-third per year over a three-year period), but its fineness can cause problems if it is applied too thickly in wetter environments.

Green waste from local council recycling depots can be used, but this must be composted for at least 3 months prior to use. Heat produced in the composting process kills any weed seeds, pests and diseases in the waste; however, if the composting is incomplete, weeds, diseases and pests can be introduced to your property.

Make sure that wood chips are well aged (composted) before use. Do not apply fresh wood chips because resins and phenols in some of these can suppress plant growth.

Applying mulch

It is best to apply mulch soon after the wet season so that the mulch can be in an advanced stage of decomposition before the onset of the next wet season. In frost-prone areas, apply mulch after the risk of frost is over. Replenish the mulch as necessary. A depth of 10 to 15 centimetres is ideal. The mulch should completely cover the under-vine area and extend about 30 centimetres beyond the drip line on both sides of the vine. Keep mulch about 10 centimetres away from the stem. Don't forget to add extra nitrogen if you are using materials with a high C:N ratio.

Growing your own mulch

The cost of purchasing, transporting and spreading mulch can deter growers from using it. A low-cost alternative is to grow your own mulch.

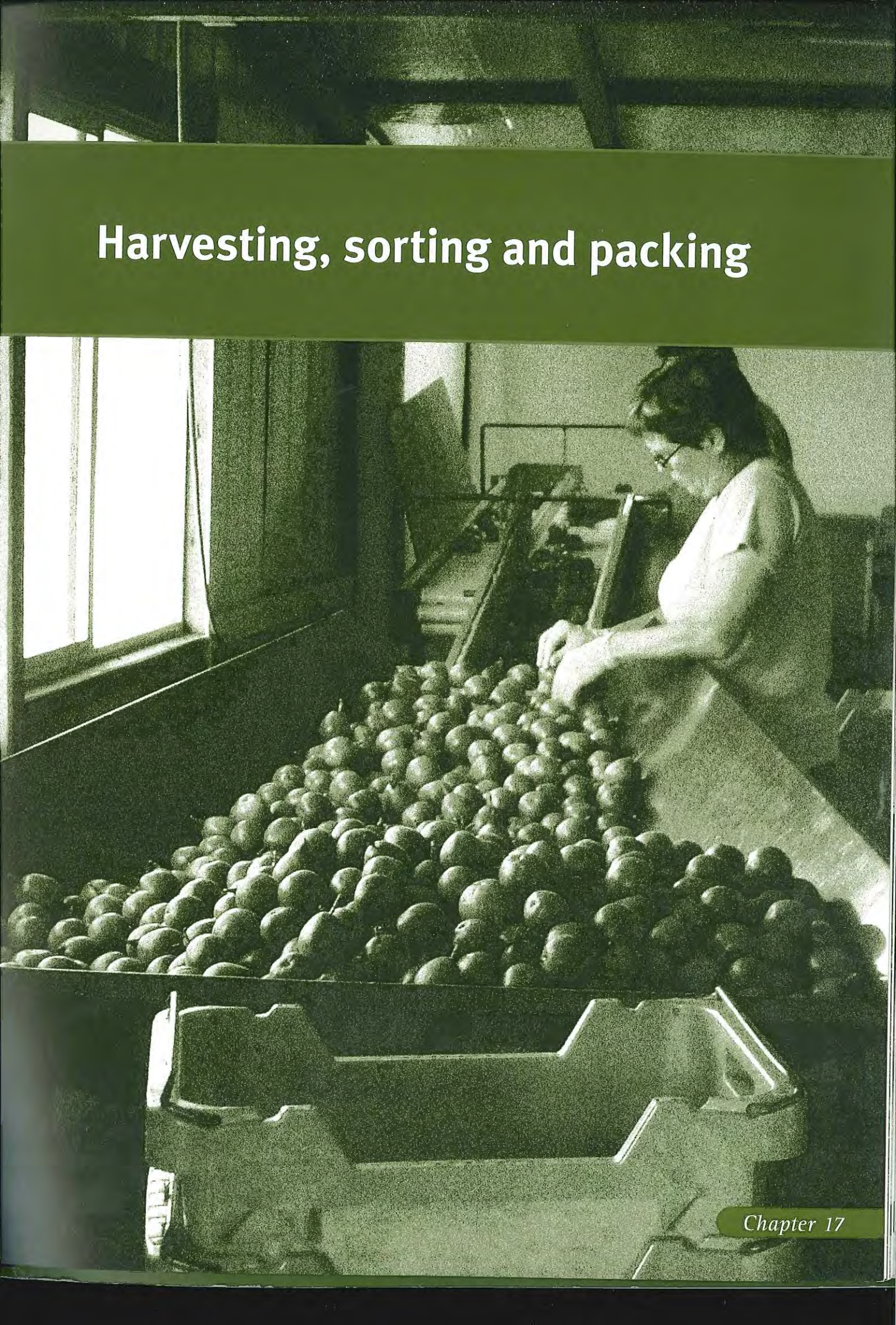
Suggested mulch crops for the seasons indicated are:

- spring/summer planting—forage sorghum such as Jumbo (a sweet sorghum hybrid with a long growth season and coarse stem) or hybrid millet such as Shiroe (see Figure 16.1) or Nutrifeed
- autumn/winter planting—oats, barley, triticale, rye grass or lupin varieties such as Kalya or Merrit.

Alternatively, you can use the grass clippings from the grass sward in the inter-row area. Many growers have modified slashers to direct slashings from the inter-row area to under the vines so that the mulch is topped up at no extra cost each time the plantation is slashed. Planting setaria, panic grass, clover or kikuyu can enrich the sward. Watering and fertilising the inter-row area can also increase the bulk of material available.

Although grass clippings are not an ideal mulch because of their fineness and low C:N ratio, adding small amounts at regular intervals does not pose a problem, especially when they are added to the existing mulch layer.

Harvesting, sorting and packing



Chapter 17

The profitability of passionfruit production depends on a strong commitment to marketing quality fruit. Only attractively presented, blemish-free fruit with good flavour and a long shelf-life will achieve premium prices. Care with harvesting and post-harvest handling will ensure that your efforts in producing high-quality fruit are not wasted. Follow the guidelines in this chapter to ensure the fruit reaches the consumer in good condition:

Harvesting

Before deciding when to harvest, remember that immature passionfruit do not continue to ripen off the vine. They may lose some acidity, but they do not develop full flavour or colour.

The method of harvesting depends upon the variety grown:

- Collect purple varieties after the mature fruit fall off the vine onto the ground. The fruit fall off the vine as soon as they are mature, and it is not possible to reliably assess their maturity while they are on the vine.
- Harvest Panama selections off the vine using secateurs. Unlike the purple varieties, Panama selections will hang on the vine for several days after they are mature. This gives growers the opportunity to harvest them from the vine. In addition, they have softer skins than purple varieties and are therefore more susceptible to damage and sunburn if they are allowed to fall to the ground. Harvest Panama fruit when they have no visible green skin. Some mature fruit will fall to the ground between harvesting rounds; collect these if they are not sunburnt.

The frequency of harvesting depends upon the variety, the type of trellis used and the prevailing weather conditions:

- Collect purple varieties daily and harvest Panama selections once or twice per week.
- On single-wire trellises, mature fruit is not protected from the sun, so depending on the variety, collect the fruit daily or once or twice a week.
- On pergola systems and A-frame trellises, the vines growing over the frames shade fallen and hanging mature fruit. This allows longer intervals between collection rounds than is the case for single-wire trellises. (However, trial pergolas and A-frames on a small scale before using them across the whole plantation, as extended harvest intervals are of no benefit if vine growth and productivity are poor.)
- During very hot, sunny weather, collect fruit more frequently (up to twice daily) to avoid sunburn damage. Regular pick-up reduces sunburn, drying out and shrivelling of the skin, and spoilage by fungal rots. Avoid leaving fruit on the ground for more than a day, especially in tropical climates.
- As a general rule, harvest more frequently during wet weather and less frequently during cool winter weather.

Gather the fruit in plastic buckets (or similar containers) and then, if necessary, carefully transfer the fruit to lugs or bins for transport to the shed (see Figure 17.1). Take care at all times not to damage the skin of the fruit.

When harvesting, gently shake the vines to remove any mature fruit that have lodged within the foliage.

Figure 17.1 Fruit gathered in plastic buckets is transferred to lugs for transport to the shed

Post-harvest handling

Handle fruit very carefully to avoid abrasions to the skin and loss of bloom. Fruit begin to lose moisture as soon as they are separated from the vine, causing a shrivelling of the skin and some loss of flavour after a few days at room temperature. Consequently, it is best to market fruit as soon as possible after harvesting. If you have a high humidity (95% humidity) coldroom, you can hold good-quality fruit for up to 2 weeks at 7 °C.

Sorting and grading

Sort fruit into 'fresh market' and 'processing' grades. Discard fruit with broken skin and rots. For fresh market fruit, grade for colour and size. Small operators can do this manually. Larger operators generally use a size grading machine. Remove any remains of the calyx from the stem of the fruit—this improves appearance and ensures that the calyx remnants do not become a source of post-harvest disease infection. Figure 17.2 shows a typical sorting and packing line for passionfruit.

Figure 17.2 Fruit is fed from a bulk hopper onto a roller incline, where it is inspected and sorted into reject, processing and fresh market fruit (which is then sorted and packed into cartons)

Grading for the fresh market

There are two grades for fruit consigned to the fresh market:

Grade 1

- No fruit with major defects are allowed.
- The proportion of fruit with minor defects must not exceed 10%.

Grade 2

- Up to 10% of fruit are allowed major defects (hut no skin breaks).
- 100% of fruit are allowed minor defects.

Minor defects include:

- calyx present
- irregular shapes (e.g. bell-shaped or flat-sided)
- rubs or blemishes covering less than 10% of the surface.

Major defects include:

- insect sting damage
- live insects
- foreign matter (e.g. soil, leaf)
- disease
- dry, brown stalks
- deformation
- wrinkling
- sunburn or bleaching
- less than 35% pulp by weight
- immaturity (patchy green skin)
- broken skin or pulled stalks
- rubs and blemishes on more than 10% of the surface.

Use these standards as a guide, but always grade and pack according to your customer's specifications.

Grading for the processing market

The exact quality standards of fruit for the processing market are set by the processing companies. Some processors test for total soluble solids (TSS) and perform a pulp recovery to determine the price paid. Green, immature and rotten fruit, as well as fruit with broken skin, are unacceptable for processing.

The passionfruit grading guide

The passionfruit grading guide poster (see Figure 17.3) is a 60 × 84 centimetre poster that shows colour photographs of examples of 'minor' and 'major' defects of passionfruit. It is designed to be used as a handy reference, and is printed on waterproof paper suitable for use in the packing shed. Using this poster will help growers and agents achieve a standard, quality product in the marketplace. The poster can he obtained free of charge from DEEDI's Maroochy Research Station by calling (07) 5453 5800 or faxing (07) 5453 5901.

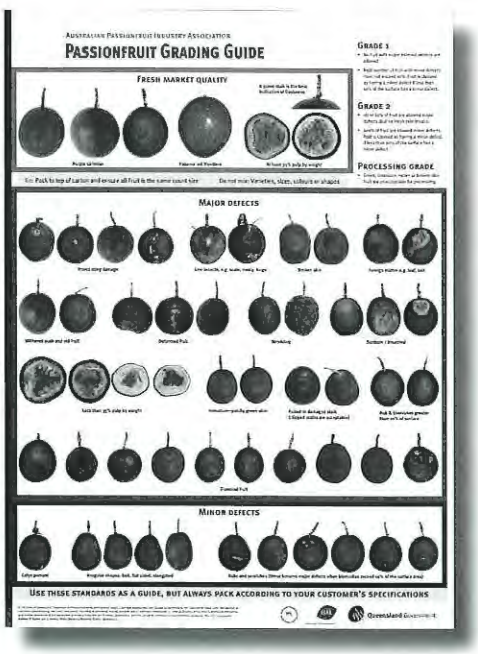


Figure 17.3 The passionfruit grading guide poster

Insecticide treatment

Interstate Certification Assurance (ICA) requirements must be met for some interstate markets. To meet these, passionfruit must be dipped or flood-treated with an insecticide for fruit fly disinfestation. Alternatively, for some purple varieties (but not Panamas), an ICA for an unbroken, wrinkle-free skin condition is available. Check for any ICA requirements and how to obtain them with your state's certification authority (see Appendix B).

Waxing

Around 50% of growers apply liquid wax coatings to their fruit. In addition to improving shelf-life (by preventing wrinkling and reducing weight loss), waxing enhances the appearance of fruit. However, some varieties have an excellent appearance without the use of wax, and some negative characteristics can occur in waxed fruit (such as change of flavour and internal breakdown).

The shelf-life of waxed passionfruit was tested in 2007 by David Peasley (Peasley Horticultural Services). The results of this trial are summarised in Table 17.1.

Table 17.1 The effects of liquid wax coatings on passionfruit held at ambient temperatures

Variety	Results
Misty Gem	This variety wrinkles more quickly than other varieties do. Waxed fruit had a shelf-life of at least 21 days; for untreated fruit, shelf-life was 14 days.*
Sweetheart	A decline in eating quality was noted in some waxed fruit. Waxing is not generally necessary, as this variety has a long shelf-life without waxing.
Pandora	21 days after waxing, unacceptable 'off' flavours and aromas developed. Waxing is not recommended.
McGuffies Red	Waxing extends shelf-life significantly, to up to 30 days; for untreated fruit, shelf-life is 18 days or less.*

* Waxing is not necessary for many markets, even for varieties that have an extended shelf-life after waxing. Waxing is most useful where fruit takes a long time to reach the consumer. Consult your agent for advice on your target market before investing in waxing equipment and materials.

Stem removal

For select markets, some growers remove the stem or stalk from fruit prior to packing to enhance presentation. This labour-intensive practice is acceptable but is not recommended for most markets, as a green stem is a useful indicator of fruit freshness. (It shrivels and browns on older fruit.) Discuss with your agent whether or not stem removal is necessary for your intended market.

If you do decide to remove stems, clip the stems—never pull them. Pulling the stem out of the fruit will damage the integrity of the fruit skin, causing premature breakdown.

Packing

The most common package used for fresh market passionfruit is the 18 litre carton (see Figure 17.4), which holds from 5 to 10 kilograms (and an average of 7 kilograms) of fruit, depending on variety, fruit size and packing method. The 18 litre carton is also known as the T35 carton. The size count (the number of fruit needed to fill a carton) ranges from 40 to 100 for Panamas and from 70 to 160 for purple varieties.

- Always pack to the top of the carton and ensure that the fruit is the same count size.
- Do not mix varieties, sizes, colours or shapes.

Most cartons are volume-filled, but pattern packing produces a very attractive pack and generally returns a higher price. This price advantage needs to be balanced against the extra cost of pattern packing, and these packs are usually only done for special markets. Typical volume-filled and pattern-packed cartons are shown in Figure 17.5. Consult your agent to find which option is better for your target market.

Figure 17.4 A typical 18 litre passionfruit carton

Figure 17.5 Volume-filled (left) and pattern-packed (right) cartons

Some buyers require fruit to be packed in plastic bags within the carton, as this slows the drying-out process, thus reducing fruit shrivelling. Make sure that fruit is dry before packing if plastic bags are used.

Tray packs offer good presentation but are more expensive. Trays that are used for stonefruit (450 × 290 × 70 millimetres) are suitable. Fruit are generally packed into plastic inserts within the tray, with counts ranging from 28 to 44 fruit for purple varieties and from 18 to 28 for Panamas. An example of a tray pack is shown in Figure 17.6. Demand for this type of pack is very low, so check with your agent before using tray packs.

Other packing options (such as punnets, multi-packs and mesh bags) are sometimes used for niche markets, and some market agents repack fruit into special packs to fill specific orders. Check with your agent regarding any requirement for these types of packs before using them.

Figure 17.6 Tray-packed passionfruit

Carton marking

Labelling is required under the *Trade Measurement Act 1990*. Every package of passionfruit must have at least the following information legibly and durably stamped, stencilled or printed on at least one end of the carton:

- the name, full address (including the state) and telephone number of the grower/packer
- the word 'passionfruit'
- the count of fruit in the package (as an indicator of fruit size).

The address must give enough detail for the person to be identified and located. A post office box number or mail service is not acceptable but can be included with the other information.

The net weight of the fruit in the package can also be shown; this is optional. There is no standard weight that must be in the package. However, if the net weight is shown on the package, at the time of final sale the weight of the package must not be less than this net weight. The word 'net' may be included, but it is not compulsory. Fruit must be weighed using approved and certified scales.

Printing on cartons should be prominent and indelible with a minimum letter height of 5 millimetres. Failure to correctly mark the package may result in fruit being withheld from sale until correctly marked.

Many growers use pre-printed cartons with pre-printed end panels such as the one shown in Figure 17.7. When completed by the grower, the panel in Figure 17.7 will include the essential information. Note that the count is included but the weight is not.

Figure 17.7 A typical end panel for a pre-printed 18 litre carton

Some passionfruit packages have panels with spaces for you to stamp or stencil your name and address, and details of your wholesaler. Spaces for details such as size count, ICA number, net weight of the fruit and a traceability code are usually included, as these details may need to be shown for quality assurance. An example of a stencil panel is shown in Figure 17.8.

Passionfruit	Variety:	Class:	Count:
Consigned to:	Grown and packed by:		Net weight:
			Consignment number:

Figure 17.8 An example of a stencil panel for labelling of passionfruit cartons

The words 'Produce of Australia' or 'Australian Passionfruit' should be clearly shown on the carton, as in Figure 17.9.

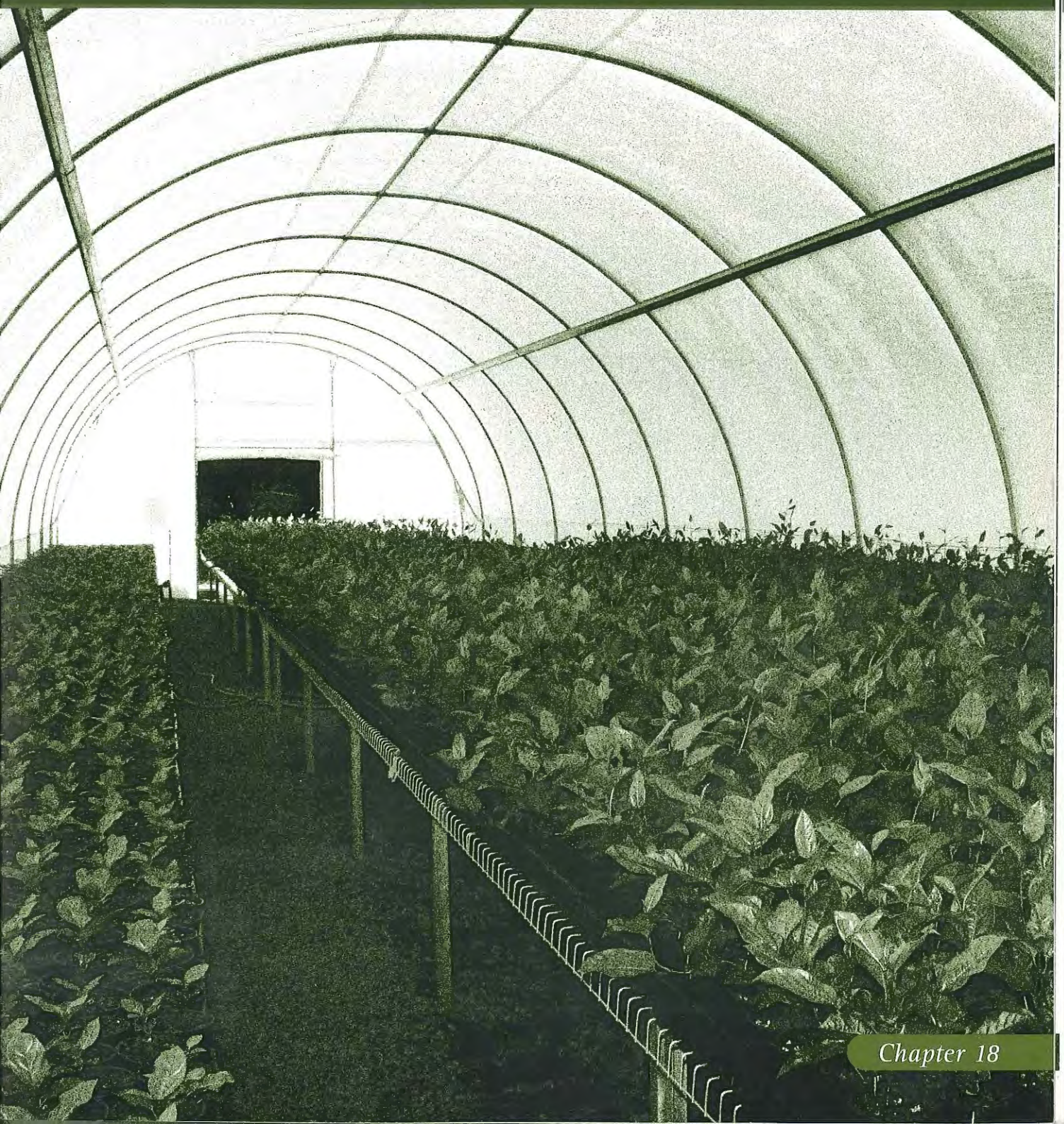
Figure 17.9 Cartons should be marked as Australian produce

Transport and storage

Fruit is usually delivered to markets by refrigerated road transport. It is important to minimise exposure of the fruit to conditions that will dry them out and result in shrivelling. Ensure that fruit is maintained at the correct storage temperature on the journey to market, ideally between 5 and 7° C.

Agents and retailers have commented that post-harvest darkening of fruit colour is impeded by low storage temperatures and recommend that fruit be held at room temperature for a while just prior to display to improve appearance. There are, however, no proven guidelines on this aspect of cool-chain management.

Propagation



Chapter 18

When establishing a new plantation, you can choose to buy seedlings or to propagate your own vines. It may seem attractive to propagate your own vines to save money. However, propagating passionfruit is a specialised job requiring specific skills and some special equipment. Therefore, we recommend that growers leave it to specialist nurseries that possess these skills and equipment. Some basic notes on propagation follow to help you understand the process:

Overview

All purple varieties are propagated by grafting selected varieties (scions) onto specially selected rootstocks that are resistant to fusarium wilt. Selected passionfruit rootstock strains of *P. edulis* f. *flavicarpa* are recommended. Plants grown on these rootstocks are available through APIA-accredited nurseries (see Appendix B).*

Most of the purple varieties currently grown commercially are products of APIA's breeding program and are subject to royalty payments. Propagation of these varieties can only be carried out with permission from APIA (see Appendix B).

The Panama selections Pandora and McGuffies Red should be grown from seed; this will ensure that the plants are at least initially free from virus infection, as passionfruit viruses are not transmitted in seeds. Seeds and seedlings of these Panama selections should be produced in a way that prevents any cross-pollination (see 'Maintaining a Panama selection' later in this chapter).

Requirements and time frame

The materials required to propagate passionfruit are:

- rootstock seed (of a strain that is resistant to fusarium wilt)
- scion wood (from vines that are free from virus symptoms and are true to type)
- tools (secateurs, grafting knife, 6 millimetre clear grafting tape)
- a hothouse with a fan heater (and preferably heated beds).

The hothouse must be able to keep the temperature above 20 °C. This is essential, as the seeds are planted in April or May for grafting in August or September. The timetable for production of grafted vines using a hothouse is shown in Table 18.1.

Table 18.1 Timetable for production of grafted vines

Step	Time from previous step	Time of year
Plant seed		April–May
Transplant seedlings	2–6 weeks later	April–June
Graft	Up to 12 weeks later	August–September
Plant out	Up to 8 weeks later	October

Raising rootstocks (or seedlings)

For rootstocks, use seeds from strains of *P. edulis* f. *flavicarpa* that are resistant to fusarium wilt. Seeds that have been tested for resistance to fusarium wilt are available from DEEDI's Maroochy Research Station; for more information, call (07) 5453 5800. Alternatively, you can use seeds from Panama selections that have been tested and shown to have a high resistance, but make sure the flowers have been self-pollinated and that no outcrossing has occurred (see 'Maintaining a Panama selection' later in this chapter).

Seeds are generally sold by the gram with 1 gram containing about 60 seeds. After allowing for some non-germinating seeds, 7 grams of seeds should yield about 350 rootstock plants.

* In 2011, APIA changed its name to Passionfruit Australia Incorporated. See Appendix B for contact details.

Extracting seeds

If you wish to propagate your own Panama plants, you can extract seeds from fruit taken from selected vines by using the fermentation method. Follow these steps:

1. Allow the fruit to fully ripen.
2. Scoop out the pulp into a plastic container.
3. Allow the pulp to ferment for 5 to 14 days, stirring it a couple of times each day.
4. After the fifth day, test whether the pulp is ready for processing by taking a small sample and washing it against a coarse sieve. If the seeds separate easily from the pulp, the batch is ready for washing and separation. If they don't, return the batch for further fermentation and retest in a couple of days.
5. When the seeds are ready, wash them, separate them from the pulp and spread them out on absorbent paper to air dry.
6. Store the seeds in paper bags in a household refrigerator until required for use.

Sowing seeds

Sow seeds into either medium sharp sand or a commercial soil-less potting mix in 15 centimetre deep seed boxes. These mixes are relatively free from disease organisms and generally fall away easily when the germinated seedlings need to be separated. If the sand or potting mix has been in contact with soil, sterilise it before use by placing it in shallow trays 8 centimetres deep in a household oven at 60 °C for 30 minutes.

Sow the seeds 6 millimetres deep and space them about 10 millimetres apart. Place the seed boxes in a hothouse with a heat lamp or heated beds that maintain temperatures above 20 °C. A seedbed temperature of 28 °C is ideal for germination. Seeds should germinate in 10 to 14 days if night temperatures are kept above 20 °C, but otherwise may take up to 6 weeks.

Transplanting seedlings

Separate out and transplant the seedlings when the first true leaves begin to appear (7 to 14 days after emergence). Transplant each seedling into a 10 centimetre pot containing a good-quality seedling mix with slow-release fertiliser. Make an 8 centimetre deep hole and with great care insert the seedling, ensuring that the root does not bend. Firm the mix around the roots and base of the stem, then water. Place the transplanted seedlings back in the hothouse.

Depending on the temperature, seedlings will take up to 12 weeks to reach grafting size. During this time, keep the plants well watered and fertilise them with either a proprietary liquid fertiliser every 7 to 10 days or a slow-release fertiliser every 3 to 4 weeks. Stop fertilising about a week before grafting is due.

Warning: Do not use urea on young seedlings. It may burn the roots and kill them.

Selecting scion wood

Traditionally, grafted purple varieties have been replanted after 2 or 3 years. However, in recent years many growers have found that vines rapidly decline in vigour and yields are poor after the first year of production. This premature 'vine decline' is thought to be due to virus diseases that are carried into new plantings in the scion material used to produce grafted plants. Poor growing conditions (such as cold, wet, windy weather) reduce the ability of vines to 'outgrow' virus infections and exacerbate the problem. (Vigorous growth minimises expression of viral symptoms.)

There is no formal scion tip accreditation scheme for the passionfruit industry and so it is important when ordering plants to check with your nursery that they have carefully inspected any vines that tips are taken from to check they are free from virus symptoms and are true to type. Scion material should be taken only

from healthy-looking vines with fast-growing tips and long internodes that are hardening off. Tips should be taken from vines that are no more than 1 year old, as there will have been minimal opportunity for the build-up of any virus in these young vines. Adhering to these guidelines will help to minimise the chance of vines being planted with high levels of virus already present in the scion part of the plant.

Grafting

Seedlings are ready for grafting when they are 25 to 40 centimetres high and the stem at grafting level is 3 to 4 millimetres in diameter. Grafting involves the following steps:

1. Cut off the seedling (rootstock) just below a leaf at the grafting point. Leave the remaining leaves on the rootstock. Grafting at a height of at least 30 centimetres on the rootstock stem will help to prevent, after planting out, the spread of phytophthora from spores in water splash from the soil onto the susceptible scion. (The selected rootstocks are resistant to this disease.)

2. To prepare the scion wood, take a tip and cut off all leaves, leaving just the growing tip with its very small leaves. Select a long internode (space between the leaf nodes) 5 to 8 centimetres back from the growing point and of similar diameter to the rootstock. Make two opposite sloping cuts about 10 millimetres long, one on each side of the stem, to form a wedge (see Figure 18.1).

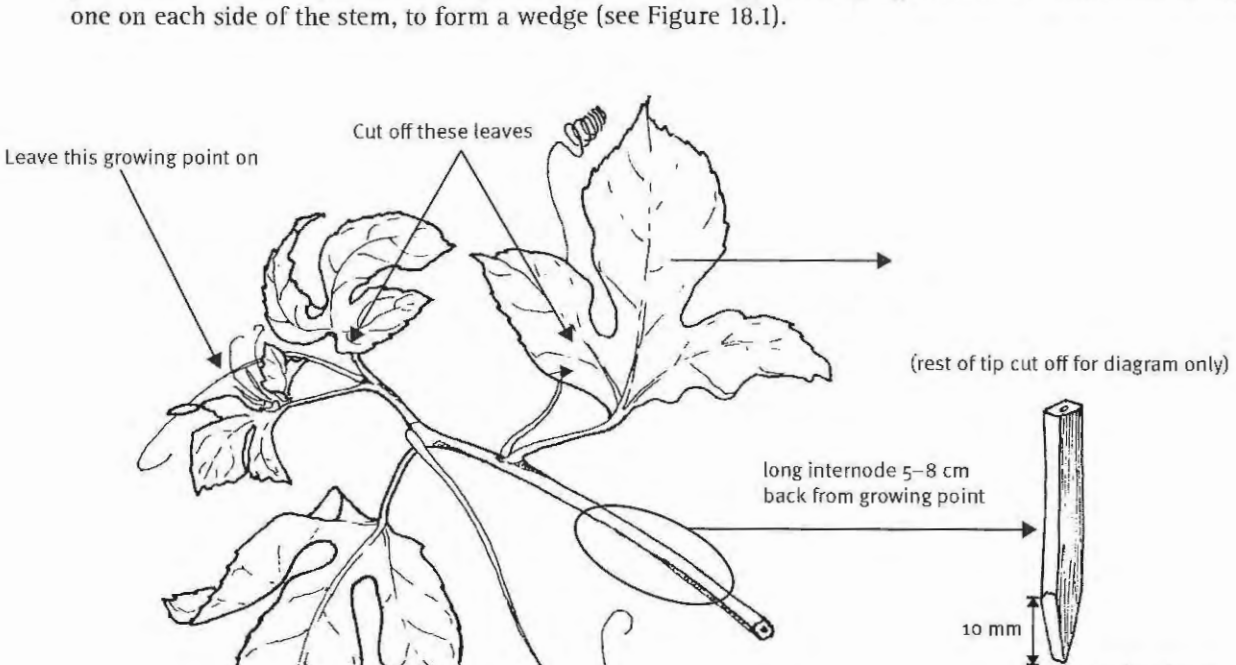


Figure 18.1 Preparing the scion wood

3. On the rootstock, make a vertical cut at the centre of the cut stem. Make this cut about 3 millimetres longer than the length of the wedge on the scion tip (see Figure 18.2, page 180). This reduces the possibility of the scion moving upwards when tying.

4. Part the cut with your thumb and push the scion tip to the bottom of the cut. Make sure that one edge of the scion is flush with the edge of the rootstock (see Figure 18.2). This is most important, as union between the two must occur for the graft to be successful.

5. Bind the graft with grafting tape. Start at the bottom; go up to the top and back down to the bottom before tying off.

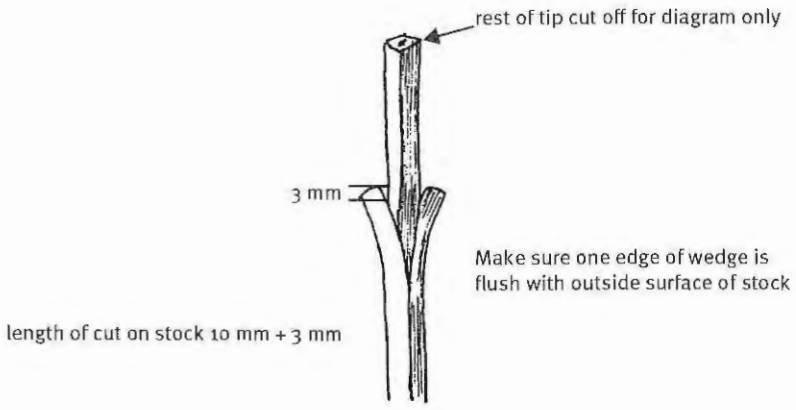


Figure 18.2 Placing the scion tip in the rootstock

6. Keep the plants shaded and under high humidity for the first 3 or 4 days until the tip stands up and shows no sign of wilting. Light misting is a good way of maintaining high humidity.
7. Do not water until the graft starts to grow.
8. Remove side shoots until the graft grows.

Maintaining a Panama selection

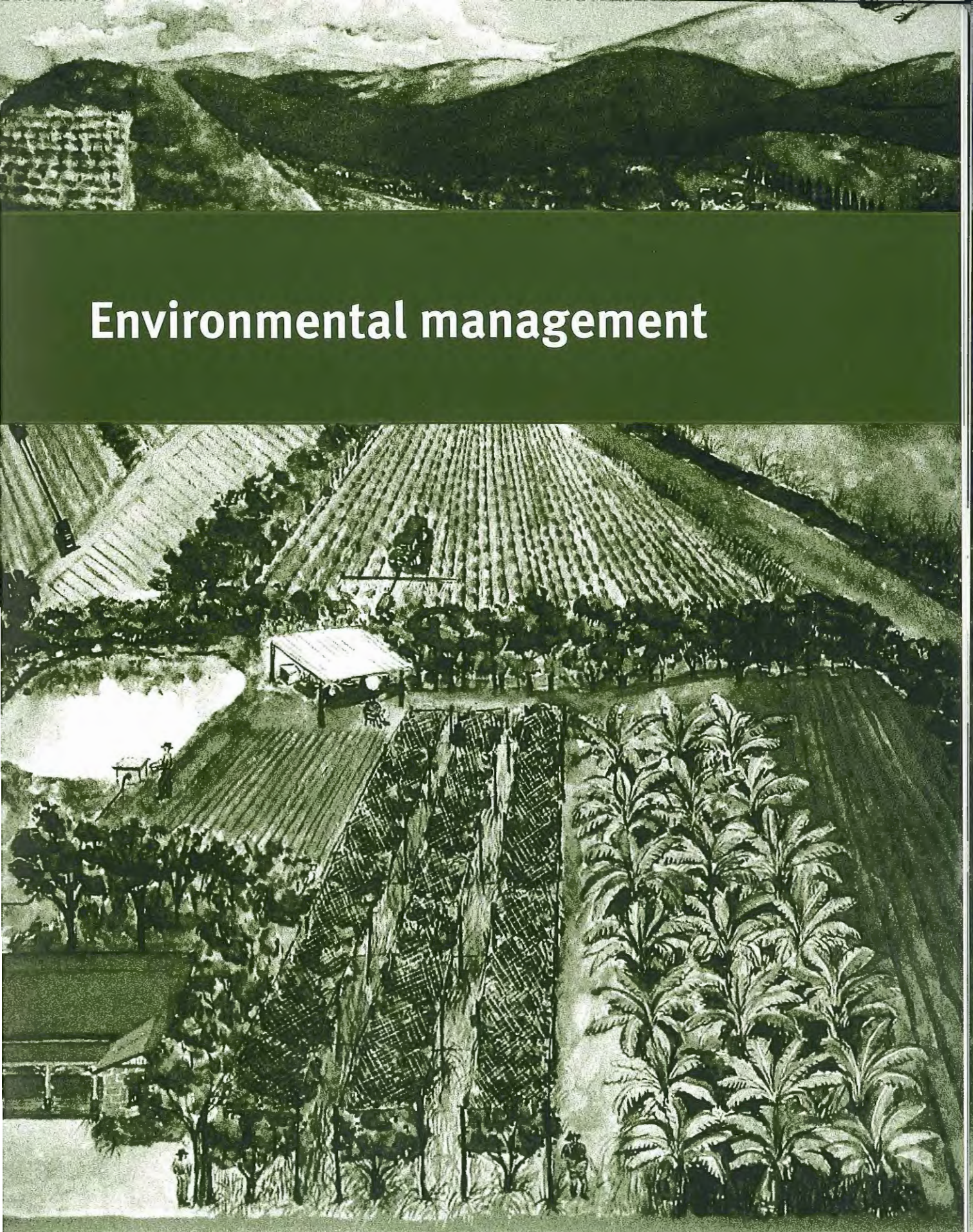
The following notes are adapted from an article by Peter Beal and David Peasley originally published in the APIA magazine The Passion Vine *in March 2005.*

Growers can propagate superior Panama selections such as Pandora and McGuffies Red by using seed collected from vines grown on their plantation. When doing this, it is essential to keep the line 'pure' and true to type. This can be done by making sure that any seed used is taken only from fruit that have developed from flowers that have not been cross-pollinated.

The following technique can be used to prevent cross-pollination. You will need tags to identify elite vines (i.e. row and number in the row) and paper bags (10 × 15 centimetres with ties) to cover the flowers.

1. Identify and tag those vines that give the best fruit that is typical of the selection. Ensure that tagged vines are clearly separated from adjacent vines. (As a guide, you could expect to identify and tag between 5 and 10 vines out of 100.).
2. Bag full-sized (unbroken) flower buds on the tagged vines a day or so before opening to prevent foreign pollen entering. Self-pollinate the opening flower in the morning of the day the bud opens.
3. Rebag the pollinated flower to protect it from foreign pollen until the fruit is set. Keep the fruit bagged or tagged for identification until it is ripe.
4. Collect seed from the ripe bagged or tagged fruit. Ferment the pulp, then wash and dry the seeds.

Environmental management



FARMCARE

Cultivating a Better Futur

Chapter 19

CODE OF PRACTICE for Sustainable Fruit and Vegetable Production in Queensland

Farmers are under increasing pressure to demonstrate their environmental credentials to the wider community. They also need to ensure that they comply with a range of state and federal environmental legislation. You can address these issues by implementing an environmental management system or by checking that your business is operating within your industry's code of practice and is following environmental best-practice guidelines. These and related matters are outlined in this chapter:

Environmental management systems

An environmental management system (EMS) is a systematic approach to managing the impacts a business has on the environment. An EMS does not dictate levels of environmental performance; however, a minimum requirement is that it enables a business to comply with legislative requirements concerning the environment. It should also build on existing activities such as industry best-management practices, industry codes of practice, quality-assurance and food-safety schemes, and workplace, health and safety considerations.

An EMS is not a product you buy off the shelf but a process that helps you to improve your business's environmental performance. This process has a number of steps:

1. Perform an environmental risk analysis to identify, assess and prioritise potential environmental impacts.
2. Set environmental objectives and targets.
3. Develop an environmental management program to meet these objectives and targets.
4. Monitor, measure and record environmental performance to check that objectives and targets are being met.
5. Review the system at regular intervals and improve the system as needed.

The EMS process is based on the 'plan, do, check, review' management cycle (see Figure 19.1). It aims to continuously improve the environmental performance of a business.

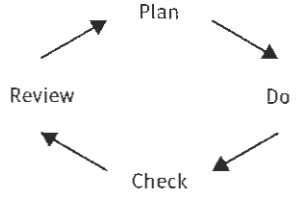


Figure 19.1 The 'plan, do, check, review' cycle for continuous improvement

ISO 14001 is the most widely recognised auditable international EMS standard. It is a 'process standard'; that is, it does not prescribe a particular level of environmental performance that a business must achieve other than the need to comply with all relevant legislation and industry codes of practice. As a process standard, however, it does have quite stringent requirements as to the steps (processes) a business must take to implement it. The system must also be auditable by an accredited third party.

In addition to the steps listed for implementing a general EMS, ISO 14001 requires a business to have:

1. an implemented, documented environmental management policy that is communicated to staff and available to the public
2. an implemented, documented EMS that includes staff training, communication, resourcing and responsibility aspects
3. procedures in place:
    a. to meet legal and industry requirements
    b. to respond to accidents and emergencies
    c. to mitigate identified environmental impacts.

For more information about ISO 14001, visit the Standards Australia website at www.standards.com.au or contact your state office of Standards Australia.

Protocols, codes of practice and best-practice guidelines

Protocols, codes of practice and best-practice guidelines differ from a process standard (such as ISO 14001) in that they prescribe a certain level of environmental performance that the business should strive to achieve.

GLOBALGAP

GLOBALGAP is a protocol for 'good agricultural practice' (the 'GAP' in GLOBALGAP) and aims to develop a single standard (with different product applications) for use across the whole of world agriculture. The protocol addresses quality, food safety, environmental management, and workplace health and safety. GLOBALGAP evolved in 2007 from EurepGAP, which began in 1997 as an initiative of the Euro-Retailer Produce Working Group (EUREP).

Details of protocols relating to fruit and vegetables can be found under the 'Standards' link on the GLOBALGAP website at www.globalgap.org

Farmcare

The Farmcare Code of Practice was developed by Growcom to meet the industry's legislative requirements and to provide guidelines for growers. It is designed to assist Queensland's fruit and vegetable growers to meet their general environmental duty of care under the *Environmental Protection Act 1994*. The code was developed under the umbrella of the Queensland Farmers' Federation (QFF) Environmental Code of Practice. However, it has no certification capability and cannot be externally audited.

The code outlines a range of potential environmental harms and management options for minimising impacts from those harms. It has seven sections:

1. land and soil management
2. water management
3. biodiversity management
4. air management
5. noise management
6. waste management
7. integrated crop management.

The Farmcare Code of Practice can be obtained from Growcom. Call (07) 3620 3844, email info@growcom.com.au or visit www.growcom.com.au

Horticulture for Tomorrow

This project helps growers link production targets to their care for the environment as an integral part of daily business management. It is managed by Horticulture Australia Limited and is funded by the Natural Heritage Trust. The project has published two information sources for growers:

1. *Introductory guide to environmental management in horticulture.* This is a basic introduction to environmental management in Australian horticulture. It outlines the issues impacting on growers, the options available and important aspects to consider before adopting any formal system or program.
2. *Guidelines for environmental assurance in Australian horticulture.* These guidelines give a clear summary of the standards and expectations for environmental management of horticultural enterprises. They provide:
    - an overview of the priority environmental management issues of concern in the horticultural sector in general
    - an outline of the environmental management outcomes that are expected from a horticultural business, by a variety of stakeholders

- guidance on how a business can assess its environmental risks
- guidance on practices that are recommended for addressing environmental and natural resource management issues
- suggestions for the records and evidence a business should keep to demonstrate that environmental management outcomes are being met.

These documents and other information on the environment and horticulture can be found on the Horticulture for Tomorrow website at www.horticulturefortomorrow.com.au

Land degradation

Land degradation is a permanent decline in productivity of land. Some forms of land degradation are soil erosion, soil structural decline, reduced fertility and increased acidity.

The two most visible types of land degradation associated with horticulture in Queensland and New South Wales are gully erosion and mass movement, including landslip. The lighter friable soils in Western Australia are also prone to gully erosion as well as loss of topsoil from wind and sheet water flow. Soil structural decline is a problem in the Northern Territory.

Gully erosion and mass movement can occur individually or in combination with other, less visible types; they seriously threaten the long-term viability of farms. Although these types of land degradation are the most visible, they are not necessarily the most significant forms. By the time you see a gully, serious soil erosion and other problems already exist in the surrounding areas.

Soil type has a major effect on the amount of soil loss. Sandy surface soils, for example, are generally more prone to erosion than clay soils are. Of equal importance is the physical condition of the topsoil (the soil tilth). Soil that has been cultivated to a fine tilth when preparing planting sites is more susceptible to erosion damage than an undisturbed soil is. Soils least likely to erode are those that are cultivated as little as possible and are protected by a mulch or a standing cover crop.

Gully erosion

Soil erosion begins on bare or cultivated ground when raindrops seal the surface and dislodge soil particles, which gradually move downhill. Any water flowing over the surface will carry this loose soil material with it, forming rills and eventually gullies. Where the soil surface is bare and the topography steep, soil erosion losses can be dramatic. In extreme cases, more than 300 tonnes of soil can be lost from each hectare each year.

Sloping land should be provided with soil conservation structures (such as diversion drains, U-drains and grassed inter-row strips) to control soil loss before it becomes a problem. Water needs to be diverted away from crop areas at regular intervals to reduce the concentration and erosive potential of run-off.

Mass movement, including landslip

Landslips usually occur when an impervious layer of either rock or clay is present beneath the surface. When the soil is saturated and subsurface water is flowing on top of the impervious layer, the ground can become mobile and move downhill. These movements are often sudden and can extend over several hectares, though most are localised and cover only a small area.

Steep slopes, high rainfall and a lack of deep-rooted vegetation greatly increase the risk of landslips.

Following a landslip, a range of rehabilitation measures can be used to make the slip and adjacent areas safe and stable. These include:

- locating diversion banks or drains above the slip area to intercept and divert run-off water away from the slip and into more stable areas
- reshaping (when ponding occurs at the back of the slip) to remove water from this vulnerable area
- using agricultural drainage pipes to intercept and remove subsurface water flows
- maintaining a good grass cover and using trees wherever possible to stabilise and 'dry out' the slip area.

Off-site effects of land degradation

The off-site or downstream consequences of land degradation affect the landholder and the community. Transported soil material contains fertilisers and chemicals, which can have serious environmental consequences some distance from the soil erosion source. Land degradation caused by erosion within a catchment can lead to:

- sedimentation of culverts, drainage lines and watercourses (which increases flooding risks and drainage costs)
- deterioration of water quality
- reduced water storage capacity of dams
- pollution of dams, creeks and rivers hy soil, agricultural chemicals and fertilisers.

Other factors that affect the environment

Many aspects of growing passionfruit commercially may affect the surrounding environment and need careful management. These include:

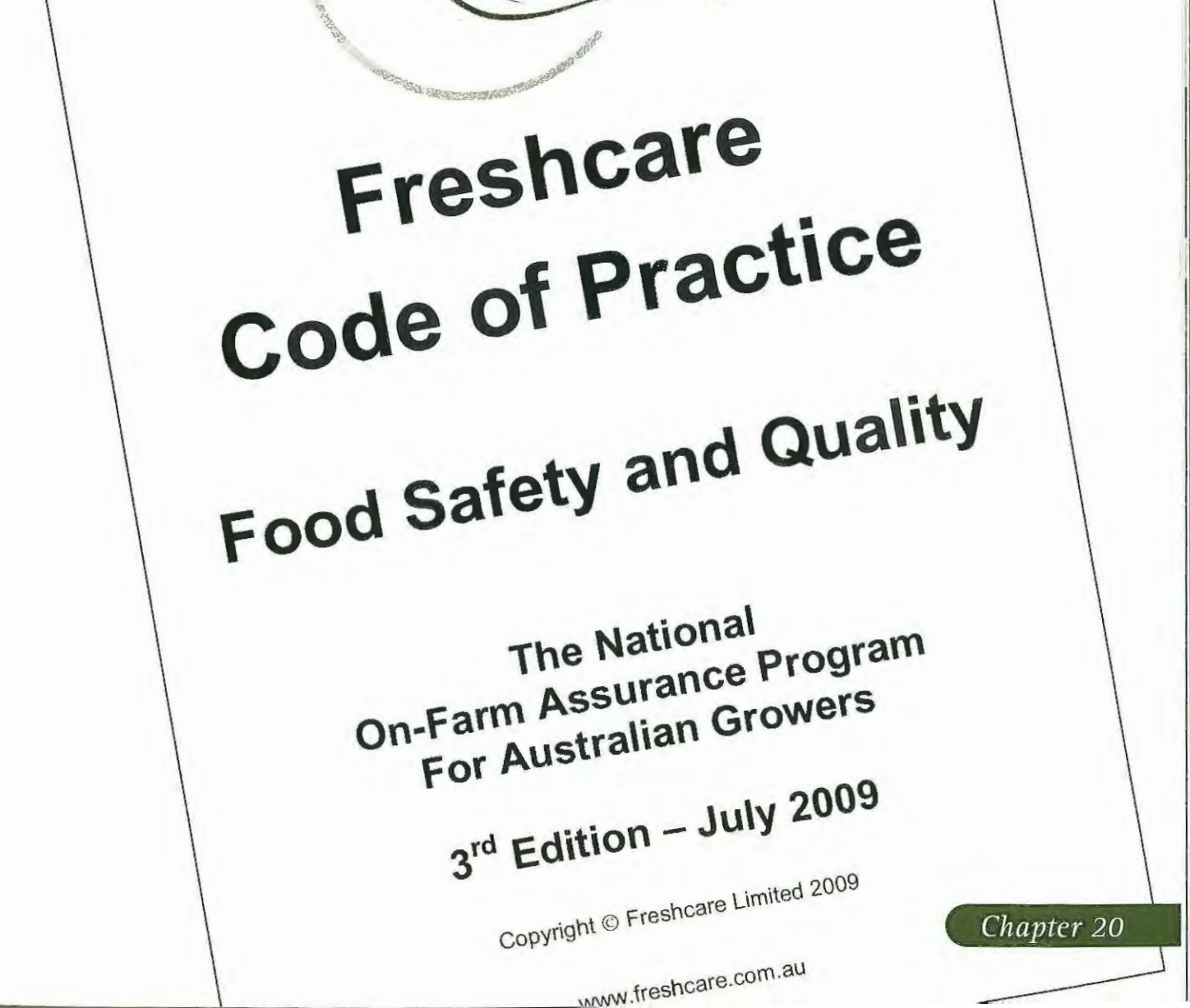
- site selection (see Chapter 2)
- plantation layout (see Chapter 3)
- use of fertilisers and pesticides (see Chapter 10, Chapter 14 and Chapter 15)
- erosion control (see Chapter 3)
- use of mulch (see Chapter 16)
- spray drift
- noise
- urban pressure
- water quality
- flora and fauna zones (including windhreaks)
- vegetation alongside watercourses.

Farm management systems fact sheets

Farm management systems fact sheets are available on the Growcom website at www.growcom.com.au. They cover:

- eco-efficiency
- farm management systems
- farm safety
- information management
- on-farm energy use
- on-farm food safety
- on-farm waste management
- on-farm water use
- record keeping
- sustainable land management
- sustainable nutrient management
- water efficiency.

Quality management and food safety



Do not be complacent about food safety. Fruit and vegetables have been implicated in several food-poisoning cases; however, if handled correctly, a crop such as passionfruit is unlikely to have such problems. Consumers want fruit that is consistently attractive, nutritious, tasty and safe to eat. The major supermarket chains in Australia have responded by demanding that all their suppliers have some level of quality management to assure the quality and safety of their products.

An understanding of the principles of quality management will help you decide what type of quality system you need to implement to meet your customers' requirements. These are the basics:

Understanding quality management

'Quality' describes a product's fitness for purpose. 'Good' or 'high' quality implies a predictable degree of uniformity and dependability. Some view 'quality management' as the planning and control of all the activities that influence product quality. This means that good managers are constantly engaged in quality management.

In the past, the suitability of the product for its intended market was determined by 'end-point inspection'—inspection at the market level. This system has several serious flaws:

- Rejecting a product late in its marketing cycle is expensive.
- Predicting product performance early in the marketing process is difficult because product history is unknown.
- The system is often driven more by tradition than by real market needs.

The objective of modern quality management is to build quality right through the production and marketing process. This has the following positive outcomes:

- It minimises rejections late in the marketing chain.
- It increases sales (by ensuring customers are satisfied) and encourages repeat sales.
- It improves productivity (by identifying problem areas, avoiding mistakes and reducing waste).
- It helps growers access markets with quarantine and other barriers to normal entry.
- It promotes greater trust and cooperation throughout the marketing chain.
- It provides consumers with documented evidence that the product they are buying will meet their needs.

There are five core principles of quality management:

1. Quality is defined by the customer, not the grower.
2. Decisions are based on facts, not feelings.
3. Problems are identified at the earliest possible point, not at the end point.
4. Quality management has to be planned, organised and managed—it does not happen by itself.
5. All those involved in the business, both the workers and the managers, are responsible for quality management.

To implement an effective quality management system, you need commitment, good planning, staff involvement and well-organised documents (including records and product specifications).

Why growers need to implement a system

National Food Safety Standards became enforceable from February 2001. Growers and packers are exempt from meeting the Food Safety Standards except where they conduct some form of processing or sell directly to the public. Further information is available at www.foodstandards.gov.au

However, growers are indirectly implicated because a food business (such as a retailer, wholesaler or processor) is required to take all practical measures to ensure that it only accepts food that is not contaminated. Contamination is defined as 'a biological substance, chemical agent, foreign matter or other substance that may compromise food safety or suitability'. The safety of food, unlike its quality, cannot be determined by simply looking at the produce.

Food Safety Standards have driven retailers, wholesalers and processors to require farmers to implement some form of food safety system. Retailers such as Woolworths/Safeway, Coles, Metcash/IGA and Aldi require packers and wholesalers who supply directly to their distribution centres to be certified to an acceptable system

such as Woolworths Quality Assurance Standard (WQA), SQF 2000, SQF 1000, Freshcare and Codex Hazard Analysis and Critical Control Point (HACCP).

Direct suppliers to supermarkets, such as packers and wholesalers, must establish approved supplier programs for their suppliers (who are indirect suppliers to supermarkets). Most growers are indirect suppliers and so must implement some form of quality assurance to become approved suppliers.

Some customers require suppliers to implement systems that cover quality requirements as well as food safety. These quality assurance (QA) systems also provide benefits such as reducing waste, downtime, repacking and lost sales. Avoiding one significant problem often more than justifies the cost of implementing and maintaining the system.

QA systems are required for supply to overseas markets. In some markets, such as the United Kingdom, the requirements are more demanding than those in Australia, and there are extra requirements for environmental management and worker welfare.

Choosing a quality system

The type of QA or food safety system that you need to implement depends on your customers' requirements. Your customers may be packers, marketing groups, wholesalers, retailers, processors or exporters.

For example, Woolworths requires that direct suppliers (such as packers and wholesalers) implement the WQA standard. To meet this standard, direct suppliers have to implement an approved program for their own suppliers (who are indirect suppliers to Woolworths). Coles requires that all direct and indirect suppliers have an externally audited food safety program based on the HACCP method.

The system you choose must also be achievable and affordable. Remember that you need to implement it *and* maintain it. The options are summarised in the following sections.

Approved supplier programs

Approved supplier programs are developed by businesses such as wholesalers, processors, packers and exporters. These programs set out specific food safety and quality requirements for their suppliers.

To meet the requirements of these programs, growers must use agricultural practices that provide assurance that their products are safe to eat. Growers must keep sufficient records to demonstrate that these practices are a part of everyday operations. For example, a completed spraying record is often required. The customer or an independent party periodically checks that the grower is carrying out the agreed practices.

The Department of Agriculture, Fisheries and Forestry (DAFF) collaborated with Horticulture Australia Limited to develop *Guidelines for on-farm food safety for fresh produce*. These guidelines help growers assess the risk of food safety hazards and provide information on the agricultural practices required to prevent, reduce or eliminate the hazards. A copy of the guidelines can be obtained from the DAFF website (www.daff.gov.au).

The guidelines include a checklist of good agricultural practices. The practices have been identified from industry food safety programs based on the HACCP method. Some customers use this checklist to develop their approved supplier programs for growers.

Other customers require their approved suppliers to implement an independently certified program such as Freshcare, SQF 1000, SQF 2000 or HACCP. Some food service customers such as Spotless Catering, McDonalds and airline caterers have developed their own approved supplier programs. Some retailers in Europe require that grower suppliers implement the GLOBALGAP protocol.

Freshcare

Freshcare is a national, on-farm food safety program for the fresh produce industry. The program is owned and managed by Freshcare Ltd, a non-profit company representing peak industry organisations. Freshcare is based on HACCP principles and provides independent verification that a recognised food safety program is followed by the certified business.

The foundation of Freshcare is a code of practice, which can be downloaded from the Freshcare website. It describes the on-farm practices required to provide assurance that fresh produce is safe to eat and has been prepared to customer specifications. Certification is achieved through an independent external audit for compliance with the code of practice. Freshcare is acceptable for indirect suppliers to Woolworths and direct and indirect suppliers to Coles. For further information, call 1300 853 508 or visit the Freshcare website (www.freshcare.com.au).

The Queensland horticulture industry's peak body, Growcom, offers Freshcare Food Safety and Quality (Fresh Produce) code training courses. Details can be downloaded from the Growcom website (www.growcom.com.au).

HACCP

HACCP is an internationally recognised method of identifying, evaluating and controlling hazards to food products. While HACCP was originally developed to ensure food safety, it is now also being used to ensure that customer quality requirements are met. Guidelines for the implementation of HACCP have been developed by an international organisation, the Codex Alimentarius Commission.

HACCP is based on prevention: potential hazards are assessed for significance and control measures are established to eliminate, prevent or reduce the hazard to an acceptable level.

A number of independent auditing companies certify HACCP plans according to the Codex Alimentarius Commission guidelines.

A supplier of HACCP training in Australia is NCS International. For more information, call 1300 856 554 or visit www.ncsi.com.au

SQF 1000^{CM} and SQF 2000^{CM}

The SQF 1000 code is for growers, while the SQF 2000 code is for packhouses, wholesalers, manufacturers and distributors. Both codes cover food safety and quality hazards and each code has three certification levels. At the highest level (level 3), a HACCP plan must be developed, validated and verified by an SQF expert.

SQF 1000 and SQF 2000 have been recognised by the Global Food Safety Initiative. There are businesses certified to SQF 2000 in the United States, Japan, Thailand and a number of other countries. SQF 1000 and SQF 2000 are acceptable for direct and indirect suppliers to Coles and indirect suppliers to Woolworths.

Training for these codes is provided by a number of organisations. Visit the SQF Institute's website (www.sqfi.com) for details.

WQA

WQA is mandatory for all Woolworths direct suppliers of fresh food. It is available by invitation only and focuses on the quality and safety of individual products. WQA requires an HACCP plan, significant support programs and an approved supplier program.

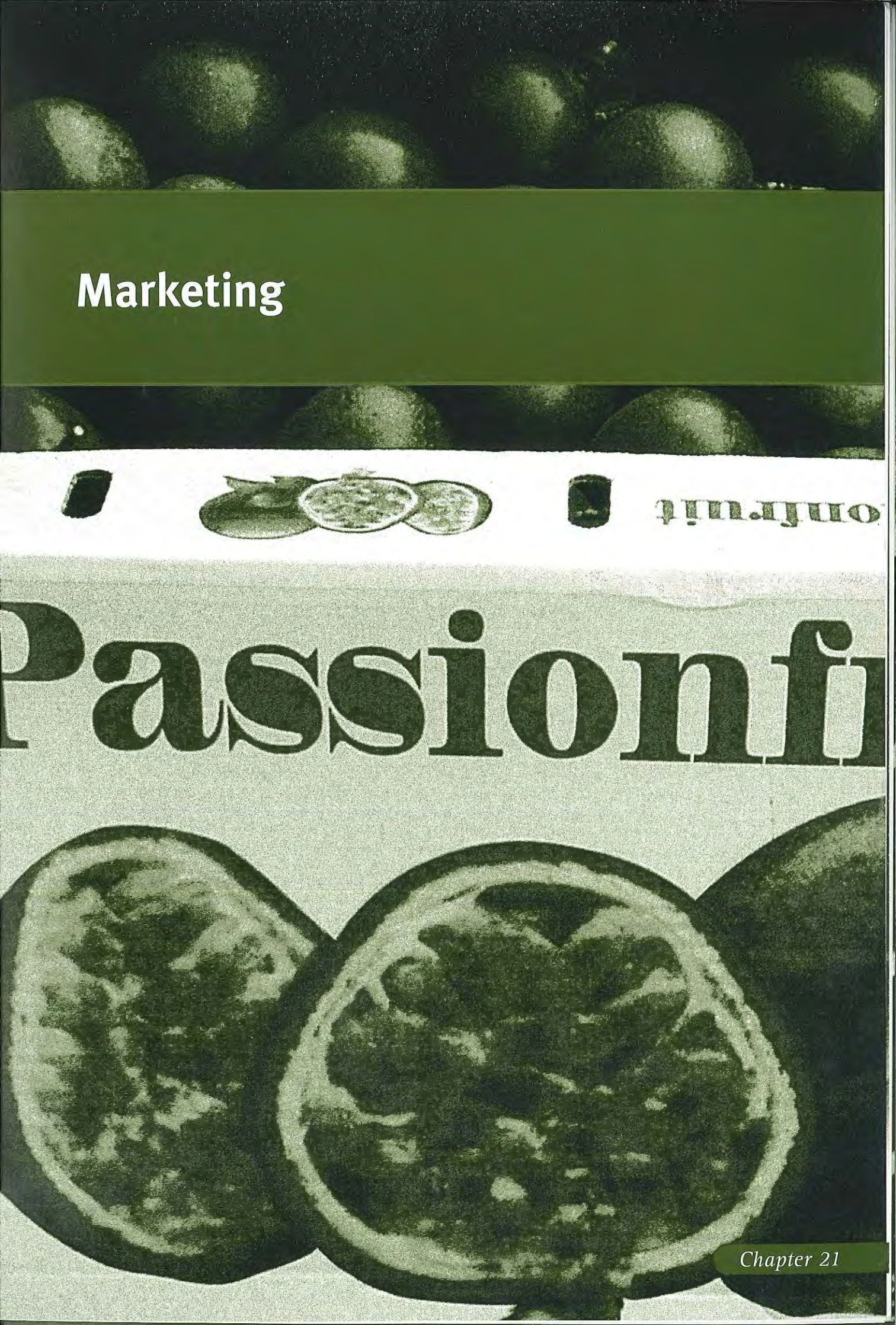
Woolworths direct suppliers sourcing from farmers must have evidence that each farmer has a certified food safety system such as Freshcare, SQF 2000, SQF 1000, HACCP or WQA. For further information, visit www.wowlink.com.au

GLOBALGAP

GLOBALGAP is a protocol for 'good agricultural practice' (the 'GAP' in GLOBALGAP). It aims to develop a single standard (with different product applications) for use in agriculture across the world. The protocol addresses quality, food safety, environmental management, and workplace health and safety. GLOBALGAP evolved in 2007 from EurepGAP, which began in 1997 as an initiative of the Euro-Retailer Produce Working Group (EUREP).

GLOBALGAP is acceptable for indirect suppliers to Woolworths and numerous United Kingdom retailers. Details of protocols relating to fruit and vegetables can be found under the 'Standards' link on the GLOBALGAP website (www.globalgap.org).

Marketing



Chapter 21

Growers often see marketing as secondary to growing the crop. However, marketing is probably the issue that will make the biggest difference to the success of your business. This section covers the main things you need to know:

The need for better marketing

As a market commodity, passionfruit has several advantages. It is a unique fruit with an 'exotic' appeal. It is versatile and fits well with modern eating trends. It is also reasonably well known and is popular with consumers.

However, growers cannot cash in on these advantages unless the product is properly marketed. There are three important issues regarding the marketing of passionfruit:

1. **Oversupply.** As the volume of production increases, making the market tighter and more competitive, the problem of oversupply in the domestic market will arise. To maintain a profitable margin, growers will need to be more active in searching out new market opportunities and strongly promoting their product to consumers. APIA is actively involved in market development using funds raised by the industry's marketing levy.*
2. **Method of sale.** The changing face of wholesale fruit marketing has seen supermarkets begin to dominate management and distribution. This will move the focus away from the central wholesale markets to more direct buying or brokering arrangements with growers and marketing groups. This will require significant structural change for growers in the marketing of their produce.
3. **Consumer preferences.** A growing focus on food safety and quality is developing to better service modern consumer needs. Consumers are becoming more demanding and are better at communicating their needs to marketers. Growers need to be in touch with these needs. The adage 'grow for the market, do not market what you grow' is good advice. Growers must gear their production and marketing system to deliver a product that meets those market needs. Quality management is the only way of consistently ensuring your product meets these market needs. See Chapter 20 for more information on this subject.

Understanding marketing

The first step in marketing is to understand what it is all about. Marketing is not selling. Marketing is not waving your product goodbye at the farm gate in the belief that someone else will act in your best interests.

Marketing is putting yourself in the consumer's shoes and profitably meeting their needs within the limits of your resources.

Successful marketing involves knowing who and where your consumers are, and what they want. It also involves knowing the level of return at which you are making a profit. Sadly, Australian horticulture provides many examples of growers who have no idea of how or even if their product is meeting consumers' needs. In addition, the financial performances of many horticultural businesses indicate that there is a lack of understanding about how cost of production is linked to marketing success. Many growers blame this state of affairs on the 'marketing system', but this suggests that growers are somehow outside the marketing system. Nothing could be further from the truth.

Here are some ideas to help you get onto the 'inside' of marketing.

Think like a consumer

What do consumers of passionfruit look for? Is it price, quality, size, colour, shelf-life or a combination of these factors? What price are consumers prepared to pay? At what point are market returns the best?

If growers do not have at least some idea of the answers to these questions, how can they set targets for production? How can growers make management decisions if they do not know what consumers want and how much they are prepared to pay?

There are two important sources of knowledge and information about what the market wants:

1. **Market research studies.** These are generally conducted by industry and research organisations and are published in special reports. Grower organisations and Horticulture Australia Limited (HAL) are sources of this information.

* In 2011, APIA changed its name to Passionfruit Australia Incorporated. See Appendix B for contact details.

2. Marketers who are in close contact with buyers and consumers. For the domestic market, specialist passionfruit wholesalers in the major metropolitan markets are an invaluable source of detailed market knowledge. Market authorities in each of the major markets can provide some advice on passionfruit wholesalers (see Appendix B).

Know the marketing chain for your fruit

To know the marketing chain for your fruit, you must identify all the steps and all the people that link your fruit at the farm gate to particular groups of consumers. One chain might include a transport company, an unloading company, a wholesale merchant, a supermarket buyer, a grocery section manager and consumers from a particular region of a city. It is important to know how the chain works because you choose some of its players, and each of the players in the chain makes decisions that collectively influence your product's market performance.

Visit the markets where your fruit is sold

There is no substitute for seeing how your fruit is performing in the market, both at the wholesale and retail level. However, just looking at the fruit is not enough. You should be monitoring the fruit's physical and financial performance.

Assess the performance of the people marketing your fruit. Remember that they are working for you, but they may happily ignore this if you are not interested in them.

Look for specialist passionfruit wholesalers and marketers who present a positive, enthusiastic impression, particularly when things are tough. Wholesalers who specialise in particular products normally develop more expertise in those products and so should market your fruit better than generalists would. Keep in regular contact with your wholesaler or marketer. Get regular feedback on consignments.

Join a marketing collective (where available)

Small growers on their own have little clout in the marketplace and miss out on sharing information with other growers. You might consider marketing on your own so that you can closely guard information that you don't want others to have. However, the greatest risk in this is that while you're busily guarding your information, the rest of the industry will pass you by because no one will want to share their information with you. By joining a group of like-minded growers, you will take a very positive marketing step towards overcoming the dual problem of lack of marketing clout and lack of information.

Deliver the product that the market wants

Once you have gained a better understanding of marketing and established what the market wants, you need to gear your production and marketing system to deliver a product with those specifications. The only way of ensuring this is to have a quality management system at the farm level. The easiest way of doing this is to become part of one of the marketing groups or cooperatives that have quality management systems in place. If you are not part of a group quality system, you can implement your own quality management system. See Chapter 20 for more information on this subject.

Marketing options

There are many options for marketing your fruit. The main ones are described in the following sections.

Whichever market outlet you choose, keep in close contact with your marketer and ask for feedback on the quality of your fruit in the marketplace. Regularly visit the major markets where your fruit is sold. Be prepared to become involved in the promotional activities of your local passionfruit grower group.

Don't expect your marketer to do all the work for you. They are often busy dealing with a whole range of crops and growers.

Capital city produce markets

Most passionfruit is sold fresh in major capital city produce markets. Fruit is consigned to either wholesale agents (who sell your fruit on commission and keep a percentage of the proceeds) or wholesale merchants (who buy your fruit at an agreed price). Most fruit is consigned to the Brisbane, Sydney and Melbourne markets, but smaller quantities go to other state capitals. Wholesale agents and merchants are your source of market intelligence. For this reason, your choice of a wholesale agent or merchant is extremely important. It is best to deal only with a specialist passionfruit wholesaler. Seek advice on selecting wholesalers from other growers in your area.

Market authorities in each wholesale market can provide market times and rules, along with a list of agents and merchants operating in their market (see Appendix B).

Marketing groups or cooperatives

If you join a marketing group or cooperative, fruit can be jointly packed and marketing decisions can be made on a group basis. This is highly recommended, as the combined resources and volume of product allow a greater range of marketing opportunities. It gives individual growers much more marketing power. Marketing groups are recommended where they are available.

Direct sale to supermarkets, chain stores or fruit barns

These outlets need a regular supply of uniform-quality fruit. This is only an option for very large farms or marketing cooperatives.

Local supply

If you live near more populated areas, you may wish to organise direct supply to local district retailers. This can be time-consuming work, and the costs of organising sales and distributing fruit need to be carefully considered. There is also the possibility, although limited, of direct supply to resorts and restaurants. If you have a high traffic flow, you can sell fruit on the farm or at a roadside stall. Small growers in tourist areas with good road access may even consider a 'pick your own' operation. If you choose to do this, check local authority requirements for signs and parking and take out public liability insurance.

Export

Export has complex and specialised requirements and is normally only available to large growers, marketing groups or cooperatives. It requires strict attention to quality standards and quarantine requirements. Growers considering entering the export market should be prepared to:

- follow strict quality standards
- work collectively with other growers
- take responsibility for the performance of their product in export markets
- accept that returns may be no better than domestic market returns at the same point in time
- travel overseas if necessary, sometimes at their own cost
- trial new and uncertain technologies (without guarantee of success)
- seek the advice of exporters or export market consultants before proceeding
- develop positive relationships built on reliability—these are the key to successful exporting.

Currently there are only opportunistic exports of passionfruit; these are made by market agents selling fruit bought from the domestic market.

Processing

Where available, this is a valuable outlet for fruit that is not up to fresh market standard. A contract setting out minimum standards is developed between the grower and the processor. Australia imports several thousand tonnes of processed passionfruit pulp and concentrate each year. Much of this comes from countries with labour costs that are lower than those in Australia. However, there is some opportunity for replacement of these imports with Australian product if reasonable prices are offered and production costs can be reduced.

Recent trends in marketing and quality management

The demand for quality management systems at the farm and packhouse levels has grown significantly in recent times. The major catalyst for this has been the growing demand from consumers and retailers for safety standards for all food, including fruit. These standards include minimal chemical residues, lack of food contamination organisms, freedom from foreign matter and quality parameters (such as good shelf-life, colour, flavour and so on). In addition, retailers are moving towards demanding that suppliers place individual produce labels containing PLUs (price look-up numbers) on fruit.

All major retailers only purchase produce from suppliers who can guarantee food safety standards under an HACCP-based food safety quality management system (see Chapter 20). As most fruit is supplied to retailers through produce wholesalers (agents and merchants in the major metropolitan produce markets), these wholesalers have to meet the HACCP requirements. In turn, growers supplying them are required to meet certain food safety standards and become approved suppliers. Without approved supplier status, growers can only supply the non-supermarket sector of the market, which is minor and is decreasing year by year.

Growers who wish to supply major retailers directly will need to implement an on-farm HACCP-based quality management system.

Legal requirements regarding movement of fruit

There are legal requirements on the movement of passionfruit from one state to another, and even on the movement of fruit and plants from one region to another within a state. You may require an Interstate Certification Assurance (ICA) accreditation in order to send fruit to some destinations.

The treatments required for ICA are subject to change. For the latest information on these regulations, contact the relevant authorities in your state.

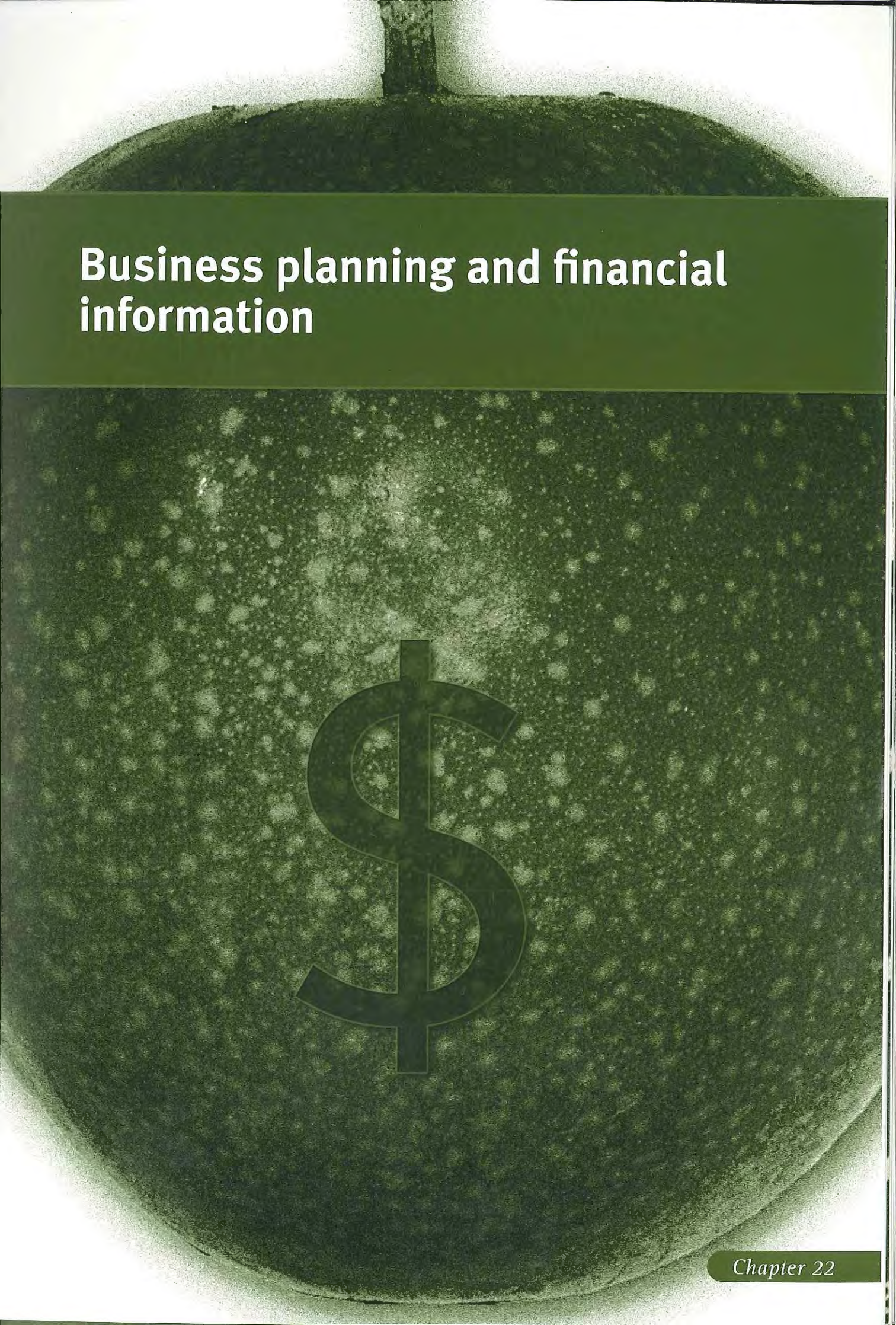
Levies

The passionfruit levy has two components, a research and development levy and a marketing levy:

- The research and development levy is 20 cents per 18 litre carton of fresh market fruit; for processing fruit, it is 1.5 cents per kilogram.
- The marketing levy is 20 cents per 18 litre carton of fresh market fruit; for processing fruit, it is 1.5 cents per kilogram.

The levies are collected by the Levy Revenue Service. Levies raised are used to fund research and development, marketing and promotions.

Business planning and financial information



Passionfruit attracts great interest from prospective growers. This may be because they believe that relatively small areas can return a high income soon after planting and that high prices on the supermarket shelf are an indication that a 'quick profit' can be made. However, in reality, a successful passionfruit crop requires careful management, attention to detail and a very high labour input. In addition, substantial reinvestment is needed because regular replanting is required to replace unproductive, diseased or pest-damaged vines. The learning curve for many new growers is steep and there is a very high drop-out rate.

For most growers, the primary aim of their farming business is to maximise profit in a sustainable way. Experience has shown that maximising and sustaining profits requires the careful integration of a range of business, crop management and marketing issues. These are outlined in this chapter:

Business planning

Approach the growing of passionfruit as a business. Plan your finance and marketing as carefully as you plan your production. Remember that no matter what quality of fruit you produce, your business will only be successful if your fruit can be sold at a price that will return a profit.

Crop management

Your business plan has to be based on your ability to grow the crop. This is the foundation of the business and regardless of how good your business skills are, you still need to be satisfied that you are able to meet the following basic production requirements:

- Make sure you have a good planting site for your plantation. Passionfruit vines are extremely sensitive to environmental stress. The plantation must be sheltered, since wind exposure causes stress that significantly diminishes the vigour of plants, lowers yields and reduces fruit quality. Also, the site must be warm and frost-free and must have an adequate supply of good-quality water. Windbreaks may be needed to provide the required shelter.
- Pay particular attention to getting the best planting material. Ensure that vines are propagated using scion material from healthy vines and rootstocks that are resistant to fusarium wilt.
- Grow varieties that the market wants and that suit your location and plantation. To determine which ones best suit your plantation, initially try all the major varieties for at least 2 years and carefully record their overall performance. Lower yielding varieties may be more profitable once quality and market prices are considered. As new varieties become available, try them in small numbers—do not rely on performance information from other plantations and regions.
- Carefully manage fertilisers and water to maintain maximum vegetative growth and vigour at all times. (Productivity in passionfruit is related to the rate of vegetative growth.) Monitor leaf and soil nutrient levels (by leaf and soil analyses) and monitor soil moisture by using an appropriate system such as tensiometers.
- Protect leaves and fruit from pests and diseases all year round. This usually requires a rigorous spraying program for diseases and a program of monitoring and timely action for insect pests. Be prepared to spray regularly with appropriate chemicals and use efficient, calibrated spraying equipment.
- Develop an efficient harvesting system based on quality management. Let the market and its quality requirements determine harvesting frequency, sorting standards etc.

Business issues

Be aware of business issues and take appropriate action:

- Before you start a passionfruit plantation, complete a thorough business plan. This will show you where the main risks lie and where you will have to focus special efforts to keep your business viable.
- Develop a forward plan for progressive replanting of the plantation. Passionfruit plants are very susceptible to pest and disease problems and generally purple varieties have a productive life of only 2 to 3 years. Panama selections grown in coastal tropical areas grow very rapidly; their foliage quickly becomes so dense that disease and pest control fails, and as a result they are usually replanted annually. It makes no commercial sense to continue to put resources into plants that are unproductive.
- Operate your enterprise as a business, not as a hobby. Carefully monitor and record your costs, prices received and actual market receipts. Also, carefully manage your labour resources so that you are using them as efficiently as possible.

- Seek professional advice, and pay for it where necessary. In our increasingly specialised world, expert advice is an essential part of business. It is available in a wide range of areas, including plantation layout, pest monitoring, spray application, irrigation monitoring and quality management.
- Become involved in the activities of your grower organisation. This will help you to learn about new developments and to network with other growers. It will provide the opportunity for you to become involved in securing the future of your industry.

Marketing issues

Know your market and plan to meet it:

- Be driven by the market, not by tradition or by what other people have told you. Investigate existing and potential markets and set yourself up to meet their requirements. Develop a marketing plan to ensure you are considering appropriate market issues.
- Aim for quality as well as quantity. Once you have established market quality requirements, look at all parts of your production and marketing system to determine how that quality can be delivered. Develop quality standards and meet them by implementing a quality management system—this is the only guaranteed way of achieving quality.
- Aim for maximum production of fruit suitable for the fresh fruit market. Profit is best achieved by supplying the fresh fruit market. If you focus on maximum production of fresh fruit, your other fruit will better suit the needs of the processing market.
- Do not regard a processing outlet as just a bonus; it is a primary marketing opportunity. The sale of second-grade fruit to processors gives value to a product that is otherwise valueless. To develop an effective and long-term relationship with processors, approach them in a businesslike manner.

Business and marketing plans

To be successful, a business needs to have some type of plan. A plan helps you to focus on the core business and what the business hopes to achieve. A business plan is generally drawn up for a period of up to 5 years. It is a living document and must be reviewed and modified annually to ensure its objectives are met.

A typical business plan includes the following sections:

1. mission
2. goals and objectives
3. situation analysis (SWOT—strengths, weaknesses, opportunities and threats)
4. action plan/implementation
5. budget
6. control plan.

Marketing and financial plans may also need to be developed. A typical marketing plan includes the following sections:

1. executive summary
2. current marketing situation
3. domestic markets
4. export markets
5. competitive situation
6. opportunity and issue analysis

7. SWOT analysis
8. issue generation and prioritisation
9. objectives
10. financial analysis
11. marketing strategy
12. pricing
13. product description and lines
14. positioning and segments
15. distribution strategy
16. sales
17. advertising and promotion strategy
18. research and development
19. action program and control
20. budget.

Plantation records

Accurate and well-organised records are essential for good business management. For a passionfruit plantation, the information that should be recorded includes:

- pre-harvest factors (pest and disease monitoring, spraying program, labour inputs, pollination details, leaf and soil analyses, soil-moisture monitoring, fertilisers, irrigation schedules)
- post-harvest factors (labour, picking, pack outs, handling and storage logs)
- quality management records and financial details.

This information is used to compare performance from year to year and to establish best practice. It can be recorded on a computer, where information can be quickly accessed and compared, or on forms.

Much of this information is used to develop business and marketing plans and to check that plan objectives have been met. Accurate records are also needed to satisfy the requirements of:

- approved supplier programs, such as those of supermarket chains
- ICA protocols required to transport fruit interstate
- workplace health and safety audits
- environmental audits that may be required (e.g. under Farmcare, Landcare or catchment and environmental management schemes).

The options for developing a recording system are:

- Use commercially available proprietary software.
- Use recording systems detailed in quality management manuals.
- Develop your own recording system (with the help of consultants if necessary).

Financial management

Accurate recording of all financial inputs and outputs (including family labour, loan interest and depreciation) ensures that the true financial situation of the business is known at all times. This is important for decision-making. There are many financial recording packages available on the market for computer use.

A financial analysis of passionfruit growing

A sensible appraisal of the financial prospects for passionfruit is only possible with a thorough economic analysis. The analysis given here is an example only. It has been developed to illustrate the costs that are involved in growing passionfruit in south-eastern Queensland and the possible returns from tbis. There will be significant variation between the data given here and what may happen on any individual plantation. This analysis does not include:

- fixed or overhead costs such as administration costs, electricity, insurance and depreciation
- capital costs (apart from the initial establishment of the plantation)
- major irrigation set-up costs such as dams, pumps, filters and mains.

Note: You will need to construct a similar analysis using your own costs and returns (expected or actual) to assess more accurately the financial prospects for passionfruit in your situation. We strongly recommend that anyone considering passionfruit growing carry out a whole-of-farm financial analysis. This would include other crops that are grown and the capital and fixed costs involved in growing all of the crops.

Background to the analysis

The analysis provided here is a simple cash-flow budget for a hectare of passionfruit. A cash-flow budget analyses cash flowing in (receipts or income) and cash flowing out (variable or capital costs). The variable or operating costs include the growing, harvesting and marketing costs. Cash-flow budgets usually include the costs of employed casual labour, but often omit owner labour. In this analysis, owner and casual labour is costed for all operations.

Assumptions

The main assumptions made in the analysis are:

- The vine spacing is 3 metres between rows and 4 metres between vines (giving 833 vines per hectare).
- The vines are sprayed with an air-blast sprayer delivering approximately 1 litre per vine (833 litres per hectare), with a spraying rate of 1.5 hours per hectare.
- Fruit flies are controlled with bait sprays of an insecticide plus yeast autolysate attractant.
- Machinery operation includes fuel, oil and normal maintenance costs only.
- Fertilisers are applied according to replacement rate for a yield of 15 tonnes per hectare.
- The annual yield is 15 tonnes per hectare; this value is used for the calculation of harvesting and packing costs. Of this, 10.5 tonnes (70% of the crop) is consigned to the fresh fruit market and 4.5 tonnes (30% of the crop) to a processing outlet.
- The fruit is packed at an average weight of 7 kilograms per 18 litre carton. (The actual range can be 5 to 10 kilograms per carton, depending upon the variety.)

- Purple varieties are grown. An average price of $21 per carton ($3 per kilogram) is obtained for the fresh fruit and $1 per kilogram for processing fruit. (Note that prices vary significantly—within a year the price can reach over $100 per carton for very high-quality fruit during periods of low supply but can fall to less than $10 per carton for low-quality fruit during periods of high supply. Prices for Panama selections may be 20 to 40% less than prices for purple varieties. Also, lack of access to a fruit processing market can have a significant financial impact—see Table 22.5 (page 209). Detailed current and historical capital city central market prices and throughput volumes are available from Ausmarket Consultants at www.ausmarket.com.au

- Freight costs are $2.10 per carton (enough for a distance of approximately 400 kilometres, say from Bundaberg to Brisbane). In practice, costs vary significantly depending on the distance from the site of production to the market.

- Labour is an opportunity cost. Even if the owner does the work instead of paying someone to do it, there is a cost involved because the owner could otherwise be in paid employment. The labour cost for each job is shown separately and is charged at $21.20 per hour (the casual rate plus superannuation and insurance).

- The plantation is well managed.

Establishment costs

The establishment costs include all the expenditure needed to plant the vines and bring them into production. The costs given in Table 22.1 (page 206) are a general guide for a hectare planted using single-wire trellises; actual establishment costs will vary depending on location, vine spacing, trellis design and materials used. Establishment costs for pergolas and A-frame trellis systems would be significantly higher than those given in this example.

Table 22.1 The approximate cost per hectare for establishing passionfruit on single-wire trellises

	Units	Cost per unit ($)	Cost per hectare ($)			Total cost ($)
			Labour	Machinery	Material	
Green manure crop						
Preparing ground, sowing, fertilising, incorporating–labour	12 h	21.20	254			
Preparing ground etc.–machinery	12 h	25.75		309		
Dolomite/lime(delivered and spread)	2.5 t	165.00			413	
Soil analysis	1 kit	125.00			125	
Urea	500 kg	0.90			450	
Superphosphate	500 kg	0.77			385	
Seed (90 kg oats, 4 kg Haifa clover)	94 kg	1.45			136	
Total			254	309	1 509	2 072
Land preparation						
Surveying, marking out and pegging vine sites–labour	12 h	21.20	254			
Posts for trellises (1 every 5 m)	666	7.00			4 662	
Wire	6666 m	0.23			1 533	
Erecting trellises–labour	22 h	21.20	466			
Erecting trellises–machinery	22 h	105		2 310		
Earthworks for mounds, drains etc.–labour	18 h	21.20	382			
Earthworks–machinery	18 h	25.75		464		
Total			1 102	2 774	6 195	10 071
Irrigation						
Trencher for submains	4 h	105		420		
Control valves, fittings etc. (estimate)					550	
Submains (50 mm LDPE)	100 m	2.22			222	
Laterals (19 mm LDPE)	3330 m	0.48			1 598	
Minisprinklers (90 L/h), riser and adaptor	833	3.10			2 582	
Installation–labour	30 h	21.20	636			
Total			636	420	4 952	6 008
Planting and establishing						
Planting–labour (5 min/vine)	69 h	21.20	1 463			
Vines (grafted purple passionfruit), including freight	833 plants	5.50			4 582	
Vine guards	833	0.50			417	
Training/trimming–labour (5 min/vine)	69 h	21.20	1 463			
Mulching–labour (2 min/vine)	28 b	21.20	594			
Mulch (1 bale hay/8 vines)	104 bales	4.95			515	
Total			3 520	0	5 514	9 034
Total establishment cost			5 512	3 503	18 170	27 185

Note: This information is only an example; there are many variables in the establishment of a plantation (such as variety, locality, trellis materials and irrigation system) that can significantly affect costs. Also, some figures have been rounded to the nearest unit or the nearest dollar.

Annual variable costs

Variable costs (sometimes called direct costs) are those expenses that are needed to operate the plantation and are specific to any particular activity and year/season. Importantly, unlike fixed costs, they vary depending upon the production; for example, more labour is needed to harvest 15 tonnes of fruit than is required to harvest 10 tonnes. They include the cost of labour for work such as harvesting and packing, the cost of chemicals and fertilisers and the cost of operating the machinery used in specific field work such as spraying chemicals and fertilising. Table 22.2 shows the variable costs per hectare for our example.

Table 22.2 The variable costs per hectare for a passionfruit plantation producing 15 tonnes of fruit per hectare per year

	Number per year	Units	Cost per unit ($)	Cost per hectare ($)			Total cost ($)
				Labour	Machinery	Material	
Weed control							
Slashing–labour	12	1 h	21.20	254			
Slashing–machinery	12	1 h	20.60		247		
Weed spraying–labour	4	1.5 h	21.20	127			
Weed spraying–machinery	4	1.5 h	20.60		124		
Weed spraying– Basta spot spray	4	1 L	23.70			95	
Total				381	371	95	847
Pest and disease control							
Spraying–labour	34	1.5 h	21.20	1 081			
Spraying–machinery	34	1.5 h	20.60		1 051		
Protectant fungicide	14	1.25 kg	12.50			219	
Amistar™	3	0.67 kg	223.72			450	
Rovral	3	1.67 L	53.56			268	
Bio-pest™	6	5 L	6.18			185	
Applaud™	2	2.5 L	267.80			1 339	
Phosphorus acid	2	2.5 L	4.89			24	
Lepidex™	4	0.83 L	30.90			103	
Fruit fly bait spraying–labour	30	0.2 h	21.20	127			
Fruit fly bait spraying–machinery	30	0.2 h	6.20		37		
Fruit fly bait spray	30	1.25 L	5.05			189	
Total				1 208	1 088	2 777	5 073
Nutrition (assuming few deficiencies)							
Leaf analysis	1	1 kit	100			100	
Soil analysis	1	1 kit	125			125	
Fertiliser spreading–labour	2	2 h	21.20	85			
Fertiliser spreading–machinery	2	2 h	20.60		82		
Super phosphate (broadcast)	1	222 kg	0.77			171	
Calcium nitrate (fertigate)	12	25 kg	0.90			270	
Potassium sulphate (fertigate)	12	35 kg	2.27			953	
Solubor™ (fertigate)	1	2 kg	4.12			8	
Lime (broadcast)	1	1.5 t	125			188	
Total				85	82	1 815	1 982
Irrigation (including checking sprinklers and fertigation labour)							
Irrigation–labour	100	0.3 h	21.20	636			
Irrigation–machinery	100	3 h	2.30		690		
Total				636	690	0	1 326

(continued)

Table 22.2 The variable costs per hectare for a passionfruit plantation producing 15 tonnes of fruit per hectare per year (continued)

	Number per year	Units	Cost per unit ($)	Cost per hectare ($)			Total cost ($)
				Labour	Machinery	Material	
Harvesting and marketing							
Picking–labour (assuming 50 kg/h from each person and 130 rounds each)	1	300 h	21.20	6 360			
Picking–machinery	130	0.5 h	20.60		1 339		
Cartons	1	1500	2.20			3 300	
Sorting and packing (assuming 10 cartons/h from each packer)	1	214 cartons	21.20	4 537			
Interstate accreditation and post-harvest treatment	1	750 cartons	0.28			210	
Freight	1	1500 cartons	2.10			3 150	
Levy	1	1500 cartons	0.40			600	
Agent's commission (12.5%)	1	1500 cartons	2.63			3 945	
Pallet hire, tape, corners etc.	1	1500 cartons	0.12			180	
Total				10 897	1 339	11 385	23 621
Total annual variable cost				13 207	3 570	16 072	32 849

Annual income and cash surplus

The estimated annual income and cash surplus per hectare for our example is given in Table 22.3. The figures are based on production of 15 tonnes of fruit, of which 70% is sold fresh (at an average of $21 per 7 kilogram carton) and 30% is sold for processing (at $1 per kilogram).

Table 22.3 The estimated annual income and cash surplus per hectare for a passionfruit plantation producing 15 tonnes of fruit per hectare

Yield (t)	Fresh fruit sales (t)	Gross income (at $3/kg)	Processing fruit sales (t)	Gross income (at $1/kg)	Total gross income	Total annual variable costs	Cash surplus
15	10.5	$31 500	4.5	$4500	$36 000	$32 849	$3151

Note: These figures exclude establishment costs for the plantation, fixed costs and capital costs.

Sensitivity analysis

Income can vary dramatically and is dependent on many factors. Table 22.4 shows the annual cash surplus per hectare after establishment for a range of:

- yields
- fresh fruit prices
- variations in the percentage of fruit harvested that can be sold as fresh fruit.

The figures do not take into account establishment costs for the plantation, fixed costs or capital costs. Therefore, they do *not* indicate the profit or loss of the plantation.

Table 22.4 Cash surplus per hectare per year for a range of yields, prices and fresh fruit percentages

Total yield (t/ha)	Cash surplus ($) at a sale price of $18 per carton			Cash surplus ($) at a sale price of $21 per carton			Cash surplus ($) at a sale price of $24 per carton		
	50% fresh	60% fresh	70% fresh	50% fresh	60% fresh	70% fresh	50% fresh	60% fresh	70% fresh
10	−5122	−4581	−4039	−3247	−2331	−1414	−1372	−81	1203
15	−2403	−1591	−779	402	1776	3151	3214	5151	7088
20	308	1391	2474	4058	5891	7724	7808	10 391	12 974

Note: In each case, the balance of fruit is sold to the fruit processing market at $1 per kilogram with delivery costs paid by the processor.

In reality, the price paid for processing-grade fruit fluctuates. It is dependent on both the availability of processing-grade fruit in Australia and the supply of passionfruit pulp from overseas. Not all growers are able to sell their low-quality fruit to processors; there are only a few processers, and they are mainly located in south-eastern Queensland, so high freight costs can prohibit some growers from accessing this market.

Growers need to consider carefully how they can manage their business when they cannot access the fruit processing market or when prices for that market decline. Table 22.5 shows the cash surpluses for the price and yield scenarios given in Table 22.4 when no income is made from the sale of processing-grade fruit. As for Table 22.4, the figures do not take into account establishment costs for the plantation, fixed costs or capital costs; therefore, they do not indicate the profit or loss of the plantation.

Table 22.5 Cash surplus per hectare per year for a range of yields, prices and fresh fruit percentages when no income is made from sales to the fruit processing market

Total yield (t/ha)	Cash surplus ($) at a sale price of $18 per carton			Cash surplus ($) at a sale price of $21 per carton			Cash surplus ($) at a sale price of $24 per carton		
	50% fresh	60% fresh	70% fresh	50% fresh	60% fresh	70% fresh	50% fresh	60% fresh	70% fresh
10	−10 122	−8581	−7039	−8247	−6331	−4414	−6372	−4081	−1789
15	−9903	−7591	−5279	−7900	−4216	−1341	−4278	−841	2588
20	−9684	−6601	−3518	−5934	−2101	1724	−2184	2391	6974

Fixed costs

Fixed costs (also known as overhead costs) are expenses that are needed to run the plantation but are not specific to any particular operation. Fixed costs are incurred throughout the life of the plantation, and are not significantly increased or decreased by the productivity of the plantation. Fixed costs include such things as office costs, electricity, accountant's fees, insurance and repairs of buildings and equipment. Fixed costs are often shared with other activities or crops. Consider carefully the fixed costs that may arise if you decide to grow passionfruit.

Capital costs

A capital cost is an amount paid for an item that is needed to set up and operate the plantation and has a useful life of several years. Because of this, a capital cost cannot be directly allocated to a specific year of production. Capital costs include such things as buildings, machinery and infrastructure items (e.g. dam construction). Some of these costs may be shared with other activities or crops. Table 22.6 gives a guide to the capital expenditure needed to establish and operate a 3 hectare passionfruit plantation. Orchard establishment can also be regarded as a capital cost (see Table 22.1).

Table 22.6 The capital expenditure needed to establish and operate a 3 hectare passionfruit plantation

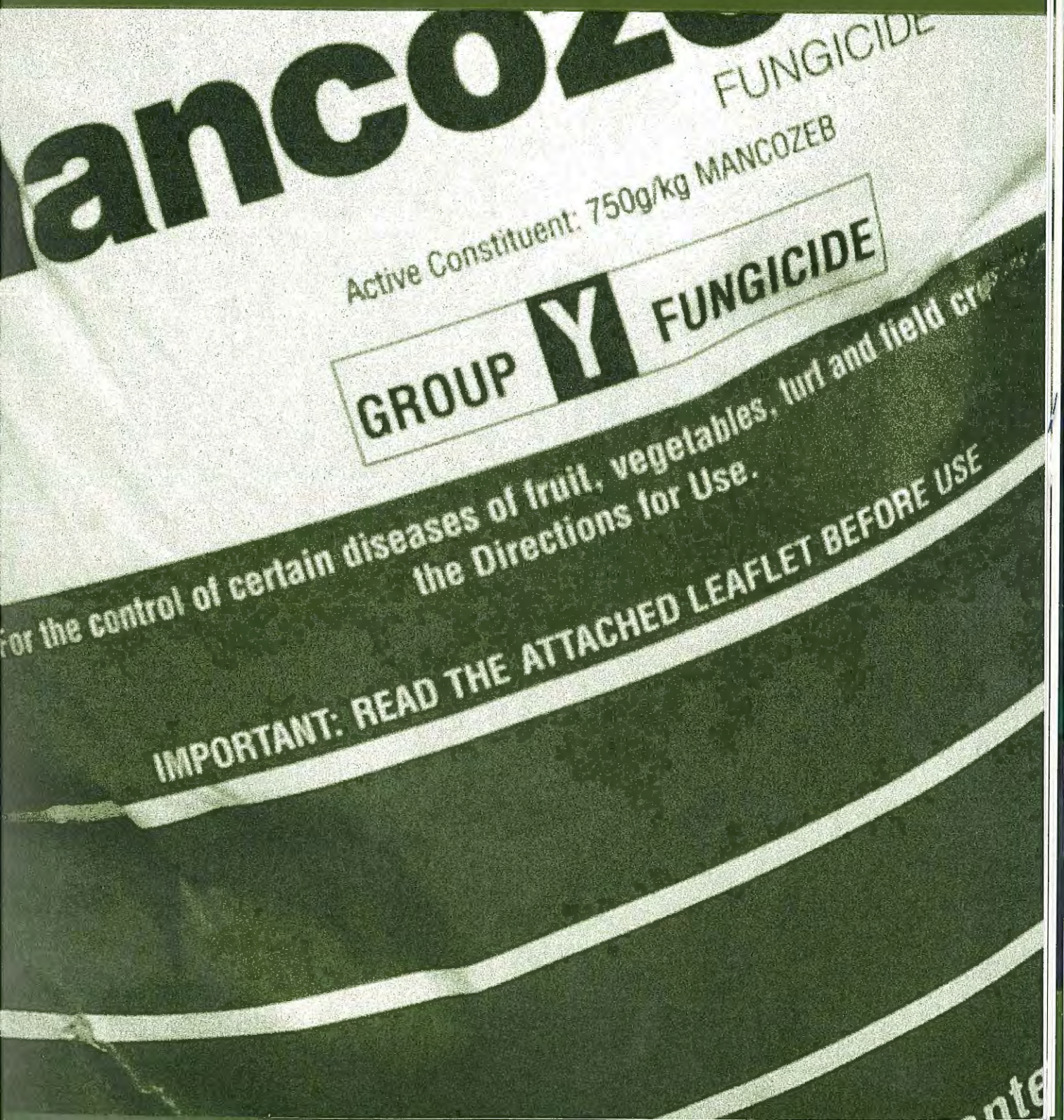
Capital item	Estimated cost ($)	
	Second hand	New
Tractor (4WD, 40 hp or 30 kW)	10 000	45 000
Spraying unit (air-blast, tractor-mounted)	5000–7000	7000–12 000
Packing shed and grader equipment	5000–8000	16 000
Slasher	1000	3000
Weed sprayer (tractor-mounted)	1500	3000
Fertiliser spreader and/or fertigation equipment	500–1000	1750–2500
Farm utility	5000	27 000
Irrigation pump (diesel/electric)	500–2000	5000–10 000
Irrigation mains and submains	1000–2000	4000
Dams/bores	–	5000–12 500
Water supply licence	–	500
Coldroom (may be needed in some situations)	5000	10 000–20 000

Costs and returns in northern Queensland

The example given above is for a plantation in south-eastern Queensland. It reflects yields and prices for fruit produced between December and August, when market throughput is normally high. In coastal tropical areas of northern Queensland, higher value fruit can be produced from September to November, when market throughput is normally low. However, the high prices for fruit produced at this time of the year are offset by lower yields and a high cost of production. The following factors influence the economics of production in northern Queensland:

- A short harvest period (4 months) limits production potential; the harvest period is 8 months in south-eastern Queensland.
- Annual replants maximise the likelihood of producing a crop during the September to November period. If replanting is done annually, expensive high-density plantings (up to 1250 plants per hectare) are needed to maximise production per hectare from vines that are less than a year old.
- Sunburn can cause high fruit loss. To avoid this, collection of fallen fruit may be required twice or even three times per day if vines are grown on single-wire trellises.
- Pergola frames are often used to support the vines to minimise sunburn damage. These are significantly more expensive to establish than single-wire trellises are.
- High humidity and temperatures lead to high pest and disease control costs (because spraying must be done more frequently than in subtropical climates). Even then, fruit losses to pests and diseases can be high.
- Freight to the main capital city markets is significantly more expensive than and takes a day longer than that for fruit grown in south-eastern Queensland and northern New South Wales.
- Freight costs to fruit processors in south-eastern Queensland may be prohibitive for low-value processing-grade fruit, which may therefore have no value.
- Cyclones can result in catastrophic loss to plants and infrastructure, which can take several years to recover from financially.

Appendix A
Registered chemicals



This appendix provides details of pesticides that are currently registered for use on passionfruit. It includes information on fungicides (Table A.1, page 213), insecticides (Table A.2, page 217), post-harvest treatments (Table A.3, page 220) and other useful registrations (Table A.4, page 220). Please refer to Table 16.1 (page 161) for a list of herbicides that are registered for use on passionfruit.

The Australian Pesticides and Veterinary Medicines Authority (APVMA) is an Australian government authority responsible for the assessment and registration of pesticides and veterinary medicines and for their regulation up to and including the point of retail sale. Visit www.apvma.gov.au for further information, including:

- the Public Chemical Registration Information System (PUBCRIS), a searchable database that gives details of all of the agricultural chemical products registered for use in Australia
- a 'Permits' database that gives details of chemicals with temporary registrations for uses not shown on the label (off-label permits).

Always read and comply with the instructions on the label!

Disclaimer

It is a legal requirement that you read the entire label of the pesticide container and use it only as recommended on the label. The Queensland Department of Employment, Economic Development and Innovation gives no warranties, expressed or implied, regarding the accuracy, completeness or fitness for a particular purpose of any information provided in this chapter. Sole responsibility and risk associated with the use of the data, irrespective of the purpose to which that use is applied, is accepted by the user.

Changes occur to registrations from time to time and it is the responsibility of the user to keep up to date with these changes. Sources of information on changes are provided in Appendix B.

Key for tables of registered chemicals

APVMA Australian Pesticides and Veterinary Medicines Authority

NA not applicable

NS not supplied on label

or concentrate can be used in a low-volume (concentrated) spray solution

WHP withholding period (in days); fruit must not be harvested until the WHP has elapsed

Note: For some active components (e.g. mancozeb), the WHP can vary, depending on the trade name of the product.

Table A.1 Fungicides

Pest name	Active components	Common trade names	Application rate (see label also)	WHP	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Chemical class
Alternata spot	Azoxystrobin (250 g/kg)	Amistar 250 SC, Mirador 250 SC	80 g/100 L or concentrate	1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group 11 fungicide
	Iprodione (250 g/L)	Chief 250, Corvette Liquid, Ipral 250, Iprine 250, Iprodione Liquid 250, Rovral Liquid	0.2 L/100 L or concentrate	7 or 1 (see label)	No	Yes	Yes	Yes	No	No	No	Yes	Group 2 fungicide
	Iprodione (500 g/L)	Chief Aquaflo, Rovral Aquaflo, Iprodione Aquaflow 500 SC, Iprodione 500 Aquaflo, Ippon 500 Aquaflo, Iprin 500 Corvette Flowable, Subscribe	0.1 L/100 L or concentrate	7 or 1 (see label)	No	Yes	Yes	Yes	No	No	No	Yes	Group 2 fungicide
Anthracnose	Copper as hydroxide (300 g/kg) + mancozeb (150 g/kg)	Mankocide DF	0.2–0.4 kg/100 L or concentrate	14	No	Yes	No	Yes	No	No	No	Yes	Group M1/ M3 fungicide
	Mancozeb (750 g/kg)	Dithane Rainshield Neo Tec, Mancozeb 750, Mancozeb 750 DF, Mancozeb DG, Mancozeb 750 WG, Manfil, Manzate DF, Manzeb, Penncozeb 750 DF, Unizeb 750 DF	0.2 kg/100 L + oil or concentrate 2–3 kg/ha (or see label)	14 or 1 (see label)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group M3 fungicide
	Mancozeb (800 g/kg)	Penncozeb	2–3 kg/ha or 0.2 kg/100 L + oil	1	Yes	Yes	Yes	No	No	No	No	Yes	Group M3 fungicide
	Petroleum oil (782 g/L)	D-C-Tron Plus	0.6 L/100 L + fungicide	1	No	Yes	No	No	No	No	No	Yes	Insecticide, spreader

(continued)

Note: Always check the chemical label or permit for current registration status and details of application rate etc. An APVMA permit is only valid between the dates specified on the permit. Check the currency of permits before use at www.apvma.gov.au

Table A.1 Fungicides (continued)

Pest name	Active components	Common trade names	Application rate (see label also)	WHP	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Chemical class
Brown spot	Copper as oxychloride (256 g/L)	Copper Fungicide & Bactericide	4.2–8.4 L/ha or 0.39–0.78 L/100 L	1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group M1 fungicide
	Copper as oxychloride (500 g/kg)	Brycop (Agric. Fungicide), Copper Oxychloride, Copper Oxychloride-WP, Copper Oxychloride 500 WP, Copper Oxychloride 50% WP, Coppox WG, Lancop 500 WP, Oxydul DF	2–4 kg/ha or 0.2–0.4 kg/100 L or concentrate	1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group M1 fungicide
	Iprodione (250 g/L)	Chief 250, Corvette Liquid, Ipral 250, Iprine 250, Iprodione Liquid 250, Rovral Liquid	0.2 L/100 L or concentrate	7 or 1 (see label)	No	Yes	Yes	Yes	No	No	No	Yes	Group 3 fungicide
	Iprodione (500 g/L)	Chief Aquaflo, Corvette Flowable, Ippon 500 Aquaflo, Iprin 500, Rovral Aquaflo, Subscribe, Iprodione 500 Aquaflow, Iprodione Aquaflow 500 Sc	0.1 L/100 L or concentrate	7 or 1 (see label)	No	Yes	Yes	Yes	No	No	No	Yes	Group 3 fungicide
	Mancozeb (750 g/kg)	Dithane Rainshield Neo Tec, Kencozeb 750 DF, Mancozeb DG, Mancozeb 750, Mancozeb 750 DF, Mancozeb 750 DF Fungicide, Mancozeb DF, Mancozeb 750 DF, Mancozeb 750 WDG, Mancozz 750 WG, Manfil, Manzate DF, Manzeb, Penncozeb 750 DF, Unizeb 750 DF, Vine 750	1.7–2.2 kg/ha or 0.15 kg/100 L or concentrate	14 or 1 (see label)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group M3 fungicide
	Mancozeb (800 g/kg)	Mancozeb 800wp, Mancozeb 800, Mancozeb Fungicide, Penncozeb	1.7 kg/ha or 0.15 kg/100 L or concentrate	14 or 1 (see label)	No	No	No	Yes	No	No	No	No	Group M3 fungicide
Cladosporium scab	Azoxystrobin (250 g/kg)	Amistar 250 SC, Mirador 250 SC	80 g/100 L or concentrate	1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group 11 fungicide

(continued)

Note: Always check the chemical label or permit for current registration status and details of application rate etc. An APVMA permit is only valid between the dates specified on the permit. Check the currency of permits before use at www.apvma.gov.au

Table A.1 Fungicides (continued)

Pest name	Active components	Common trade names	Application rate (see label also)	WHP	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Chemical class
Phytophthora blight	Phosphorous acid (200 g/L, 400 g/L and 600 g/L product)	APVMA permit number 9480	0.5–0.6 L for 200 g/L product or 0.25–0.3 L/100 L for 400 g/L product or 0.165–0.2 L for 600 g/L product	NA	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Group 33 fungicide
	Copper as hydroxide (350 g/kg)	Cung Fu, Kocide Blue Xtra	75 g/L (water or paint*)	1	No	Yes	No	Yes	No	No	No	No	Group M1 fungicide
	Copper as hydroxide (375 g/kg)	Champ Dry Prill	70 g/L (water or paint*)	1	No	Yes	No	Yes	No	No	No	No	Group M1 fungicide
	Copper as hydroxide (400 g/kg)	Blu-Cop 400 DF	0.1 kg/L (water or paint*)	1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group M1 fungicide
	Copper as hydroxide (500 g/kg)	Blue Shield DF, Hydrocop	0.1 kg/L (water or water-based paint*)	1	No	Yes	No	Yes	No	No	No	Yes	Group M1 fungicide
	Copper as hydroxide (50 g/L)	Flo-Bordo	1 L undiluted or 0.1 L/L (water-based paint*)	1	No	Yes	No	Yes	No	No	No	No	Group M1 fungicide
	Copper as oxychloride (256 g/L)	Copper Fungicide & Bactericide	0.39 L/100 L	1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group M1 fungicide
	Copper as oxychloride (500 g/kg)	Brycop (Agric. Fungicide), Copper Oxychloride, Copper Oxychloride-WP, Copper Oxychloride 500 WP, Copper Oxychloride 50% WP, Coppox WG, Lancop 500 WP, Oxydul DF	0.1 kg/L (paste)*, 0.3 kg/100 L or concentrate	1	Yes	Yes	Yes	Yes	No	No	No	Yes	Group M1 fungicide
	Copper as sulfate (tribasic) (190 g/L)	Tri-Base Blue	0.14 L/L (water or paint*) or concentrate	1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group M1 fungicide

(continued)

* For the control of phytophthora blight, some copper fungicide labels give an application rate for a water-based or paint-based paste. This appears to arise out of a misconception by some chemical companies that phytophthora blight is a canker. A cover spray using a dilute solution of one of the products that has a dilution rate on its label is more appropriate.

Note: Always check the chemical label or permit for current registration status and details of application rate etc. An APVMA permit is only valid between the dates specified on the permit. Check the currency of permits before use at www.apvma.gov.au

Table A.1 Fungicides (continued)

Pest name	Active components	Common trade names	Application rate (see label also)	WHP	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Chemical class
Phytophthora stem rot	Copper as cuprous oxide (750 g/kg)	Norshield WG	65 g/L or 65 g/L (water-based paint)	1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group M1 fungicide
Rootrot and collar rot	Copper as oxychloride (500 g/kg)	Copper Oxychloride	0.1 kg/L (paste)	1	Yes	Yes	No	Yes	No	No	No	Yes	Group M1 fungicide
	Copper as cuprous oxide (750 g/kg)	Ag Copp 750, Norshield 750 WP	65 g/L (water-based paint)	1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group M1 fungicide
Septoria spot	Copper as oxychloride (256 g/L)	Copper Fungicide & Bactericide	4.2–8.4 L/ha or 0.39–0.78 L/100 L	1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group M1 fungicide
	Copper as oxychloride (500 g/kg)	Brycop (Agric. Fungicide), Copper Oxychloride, Copper Oxychloride-WP, Copper Oxychloride 500 WP, Copper Oxychloride 50% WP, Coppox WG, Lancop 500 WP, Oxydul DF	2–4 kg/ha or 0.2–0.4 kg/100 L or concentrate	1	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Group M1 fungicide
	Mancozeb (750 g/kg)	Dithane Rainshield Neo Tec, Kencozeb 750 DF, Mancozeb DF, Mancozeb DG, Mancozeb 750, Mancozeb 750 WG, Mancozeb 750 DF, Manfil, Manzate DF, Manzeb, Penncozeb 750 DF, Unizeb 750 DF, Vine 750	1.7–2.2 kg/ha or 0.15 kg/100 L or concentrate	14 or 1 (see label)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group M3 fungicide
	Mancozeb (800 g/kg)	Mancozeb 800 WP, Mancozeb 800 WP, Dithane M-45, Mancozeb Fungicide, Penncozeb	1.7 kg/ha or 0.15 kg/100 L or concentrate	14	No	No	No	Yes	No	No	No	No	Group M3 fungicide

(continued)

Note: Always check the chemical label or permit for current registration status and details of application rate etc. An APVMA permit is only valid between the dates specified on the permit. Check the currency of permits before use at www.apvma.gov.au

Table A.1 Fungicides (continued)

Pest name	Active components	Common trade names	Application rate (see label also)	WHP	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Chemical class
Trunk (stem) canker	Copper as ammonium acetate (80 g/L)	Cop-It, Liquicop	0.25 L/L (water or paint)	1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group M1 fungicide
	Copper as ammonium complex (93 g/L)	Copperguard	0.25 L/L (water or paint)	1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group M1 fungicide
	Copper as cuprous oxide (500 g/kg)	Nordox 500	0.1 kg/L (water or paint)	1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group M1 fungicide

Table A.2 Insecticides

Pest name	Active components	Common trade names	Application rate (see label also)	WHP	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Chemical class
Aphids	Dimethoate (400 g/L)	Danadim, Dimethoate, Dimethoate 400, Dimetholinx, Rover Insecticide, Stalk, Saboteur, Unidime 400	75 mL/100 L or concentrate	7	Yes	Yes	No	No	No	No	No	Yes	Group 1B insecticide
Flower-eating caterpillars	Spinosad (240 g/L)	Success2	20 mL/100 L or concentrate	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group 5 insecticide
	Spinosad (800 g/kg)	Entrust Naturalyte	6 g/100 L or concentrate	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group 5 insecticide
Fruit flies	Fenthion (550 g/L)	Lebaycid	75 mL/100 L	7	No	Yes	Yes	Yes	No	No	Yes	Yes	Group 1B insecticide
	Maldison (1150 g/L)	APVMA permit number 12359, Hy-Mal	0.435 L/100 L + lure (see permit)	3	No	Yes	No	Yes	No	No	No	No	Group 1B insecticide
Fruitspotting bugs	Endosulfan* (350 g/L)	Endo 350 EC, Endosan, Endosulfan 350 EC, Thiodan EC	0.2 L/100 L or concentrate	14	No	No	No	Yes	No	No	No	Yes	Group 2A insecticide
Green vegetable bugs	Endosulfan* (350 g/L)	Endo 350 EC, Endosan, Endosulfan 350 EC, Thiodan EC	0.2 L/100 L or concentrate	14	No	Yes	No	Yes	Yes	Yes	No	Yes	Group 2A insecticide
	Trichlorfon (500 g/L)	Dipterex 500 SL, Lepidex 500	0.1 L/100 L	2	No	No	Yes	Yes	No	No	No	No	Group 1B insecticide

(continued)

* Endosulfan's registration was cancelled on 12 October 2010. Use of existing stocks of product containing endosulfan in accordance with label instructions is permitted until 12 October 2012.

Note: Always check the chemical label or permit for current registration status and details of application rate etc. An APVMA permit is only valid between the dates specified on the permit. Check the currency of permits before use at www.apvma.gov.au

Table A.2 Insecticides (continued)

Pest name	Active components	Common trade names	Application rate (see label also)	WHP	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Chemical class
Hemispherical scale	Paraffinic oil (815 g/L)	APVMA permit number 10765, Sacoa Biopest Paraffin Oil	0.5–1 L/100 L	NA	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Unspecified class
Leafroller moths	Spinosad (240 g/L)	Success2	20 mL/100 L or concentrate	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group 5 insecticide
	Spinosad (800 g/kg)	Entrust Naturalyte	6 g/100 L or concentrate	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group 5 insecticide
Loopers	Spinosad (240 g/L)	Success2	20 mL/100 L or concentrate	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group 5 insecticide
	Spinosad (800 g/kg)	Entrust Naturalyte	6 g/100 L or concentrate	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group 5 insecticide
Mealy bugs	Buprofezin (440 g/L)	Applaud, Clap, Praise 500 WG, Scale & Bug	30–60 mL/100 L	1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group 17A insecticide
	Methidathion (400 g/L)	Supracide 400, Suprathion 400 EC	0.125 L/100 L + wetter or concentrate	14	No	Yes	No	Yes	No	No	No	Yes	Group 1B insecticide
Mediterranean fruit flies	Dimethoate (400 g/L)	Danadim, Dimethoate, Dimethoate 400, Dimetholinx, Rover Insecticide, Stalk, Saboteur, Unidime 400	75 mL/100 L or concentrate	7	Yes	Yes	No	No	No	No	Yes	Yes	Group 1B insecticide
Passionvine bugs	Endosulfan* (350 g/L)	Endo 350 EC, Endosan, Endosulfan 350 EC, Thiodan EC	0.15 L/100 L or concentrate	14	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group 2A insecticide
	Trichlorfon (500 g/L)	Dipterex 500 SL, Lepidex 500	0.1 L/100 L or concentrate	2	No	No	Yes	Yes	No	No	No	No	Group 1B insecticide
Passionvine mealy bugs	Paraffinic oil (815 g/L)	APVMA permit number 10765, Sacoa Biopest Paraffin Oil	0.5–1 L/100 L (suppression)	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Unspecified class
Passionvine mites	Propargite (300 g/kg)	Omite 300 W, Betamite 300 WG	0.1 kg/100 L	7	No	No	No	Yes	No	No	No	Yes	Group 14A insecticide

(continued)

* Endosulfan's registration was cancelled on 12 October 2010. Use of existing stocks of product containing endosulfan in accordance with label instructions is permitted until 12 October 2012.

Note: Always check the chemical label or permit for current registration status and details of application rate etc. An APVMA permit is only valid between the dates specified on the permit. Check the currency of permits before use at www.apvma.gov.au

Table A.2 Insecticides (continued)

Pest name	Active components	Common trade names	Application rate (see label also)	WHP	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Chemical class
Queensland fruit flies	Chlorpyrifos (500 g/kg)	Cyren 500 WP, Strike-Out 500 WP	0.12 kg/30 L + yeast autolysate or concentrate	14	No	Yes	No	Yes	No	No	No	Yes	Group 1B insecticide
	Chlorpyrifos (750 g/kg)	Lorsban 750 WG	80 g/30 L/ha + yeast hydrolysate	14	No	Yes	No	Yes	No	No	No	No	Group 1B insecticide
	Dimethoate (400 g/L)	Danadim, Dimethoate, Dimethoate 400, Dimetholinx, Rover Insecticide, Saboteur, Stalk, Unidime 400	75 mL/100 L or concentrate	7	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Group 1B insecticide
Red scale	Methidathion (400 g/L)	Supracide 400, Suprathion 400 EC	0.125 L/100 L + wetter or concentrate	14	No	Yes	No	Yes	No	No	No	Yes	Group 1B insecticide
	Paraffinic oil (815 g/L)	APVMA permit number 10765, Sacoa Biopest Paraffin Oil	0.5–1 L/100 L	NA	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Unspecified class
Rutherglen bugs	Endosulfan* (350 g/L)	Endo 350 EC, Endosulfan 350 EC, Thiodan EC, Endosan	0.15 L/100 L or concentrate	14	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group 2A insecticide
Scale insects	Buprofezin (440 g/L)	Clap, Applaud, Praise 500 WG, Scale & Bug	30–60 mL/100 L	1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group 17A insecticide
	Methidathion (400 g/L)	Supracide 400, Suprathion 400 EC	0.125 L/100 L or concentrate	14	No	Yes	No	Yes	No	No	No	Yes	Group 1B insecticide
Sorghum head caterpillars	Spinosad (240 g/L)	Success2	40 mL/100 L or concentrate	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group 5 insecticide
	Spinosad (800 g/kg)	Entrust Naturalyte	12 g/100 L or concentrate	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group 5 insecticide
Yellow peach moths	Spinosad (240 g/L)	Success2	40 mL/100 L or concentrate	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group 5 insecticide
	Spinosad (800 g/kg)	Entrust Naturalyte	12 g/100 L or concentrate	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group 5 insecticide

* Endosulfan's registration was cancelled on 12 October 2010. Use of existing stocks of product containing endosulfan in accordance with label instructions is permitted until 12 October 2012.

Note: Always check the chemical label or permit for current registration status and details of application rate etc. An APVMA permit is only valid between the dates specified on the permit. Check the currency of permits before use at www.apvma.gov.au

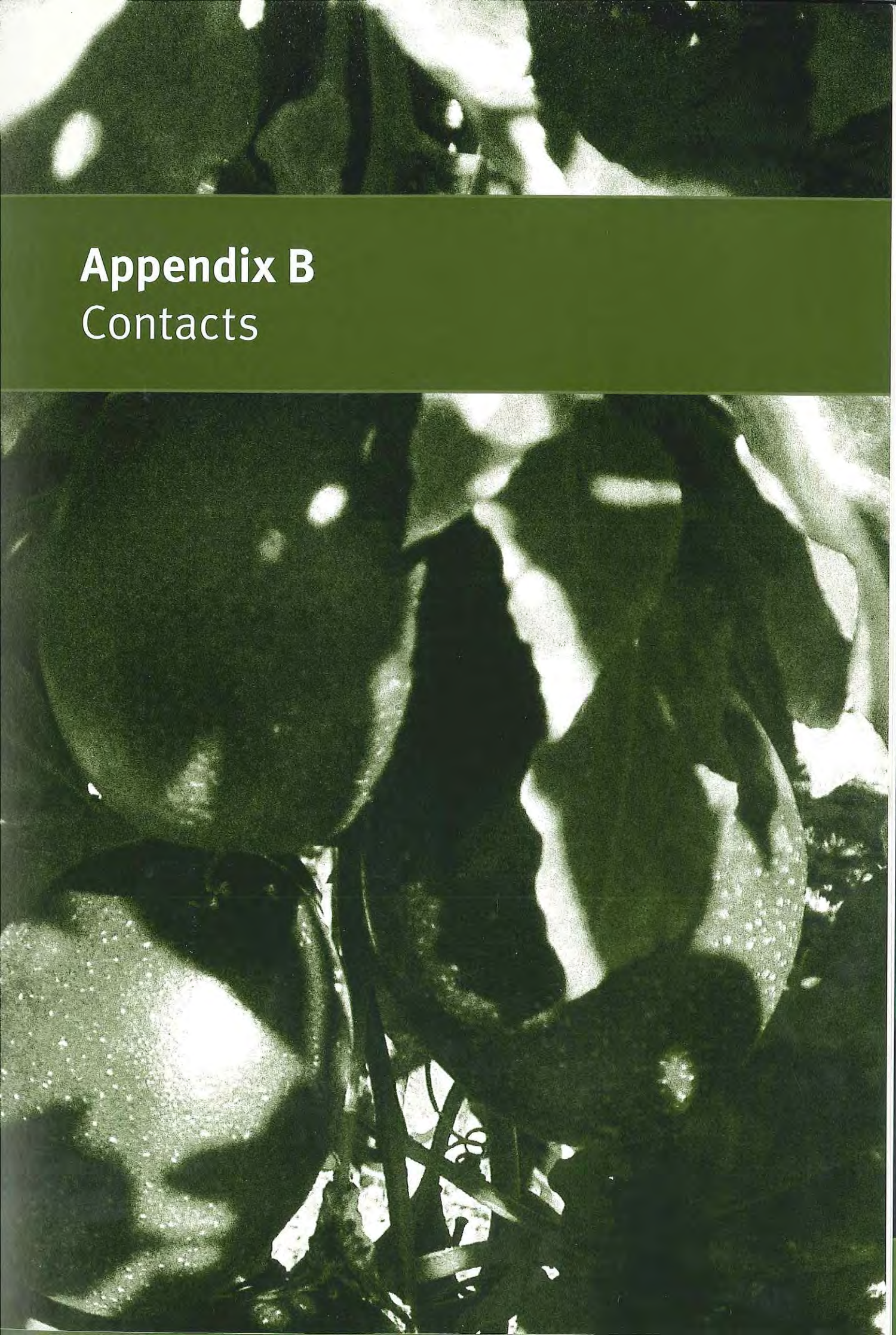
Table A.3 Post-harvest treatment

Pest name	Active components	Common trade names	Application rate (see label also)	WHP	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Chemical class
Mediterranean fruit flies	Dimethoate (400 g/L)	Dimethoate, Dimethoate 400	0.1 L/100 L (dip)	NS/NA	No	Yes	Yes	Yes	No	No	No	No	Group 1B insecticide
Queensland fruit flies	Dimethoate (400 g/L)	Dimethoate, Dimethoate 400, Danadim, Rover Insecticide, Saboteur, Stalk, Unidime 400, Dimetholinx	0.1 L/100 L (dip)	NA/NS	Yes	Yes	Yes	Yes	No	No	No	Yes	Group 1B insecticide
	Dimethoate (400 g/L)	APVMA permit number 12074	1 mL/L (dip/flood spray)	NA	No	Yes	No	No	No	No	No	No	Group 1B insecticide
	Fenthion (550 g/L)	APVMA permit number 10555	75 mL/100 L (dip/flood spray)	NA	No	No	No	No	Yes	No	No	No	Group 1B insecticide
	Dimethoate (400 g/L)	APVMA permit number 10555	1 mL/L ((dip/flood spray)	NA	No	No	No	No	Yes	No	No	No	Group 1B insecticide

Table A.4 Other useful registrations

Pest name	Active components	Common trade names	Application rate (see label also)	WHP	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Chemical class
Ants	Chlorpyrifos	APVMA permit number 11614 **For use in agricultural areas close to irrigation sprinklers**	95 mL/10 L (500 g/L product)	14	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group 1B insecticide
Queensland fruit flies	Fipronil (3.4 g/kg) + acetoxyphenylbutanone (94 g/kg)	Amulet Cue-Lure **For use in fruit crops susceptible to fruit fly**	10–16 stations/ha	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group 2B insecticide
Fruit flies, Mediterranean fruit flies, Queensland fruit flies	Spinosad (0.24 g/L)	Eco-Naturalure, Naturalure **A general registration for vine crops**	1 part + 6.5 parts water, apply mixture at 1 L/ha	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Group 5A insecticide

Note: Always check the chemical label or permit for current registration status and details of application rate etc. An APVMA permit is only valid between the dates specified on the permit. Check the currency of permits before use at www.apvma.gov.au



Appendix B
Contacts

This appendix contains the names and contact details of people and organisations serving the passionfruit industry.

> **Note:** The names in this appendix are provided solely to assist readers to make contact. Inclusion of a person or organisation does not constitute an endorsement by the Queensland Department of Employment, Economic Development and Innovation or the authors, nor does it endorse a particular person or organisation over others not mentioned. While every effort has been made to make this list as complete as possible, it should not be regarded as definitive.

Passionfruit growers association

Passionfruit Australia Incorporated (formerly the Australian Passionfruit Industry Association) is the national peak industry body representing passionfruit growers. It makes representations on behalf of the industry, directs and funds a research, development and extension program, conducts field days and publishes a newsletter, *The Passion Vine*.

Email: admin@passionfruitaustralia.com.au
Website: www.passionfruitaustralia.com.au

Nursery vine suppliers

Nurseries licensed by Passionfruit Australia Incorporated:

Birdwood Nursery
71–83 Blackall Range Road
WOOMBYE QLD 4559
Phone: (07) 5442 1611
Fax: (07) 5442 1053
Email: info@birdwoodnursery.com.au
Website: www.birdwoodnursery.com.au

Widebay Passionvine Nursery
408 Dahls Road
BUNDABERG QLD 4670
Phone: (07) 4159 7394
Fax: (07) 4159 7394
Mobile: 0429 656 922
Email: peterandsally4@bigpond.com

Suppliers of rootstock seed

Queensland Department of Employment, Economic Development and Innovation
Maroochy Research Station
PO Box 5083 SCMC
NAMBOUR QLD 4560
Phone: (07) 5453 5800
Fax: (07) 5453 5901

Passionfruit processors

Foodpac Pty Ltd
Godfrey O'Neill
PO Box 60
FINCH HATTON QLD 4756
Phone: (07) 4958 3271
Fax: (07) 4958 3141
Mobile: 0438 776 592
Email: enquiries@foodpac.com.au

Sunshine Tropical Fruit Products Pty Ltd
Michael Hughes
320 Image Flat Road
NAMBOUR QLD 4560
Contact: Michael Hughes
Phone: (07) 5441 1920
Fax: (07) 5441 1152
Email: Michael@sunshinetropical.com.au

Tropico Fruit Pty Ltd
Montville Road
PALMWOODS QLD 4555
Phone: (07) 5445 9055
Fax: (07) 5445 9437
Mobile: 0411 734 015

Consultants

Hortus Technical Services Pty Ltd
Locked Bag 3901
BUNDABERG QLD 4670
Phone: (07) 4132 5000
Fax: (07) 4155 6656
Mobile: 0427 794 524
Email: techservices@hortus.net.au
Website: www.hortus.net.au

Horticultural Crop Monitoring
Paul Jones
PO Box 3725
CALOUNDRA QLD 4551
Phone: (07) 5439 6077
Fax: (07) 5439 6088
Mobile: 0412 714 905
Email: pjones@biomites.com.au
Website: www.biomites.com.au

LW Crop Services
Leonie Wittenberg
PO Box 90
MAREEBA QLD 4880
Phone: (07) 4092 6260
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Email: leoniewittenberg@westnet.com.au

Jeff Watson
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MAREEBA QLD 4880
Phone: (07) 4092 4059
Fax: (07) 4092 4059
Mobile: 0429 924 059

Peasley Horticultural Services
David Peasley
PO Box 542
MURWILLUMBAH NSW 2484
Phone: (02) 6677 7174
Fax: (02) 6677 7174
Mobile: 0427 126 245

Ross Fitzell Plant Health Services
PO Box 619
ALSTONVILLE NSW 2477
Phone: (02) 6629 5116
Fax: (02) 6629 5116
Mobile: 0410 615 209
Email: fitzell2bigpond.com

Soil, water and plant-tissue testing laboratories

Your local agricultural supply store will also be able to assist with soil, water and plant-tissue analysis services.

SGS Australia Food and Agriculture Pty Ltd
214 McDougall Street
TOOWOOMBA QLD 4350
Phone: (07) 4633 0599
Fax: (07) 4633 0711
Email: au.food.agriculture.twb@sgs.com
Website: www.sgs.com.au

Hortus Technical Services Pty Ltd
Locked Bag 3901
BUNDABERG QLD 4670
Phone: (07) 4132 5000
Fax: (07) 4155 6656
Website: www.hortus.net.au

Incitec Pivot Fertilisers Ltd
Free call: 1800 009 832
Fax: 1800 801 094
Website: www.incitecpivotfertilisers.com.au

Suppliers of beneficial insects

Biomites
PO Box 3725
CALOUNDRA QLD 4551
Phone: (07) 5434 6077
Fax: (07) 5439 6088
Mobile: 0403 331 957
Email: pjones@biomites.com.au
Website: www.biomites.com.au

Bugs for Bugs
Bowen Street
MUNDUBBERA QLD 4626
Phone: (07) 4165 4663
Fax: (07) 4165 4626
Email: info@bugsforbugs.com.au
Website: www.bugsforbugs.com.au

Suppliers of sweet smother grass turf

Clifton Park Turf Supplies
CHAMBERS FLAT QLD 4133
Phone: (07) 5546 8899 or 1800 468 869

Greenfield Turf
KALLANGUR QLD 4503
Mobile: 0411 664 599

Merv Dudgeon
WOOLONGBAR NSW 2477
Phone: (02) 6628 7129
Mobile: 0415 897 321

Domestic market information

Ausmarket Consultants
PO Box 229
BRISBANE MARKET QLD 4106
Phone: (07) 3379 4576
Fax: (07) 3379 4103
Mobile: 0417 712 427
Email: admin@ausmarket.com.au
Website: www.ausmarket.com.au

Market Information Services
PO Box 229
BRISBANE MARKET QLD 4106
Phone: (07) 3379 4576
Fax: (07) 3379 4103
Mobile: 041 871 3688
Email: adminmis@marketinfo.com.au
Website: www.marketinfo.com.au

DataFresh Pty Ltd (FreshState)
Box 113 Melbourne Markets
542 Footscray Road
FOOTSCRAY VIC 3011
Phone: (03) 9689 3233
Fax: (03) 9689 9223
Email: info@datafresh.com.au
Website: www.datafresh.com.au

Adelaide Produce Markets Ltd
Burma Road
POORAKA SA 5095
Phone: (08) 8349 4493
Fax: (08) 8349 6574
Mobile: 0419 814 948
Email: wendy@adelaidemarkets.com.au
Website: www.adelaidemarkets.com.au

Sydney Produce Surveyors Pty Ltd and Sydney Market Reporting Service
PO Box 350
FRENCHS FOREST NSW 2086
Phone: (02) 9746 3437
Fax: (02) 9746 1075
Mobile: 0416 108 639
Email: accounts@sydprod.com.au
Website: www.sydprod.com.au

Perth Market Authority
MP 1, Market City
280 Bannister Road
CANNING VALE WA 6155
Phone: (08) 9456 9200
Fax: (08) 9456 9222
Email: pma@perthmarket.com.au
Website: www.perthmarket.com.au

Market authorities and wholesaler information

Adelaide Produce Markets Ltd
Burma Road
POORAKA SA 5095
Phone: (08) 8349 4493
Fax: (08) 8349 6574
Email: enquiry@adelaidemarkets.com.au
Website: www.adelaidemarkets.com.au

Brisbane Markets Ltd
Upper Level, Brisbane Markets Commercial Centre
Sherwood Road
ROCKLEA QLD 4106
Phone: (07) 3379 1062
Fax: (07) 3379 4903
Marketline freecall: 1800 631 002
Website: www.brisbanemarkets.com.au

Perth Market Authority
Mail Point 1, Market City
280 Bannister Road
CANNING VALE WA 6155
Phone: (08) 9455 2900
Fax: (08) 9455 2902
Email: pma@perthmarket.com.au
Website: www.perthmarket.com.au

Sydney Markets Ltd
PO Box 2
SYDNEY MARKETS NSW 2129
Phone: (02) 9325 6200
Fax: (02) 9325 6288
Email: sydma@sydneymarkets.com.au
Website: www.sydneymarkets.com.au

Victorian Chamber of Fresh Produce Wholesalers Inc. (trading as Freshstate)
Melbourne Markets Box 113
542 Footscray Road
WEST MELBOURNE VIC 3003
Phone: (03) 9689 3233
Fax: (03) 9689 9223
Email: vicchamber@freshstate.com.au
Website: www.freshstate.com.au

The Australian Chamber of Fruit and Vegetable Industries
Website: www.freshmarkets.com.au

Quality assurance information and services

Freshcare Ltd
(Providers of a national on-farm food safety program for fresh produce)
PO Box 247
SYDNEY MARKETS NSW 2129
Phone: (02) 9764 3244
Fax: (07) 9764 2776
Email: freshcare@freshmarkets.com.au
Website: www.freshcare.com.au

Rudge Produce Systems Pty Ltd
(Quality management consulting services)
PO Box 177 Melbourne Markets
542 Footscray Road
WEST MELBOURNE VIC 3003
Phone: (03) 9689 1234
Fax: (03) 9689 1232
Email: office@rudge.com.au
Website: www.rudge.com.au

Chemical information

Australian Pesticides and Veterinary Medicines Authority
PO Box 6182
KINGSTON ACT 2604
Phone: (02) 6210 4701
Fax: (02) 6272 4753
Email: contact@apvma.gov.au
Website: www.apvma.gov.au

Infopest–pest management
Infopest
Biosecurity Queensland
Department of Employment, Economic Development and Innovation
GPO Box 46
BRISBANE QLD 4001
Phone: (07) 3239 3967
Fax: (07) 3211 3293
Email: infopest@deedi.qld.gov.au
Website: www.deedi.qld.gov.au

ChemCert training

New South Wales
ChemCert (NSW) Ltd
PO Box 2600
BONDI JUNCTION NSW 1355
Phone: (02) 9380 7271
Fax: (02) 9380 7471
Email: info@chemcert.com.au
Website: www.chemcert.org.au

Northern Territory
Mobile: 0418 892 260
Fax: 08 8941 4088
Email: nt@chemcert.org.au

Queensland
ChemCert Training Queensland
Training Manager
Farmsafe Queensland Ltd
PO Box 1474
UQ GATTON CAMPUS QLD 4343
Phone: (07) 5466 5850
Fax: (07) 5466 5860
Mobile: 0427 732 886
Email: chemcertqld@farmsafe.com.au
Website: www.farmsafe.com.au

Western Australia
ChemCert WA Incorporated
Phone: (08) 9341 5325
Email: farmcarewa@bigpond.com.au
Website: www.chemcertwa.com.au

National
SMARTtrain National Support Centre
New South Wales Department of Primary Industries
PMB YANCO NSW 2703
Phone: 1800 138 351
Fax: (02) 6951 2565
Website: www.smarttrain-publications.com

Government technical services

Passionfruit technical enquiries (commercial growers only):

Queensland Department of Employment, Economic Development and Innovation
Peter Rigden, Extension Officer
Maroochy Research Station
PO Box 5083 SCMC
NAMBOUR QLD 4560
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Email: peter.rigden@deedi.qld.gov.au

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