Mango information kit

Reprint – information current in 1999

REPRINT INFORMATION – PLEASE READ!

For updated information please call 13 25 23 or visit the website www.dpi.qld.gov.au

This publication has been reprinted as a digital book without any changes to the content published in 1999. We advise readers to take particular note of the areas most likely to be out-of-date and so requiring further research:

- Chemical recommendations—check with an agronomist or Infopest www.infopest.qld.gov.au
- Financial information—costs and returns listed in this publication are out of date. Please contact an adviser or industry body to assist with identifying more current figures.
- Varieties—new varieties are likely to be available and some older varieties may no longer be recommended. Check with an agronomist, call the Business Information Centre on 13 25 23, visit our website www.dpi.qld.gov.au or contact the industry body.
- Contacts—many of the contact details may have changed and there could be several new contacts available. The industry organisation may be able to assist you to find the information or services you require.
- Organisation names—most government agencies referred to in this publication have had name changes. Contact the Business Information Centre on 13 25 23 or the industry organisation to find out the current name and contact details for these agencies.
- Additional information—many other sources of information are now available for each crop. Contact an agronomist, Business Information Centre on 13 25 23 or the industry organisation for other suggested reading.

Even with these limitations we believe this information kit provides important and valuable information for intending and existing growers.

This publication was last revised in 1999. The information is not current and the accuracy of the information cannot be guaranteed by the State of Queensland.

This information has been made available to assist users to identify issues involved in the production of mangoes. This information is not to be used or relied upon by users for any purpose which may expose the user or any other person to loss or damage. Users should conduct their own inquiries and rely on their own independent professional advice.

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Queensland Government

Key ISSUES

This section contains more detailed information on some of the important decision-making areas for mango growers. It supplements the growing and marketing recipe in Section 3. The information covers the key points that need to be known and understood rather than a complete coverage of each issue. Where additional information may be useful, we refer you to other parts of the kit. Symbols on the left of the page will help you make these links.

Understanding the mango tree

The aim of mango growing is to regularly produce a large crop of high quality fruit. To achieve this, it is helpful to know what governs flowering, fruit production and quality.

Origin and early history

The mango (*Mangifera indica*) belongs to the family Anacardiaceae. Other cultivated trees in this family include cashew and pistachio.

There are two major sites of evolution for mangoes (Figure 1). One is in the mild, subtropical, northern Indian/Burmese region where mangoes have been cultivated for more than 4000 years. This region has produced varieties that are monoembryonic with greater tolerance to low temperatures for growth and fruit set. Monoembryonic varieties produce a single seedling from each seed. Commonly grown monoembryonic varieties include Keitt, Kent, Palmer, Tommy Atkins and Irwin.

About 2000 years ago a secondary site of evolution developed in the hot, humid, tropical areas of south-east Asia. From this region the polyembryonic varieties have evolved. Polyembryonic varieties produce several seedlings from each seed. These varieties need higher temperatures for growth, and fruit set is more susceptible to cold weather. This group of varieties includes Nam Doc Mai (Thailand) and Carabao (Philippines). Trade has spread the fruit throughout every tropical and most subtropical regions of the world.

The polyembryonic variety Kensington Pride was selected from a group of seedlings grown in the Bowen district during the late 1880s. At this time shipping between north Queensland and south-east Asia was common, so it is likely that the seed came into Australia this way.

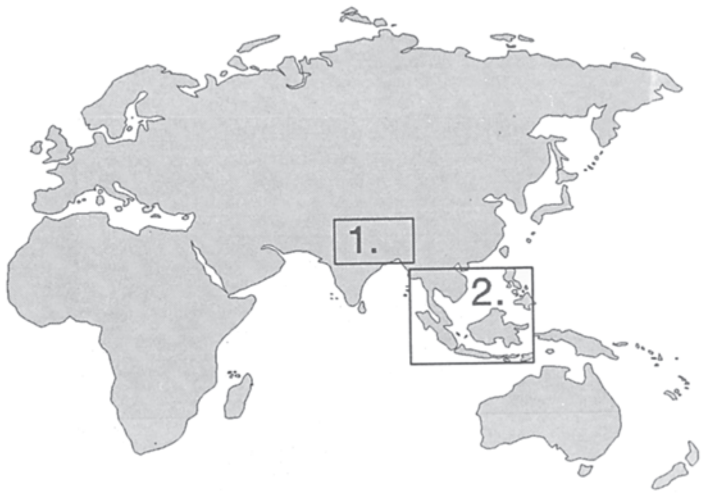

Figure 1. Sites of evolution for mango varieties

The mango tree

The mango tree is a densely foliaged evergreen that grows from 15 to 20 m high. Trees are naturally long-lived.

The tree is well adapted to a monsoonal climate with a long dry season, followed by a predictable short wet season. To survive and grow in these conditions the tree has several adaptive features:

- It has a large taproot system that can find underground water 3 m or more below the surface.
- The feeder roots are tolerant of drying out, so they can regrow rapidly when the soil is re-wetted.
- The tree has a resin duct system that helps to maintain the water balance during long periods of drought. The sap that spurts from the fruit at picking is part of this resin system.
- The leaves are long-lived and have a hard, leathery texture that minimises water loss when dry and supports efficient photosynthesis when conditions are good.
- Carbohydrate for plant growth and fruiting is stored in the roots, trunks and branches.
- The tree is able to adjust its crop load through heavy fruit drop.

These adaptations have helped the tree to survive in the wild. In an orchard these features can have a negative impact because they direct energy away from fruit production into survival mechanisms.

Annual growth cycles of bearing trees

Growth events such as vegetative flush and flowering in mango follow a predictable pattern throughout the year. This is the growth cycle and there are four major growth cycle events.

Vegetative growth

The mango tree usually has between one and four separate vegetative flushes during the year. In bearing trees they are synchronised into fairly uniform flushes and growth generally stops between each flush. Each vegetative flush starts from the terminal or axillary buds and develops into an elongation of the growing tip. New leaves are often red or deep purple and change to green as they harden and mature. The length of the flush is determined by the vigour of the tree, crop load and temperature. The number of flushes is dependent on variety, temperature and tree health.

The most important growth flush is in summer after harvest, also referred to as the postharvest flush, which in Queensland occurs between January and April. Growers should try to encourage most of the branches to flush at the same time, particularly the summer flush, so that most of the terminals are of similar age and are ready to flower at the same time.

Flowering

Most varieties flower once a year during winter and early spring. A few varieties at tropical latitudes can flower more often, giving two crops a year. Flower initiation is triggered during the dormant period that is usually brought on by cool night temperatures and dry conditions. Terminal vegetative buds from the most recent mature shoots turn into floral buds shortly before flowering begins. If the terminals have been pruned, flowers can also develop from axillary buds. Flower emergence continues for four to six weeks and the intensity of flowering is dependent on the age of the terminals, the season and tree health.

Temperature, geographical region and altitude influence the timing of flowering. Flowering is earliest for trees along the northern coastal areas of Queensland. Trees in the Dry Tropics (Burdekin, Bowen) region flower first, in early July, followed by the Atherton Tableland, then Central Queensland and Bundaberg/Childers in September and the drier areas of the Sunshine Coast in late September/October.

Both the timing and intensity of flowering determine the potential crop. In Kensington Pride, inconsistencies in flowering and fruit set are major limitations to production.

In the hotter tropical regions, mild winter temperatures during floral induction often lead to shoot growth at the expense of flowering, resulting in a low percentage of flowering terminals. Night temperatures between 10° and 12°C promote flower initiation. In tropical regions, water stressing the trees for two or three months before flowering also improves floral induction by preventing late summer shoot growth. This ensures flowering terminals are at least three months old and mature enough to flower.

In the cooler subtropical regions, the lower temperatures generally ensure a high percentage of flowering terminals. However, when temperatures regularly fall below 10°C, pollen viability and the number of hermaphrodite flowers on polyembryonic varieties is reduced. This usually results in poor fruit set.

Each inflorescence bears several thousand male and hermaphrodite (bisexual) flowers. Their proportions vary with variety, temperature during formation and position in the inflorescence. In some seasons, a low number of hermaphrodite flowers can result in poor yield. The flowers of most mango varieties are self-compatible, that is they can be fertilised by their own pollen.

Chemical flower induction

Flowering can be improved by the use of certain chemicals. The growth regulator Cultar® (paclobutrazol) can be used to reduce erratic flowering. It will also control vegetative growth and help build up carbohydrate reserves before flowering. This promotes stronger flowering, fruit set is increased, and fruit growth is faster when the crop's nutrient and water requirements are managed properly. Cultar® also reduces the alternate bearing habits of some varieties.

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Growth regulators
Growing the crop
Section 3

Chemicals such as ethepon (Ethrel®) or foliar application of potassium nitrate can also initiate flowering. Their effectiveness is highly dependent on variety and location. Many trials have shown inconsistent results, though a few varieties will respond well.

Pollination and fruit set

The inflorescences initially set a large number of fruit, but the tree sheds most of them, leaving on average less than one fruit per terminal by harvest. Any stress will increase the amount of fruit shed.

Poor fruit set can often be due to poor pollination. Pollen viability is affected by night temperatures below 15°C. Varieties vary in their sensitivity to cold, but flowers that open when night temperatures fall below 10°C are unlikely to set fruit. Although low temperatures promote strong flowering in mangoes, fruit often fails to set because of low pollen viability or embryo death in the early stages of fruit development. This is more common in the polyembryonic group of varieties, which includes Kensington Pride.

In the cooler subtropics, fruit set can be improved by encouraging late flowering during warmer weather. This can be achieved by the removal of early flowers, which then stimulates a later, secondary flowering from axillary buds.

Wind and insects pollinate mangoes. The most efficient insect pollinators are wasps, bees and large flies.

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Boron
This section page 41

Nutrition has an important role in successful fruit set. An adequate level of boron, is important for pollen germination and normal flower development. Adjust boron levels just before floral bud break to ensure trees are not deficient in this micronutrient during flowering so that fruit set is optimised.

Fruit development

The fruit takes four to five months to mature (80 to 150 days after first flower bud burst), depending on the growing district. Fruit growth is faster in the hotter, northern regions of Queensland than in the subtropical, southern regions. Fruit grows slowly at first, then more quickly and growth slows again towards maturity.

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Mango Care newsletters
References page 28

There is evidence to suggest that fruit maturity can be predicted by using a heat sum technique. This technique sums a calculated base temperature for each day from inflorescence development. The DPI newsletter *Mango Care,* Issue 28, outlines how growers can calculate heat sums for their area.

Dormancy

There are two dormant periods during the mango growth cycle. After harvest the tree goes into a short dormancy lasting four to eight weeks before the summer leaf flush. The second and main dormancy is after the vegetative growth flushes have matured and the cooler weather stops tree growth. This period is vital for the induction of flowering.

Fruit characteristics

a key issue
Varieties
This section page 22

The shape, size and colour of mango fruit vary greatly with varieties. The fruit has a large seed enclosed in a fibrous coat and the fibres extend from the seed into the pulp. Most commercial varieties are selected for low fibre content.

Seed type

Mango trees can have either monoembryonic (produce a single seedling from each seed) or polyembryonic seeds (produce several seedlings from each seed) Figure 2.

Monoembryonic seeds

The seed of monoembryonic varieties has two solid cotyledons and on germination only one plant grows. This seedling is the result of pollination and the fruit from this new plant will not be the same as the parent tree. Therefore monoembryonic varieties must be grafted to maintain trueness-to-type. Most of the recently introduced mango varieties (Palmer, Keitt, Kent, Irwin and Haden) are monoembryonic.

Polyembryonic seeds

Polyembryonic seeds have segmented cotyledons, all of which are capable of producing new plants. The cotyledons originate from the parent tree and any seedling growing from these sections will come true-to-type. Typically two to four plants will grow from a polyembryonic seed. Grafting of these seedlings is optional, but there are some advantages. Kensington Pride, Carabao and Nam Doc Mai are examples of polyembryonic mangoes.

Some of the new hybrid varieties produce seeds that may be either monoembryonic or polyembryonic. For instance only about two thirds of R2E2 seedlings come true-to-type so it is advisable to graft trees when establishing an orchard of this variety .

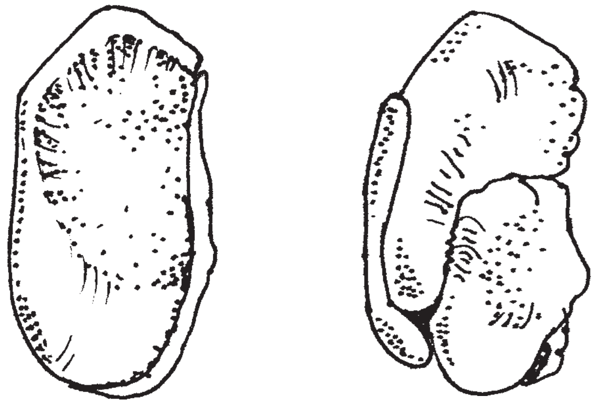

Figure 2. Monoembryonic seed (left) has two solid cotyledons and on germination only one plant grows. Polyembryonic seed has segmented cotyledons, all of which are capable of producing new plants

SKIN COLOUR
For further information on colour development read the Mango Care newsletter, Issue 20, Section 6 page 13.

Colour development

Mango skin colour can be separated into ground and blush colour. The ground colour is the background colour of the fruit, which when unripe is generally green, developing into yellow to orange as the fruit ripens. The blush colour, an attractive pink to purple, appears on the shoulders and down the exposed side of the fruit. The variety, crop nutrition, exposure to light and maturity at harvest influence skin colour, though postharvest handling (primarily ripening temperature) also has an important effect.

Flavour

Many components of the fruit pulp contribute to the flavour of mangoes and different varieties can be distinguished by their unique flavours. Kensington Pride's flavour, for example, comes from the relatively high levels of terpinolene in the fruit pulp. Terpinolene is also present at lower levels in R2E2. Other varieties such as Keitt have lower terpinolene but higher carene levels.

Implications for crop management

HINT
Apply most of the nitrogen fertiliser just after harvest for best fruiting.

High performing trees follow a regular annual pattern of shoot growth, flowering and fruit development. The aim of crop management is to keep trees within this desired cycle by carefully managing fertilising, watering and pruning.

Fertiliser management, particularly nitrogen fertiliser, is designed to produce a strong summer flush after harvest. This flush sets up the fruiting wood for the next crop.

Ensure the water supply is adequate, particularly during flowering and fruit development. Use soil moisture monitoring devices to carefully schedule irrigation to the needs of the tree. Control weeds within the root zone to remove competition for water and nutrients.

Prevent damage to the main growth flushes and fruit by controlling pests and diseases and minimising wind and frost damage.

Maximise the production of carbohydrate in the tree by making sure as much of the leaf canopy as possible is available for photosynthesis. This means regular pruning to ensure adequate light penetration into the canopy. Pruning also reduces fruit marking, makes harvesting easier and ensures more effective spray penetration for pest and disease control.

Propagation

Mangoes can be propagated as seedlings or as grafted trees and their propagation is fairly straightforward. Here are some notes on how to propagate mango trees.

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Mango seed types
This section page 6

Seed types

The methods used to propagate trees depend on the seed type of the variety to be grown, that is monoembryonic or polyembryonic. Only seed from polyembryonic varieties will produce true-to-type seedlings.

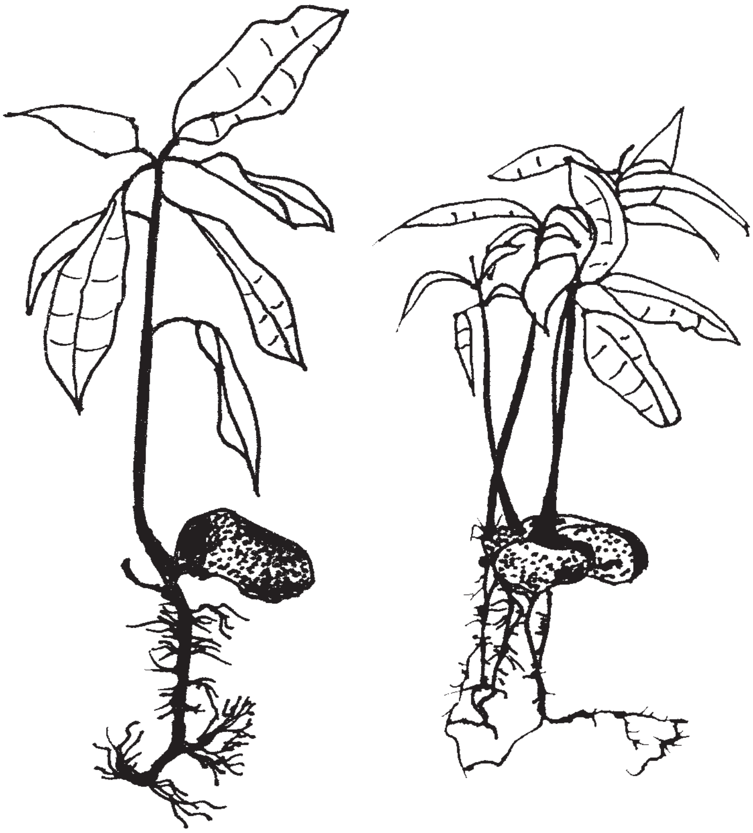

Figure 3. *Monoembryonic (left) and polyembryonic seed, with seedlings. Only seed from polyembryonic varieties will produce true-to-type seedlings*

Seedlings or grafted trees

The establishment of an orchard from seedling plants is only an option with polyembryonic varieties. Although they are easier and cheaper to propagate, there are several advantages in using grafted trees to establish an orchard. These are:

- more uniform plant type
- earlier cropping (generally one to two years earlier than seedlings)
- true-to-type (there is generally up to 7% off-types produced from polyembryonic seeds)
- ability to propagate from a superior selection of the variety.

Even if you are producing grafted trees, you will need to grow seedlings to use as rootstocks.

Growing seedlings

Seed collection

Collect seed only from true-to-type, highly productive trees. Pick fruit for seed at the early, green mature stage to reduce the incidence of mango seed weevil damage to the cotyledons. It is best to use fresh seed as older seed loses viability.

Seed extraction

To extract seed, remove the flesh and allow the seed to air dry in the shade for one to two days. Once dry force the husk open with a pair of electrician's pliers (pliers in which the jaws open when the handles are closed). Inspect the exposed cotyledons for mango seed weevil and keep only undamaged seed. Dip seed into a fungicide solution before planting into a sandy, germination mixture.

Seed planting and germination

Seeds may be planted into prepared seedbeds or directly into poly nursery bags. Plant seeds with the convex side upward and just exposed. They take from two to four weeks to germinate. Place galvanised iron or similar material about 15 cm under the soil in the seedbed to prevent the taproot going too deep. If planting directly into pots, select the strongest seedling and cut off the additional seedlings that grow.

A polyembryonic seed may produce up to 12 seedlings. When transferring plants from the seedbed, small or weak seedlings should be discarded.

Caring for young seedlings

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Problem solver
Section 5

Apply standard nursery practises of regular irrigation, fertilising and pest and disease control to young mango seedlings. Young trees are particularly susceptible to mango scab and bacterial black spot.

Leave plants in the seedbeds until they are about 0.5 m high and then transplant into pots or poly nursery bags.

Seed germinated in November/December should be ready to field plant the following March/April. Seed germinated in January/February is generally not ready for planting out until the following spring-early summer. Once seedlings grown for rootstocks are 0.5 m high, they are ready for grafting.

Grafting

The primary aim of grafting is to produce plants that are identical to the parent plant. Grafting is also used to induce earlier maturity and to achieve a more uniform orchard. After a little practice successful grafting is easy, if certain basic requirements are met. There are two parts to a grafted tree. The rootstock, usually a seedling that provides the tree's roots, and the scion, which is the variety used for the top of the tree.

Rootstocks

Kensington Pride and Common mango seedlings are suitable to use as rootstocks. Both varieties produce genetically uniform, vigorous seedlings that are compatible with other varieties. The main requirement is to have a healthy and vigorous rootstock for grafting. If the rootstock is not vigorous, do not attempt to graft it. Dwarfing rootstocks are used in some overseas growing regions but have yet to prove themselves under Australian conditions.

The ideal rootstock is about 12 months old, about 50 cm tall and 1 cm wide at a point about 30 cm above ground level.

Scion or budwood

Take the scion from a healthy tree that is true-to-type and that bears well. Wood from the most recent hardened growth flush is suitable for grafting. The best terminals to use are those that have prominent eyes or buds indicating that regrowth is imminent. These terminals are generally fully mature with good reserves of carbohydrate that assist the grafting process. All scion wood should be free of pests and diseases.

Prepare the scion wood by cutting the hardened vegetative flush (about 10 cm) off the parent tree and trimming the leaves back, leaving about 1 cm of petiole on the scion. These short petioles protect the juvenile buds at the base of each tip and terminal. Cut back the entire leaves and petioles from the lower half of the scion.

Grafting tools

- A special grafting knife that is sharpened on one side only. Always keep it very sharp and clean. A fine sharpening stone will help keep the knife sharp.

- Special PVC grafting tape, 1.25 cm wide, is available from most outlets that carry horticultural supplies.
- Clean secateurs for cutting budwood.
- Small plastic bags and brown paper bags to place over the graft will improve the success rate.

Time of grafting

Only attempt grafting when the rootstocks are vigorous and the buds on the scion wood are swollen. For best results, graft rootstocks during warm, humid weather, usually from January to the end of April. Grafts at other times of the year are successful if temperature and humidity are increased artificially. Day temperatures of 25° to 30°C, and nights at 18° to 21° C, are ideal.

Grafting technique

The most suitable height for grafting is about 20 to 30 cm above ground level. At this point, the rootstock should be straight, at least pencil thick, and have green bark. If the bark is old, brown or corky avoid the area. Retain the leaves on the rootstock below the point of grafting.

A wide range of grafts can be used on mangoes, but the two most common are the whip and the cleft or wedge graft. The whip graft is used widely by nurseries and other highly experienced operators, while most other people use the wedge. Both grafts are easy to do after practice. Provided certain basic steps are followed, the success rate will be high.

With all grafting, observe the following points:

- Practise good hygiene.
- Have vigorous and healthy rootstocks.
- Have bud activity and health in the scion or budwood.
- Wrap unused budwood in plastic and store in an esky or refrigerator.
- Wherever possible use young, fresh, scion wood.
- Keep the grafting knife clean and sharp. Make only single cuts when grafting.
- Make sure the area where the graft is to be made is straight and preferably young, with green bark.
- Always cover the fresh graft with a plastic bag to create a warm, humid environment.
- If grafting in full sun, cover the plastic bag with a brown paper bag to prevent excessive build-up of heat.
- Do not over water after grafting.
- Always match the cambium layers on one side when tying the graft. Don’t worry if both sides are not matching.

Hygiene

Maintain a high level of hygiene at all times. Periodically dip grafting knives and secateurs in methylated spirits to sterilise them. It is also advisable to spray the stocks and dip the scion wood in a 0.2% solution of mancozeb fungicide.

Cleft graft

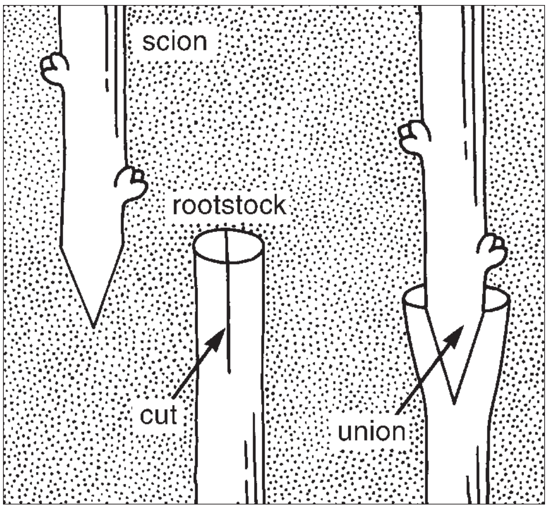
Prepare the scion wood by making two sloping cuts at its base to form a wedge 2.5 to 3 cm long, depending on the width of the stock. Match the thickest side of the wedge with the cambium. Cut off the rootstock 20 to 30 cm above soil level and make a clean-edged cut down the centre of the stem for about 3 cm (Figure 4).

Insert the scion wood wedge into the rootstock cut to match the cambium on the thick side of the scion. Tie the union firmly with grafting tape to seal it to prevent moisture loss, and to stop scion movement (Figure 4).

Whip graft

A whip graft consists of a single, angled-cut through both the rootstock and the scion wood. This cut would be similar to the first cut used on the cleft graft, though it need not be as long. Make only one angled cut on both the rootstock and the scion, preferably about the same length.

When tying the graft, start taping at the bottom of the graft and finish above the top. Match the cambium of the scion and the stock on at least one side during this process.



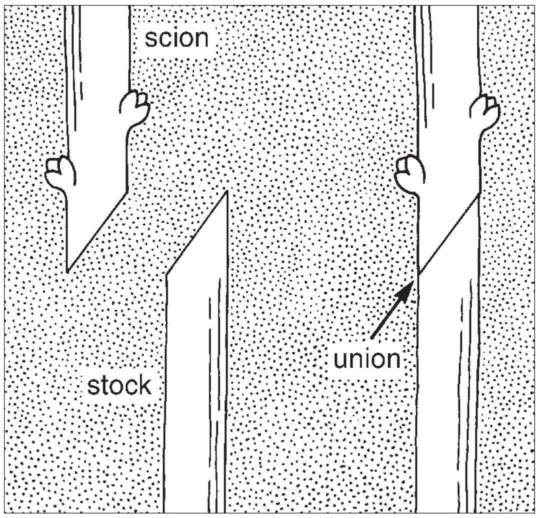


Figure 4. *Cleft (left) and whip grafts*

Covering the graft

The success rate of grafting is better if the newly completed graft is covered with a small, plastic bag and tied on the bottom to allow heat and humidity to build up. Further covering is not needed in a shaded greenhouse. If grafted rootstocks are in the sun, place a small, brown paper bag over the plastic bag to prevent excessive heat build-up.

Removing bags and grafting tape

Remove the plastic and paper bags once the graft has started active growth and is 2 to 3 cm long. This time may vary from two to four weeks. The new shoot growth is very brittle, so be careful when handling the plant.

The grafting tape should not be removed until the first new growth has matured. If the tape is left on too long, it may restrict growth by becoming too tight at the union area. The time taken for removing the tape will vary from two to four months. Young trees can be planted out in the field at this stage.

Figure 5. *Cover the new graft with a small plastic bag for best growth*

Care after grafting

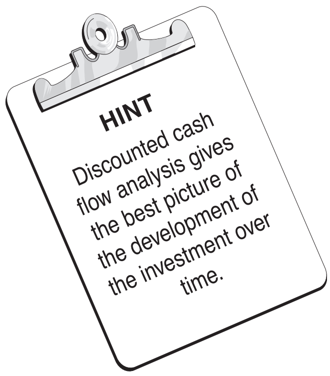
Over watering of recently grafted plants is the most common fault. Rootstocks have little leaf surface remaining after grafting and water loss through transpiration is minimal. Periodically remove sucker growth that may emerge from the rootstock after grafting.

Economics

Producers considering growing mangoes should prepare a thorough economic analysis to assess the profitability of their investment. As mango production is continuing to increase, profitability will depend on market expansion and development of new market opportunities. At certain times the domestic market can be oversupplied, leading to very low prices for all but outstanding quality fruit. Higher returns at the beginning and end of the season are still attracting investment.

Analysing horticultural investments

Several methods can be used to analyse the profitability of a horticultural investment. Two analysis methods have been chosen to give an overview of the profitability of mango production.



Discounted cash flow analysis

Discounted cash flow analysis is based on the observation that a dollar today is worth more than the promise of a dollar in the future. It converts a future sum of money to its present value, using a discount rate. The discount rate represents the decline in present value of a dollar for each successive year or, alternatively, the 'real' return of capital if it was invested elsewhere. Without discounting, comparisons between investments would be more difficult and sometimes meaningless. A discounted cash flow analysis includes all the incoming and outgoing cash flows the orchard is likely to experience over the life of the crop. It does not take into account financing issues or taxation.

Gross margin analysis

The simplest analysis is a gross margin, which looks at the costs and returns at a steady state yield. The gross margin is a valuable analysis and easy to understand, but it does not take into account fixed costs or capital expenditure. As these are often a large part of expenditure, growers should also consider an analysis that includes these components.

Discounted cash flow analysis

Background to the analysis

This discounted cash flow analysis examines the profitability of a hypothetical mango farm in the Mareeba-Dimbulah Irrigation Area. A farm size of 27 ha (5022 trees) is used. This farm size is chosen as representative for the region and is considered to be a 'living area' for a family unit.

This analysis allows for the timing of the costs and benefits over the life of the enterprise, which was assumed as 30 years. Yields and costs for the model mango farm were determined with the assistance of mango producers and DPI technical officers.

Assumptions

Several assumptions are made about the farm and its production. When checking this analysis for your situation, check that these assumptions are true for you.

- The hypothetical mango farm has 27 ha of Kensington Pride mangoes under irrigation.
- A planting density of 186 trees/ha is used with 6 m between trees and rows 9 m apart.
- The yields used are given in Table 1. The maximum yield is assumed to peak at 12 tray equivalents (7 kg trays) per tree. Tray equivalents are used because mangoes can be marketed in trays or in bins (juicing and slicing). Steady-state or full production is achieved in the eighth year.

***Table 1**. Mango yield estimates used for the model mango farm*

Year	Yield (7 kg tray equivalents/tree)
1	0
2	0
3	1
4	3
5	4
6	7
7	10
8+	12

- Forty per cent of the mangoes produced are sold as first grade, 40% as second grade, 10% for slicing and the remainder for juicing.
- The prices received are:
  - $14/tray for first grade mangoes
  - $10.50/tray for second grade mangoes
  - $0.54/kg for slicing mangoes
  - $0.34/kg for juicing mangoes.

Slicing and juicing prices are net of bin hire costs.

- Based on these price and yield assumptions, the average price per tray equivalent was $10.42.

- First and second grade mangoes are sold to the Sydney market. The slicing and juicing mangoes are sold for processing in Brisbane.
- A project life of 30 years is used with a discount rate of 6% (real rate) to calculate the net present value. The productive life of the orchard was considered to be 30 years because new and better mango varieties are being released. Although the existing trees planted are physiologically still growing and producing fruit, tree obsolescence becomes more important than tree age.

Harvesting and marketing

Harvesting and marketing costs are calculated on a per tray or per tray equivalent basis. Table 2 shows the harvesting and marketing costs used in the model mango farm. The total harvesting and marketing costs vary from year to year due to the different yields. Only the eighth year figures are presented in Table 2, however, the cost per tray figures can be applied to the given yields in previous years. The total harvesting and marketing costs from the eighth year are estimated to be $12 551/ha.

Table 2. *Harvesting and marketing costs in the model mango farm*

Item	Cost/tray ($)	Cost/ha ($)
Picking (casual labour)	1.00	2,232.00
Desapping, sorting, packing, casual labour, etc.	0.59	1,048.29
Dipping	0.12	267.84
Gas	0.06	133.92
Pallet hire	0.05	89.28
Packaging	2.07	3,696.20
Commission (12.5%)	1.30	2,324.85
Levies	0.10	178.56
Freight – Sydney	1.45	2,580.75

Capital costs

An annual capital requirement cost is calculated based on the replacement value of farm assets and the opportunity cost of the land. The cost represents an annuity or payment of equal instalments for capital in 1999 dollars. An estimated $48 114/year is required to cover capital requirements for the model mango farm.

Table 3 summarises the capital equipment requirements for the 27 ha model farm.

Table 3. Capital costs for mango production using the 27 ha model farm

Capital item	Value ($)	Year of purchase
Tractor – 100HP	72,500	3,13,23
Tractor – 70HP	45,000	0,15
Truck – 4 tonne*	17,500	3,18
Fork-lift*	6,000	3,18
Utility*	15,000	0,10,20
Spray machine	22,000	3
Spray machine pump replacement	8,000	13,23
Boom sprayer	2,750	0,10,20
Herbicide sprayer	2,000	0,10,20
Slasher	5,000	0,10,20
Cool room	30,000	6
Machinery in packing shed	75,000	3
Crates	21,384	3,18
Pruning equipment	1,500	1,18
Pruning equipment (replacement)	825	2,3,4,5...30
Land preparation	31,050	0
Marking planting sites	502	0
Planting labour (casual)	1,575	0
Trees (grown on farm)	10,044	0
Sprinklers/laterals	15,066	0
Sprinklers/laterals (replacement)	600	1,2,3,4,...30
Main lines (irrigation)	44,696	0
Pump	15,000	0,15
Power to pump	15,000	0
Water (nominal allocation)	33,413	0
Filter	3,500	0
Fertigator	800	0
Miscellaneous tools	5,000	0,15
Packing shed	100,000	3
Storage shed	20,000	0
Land**	126,000	0

* Second-hand market values

** The value of land in this discounted cash flow analysis represents the opportunity cost of the bare land ($4500/ha) which was cleared with access to channel irrigation.

Results

Table 4 details the discounted cash flow for the 27 ha model mango farm. The farm profit (NPV [Net Present Value] format) was $33 581/farm/year, $6.69/tree/year or $0.79/tray equivalent/year. Since the return is positive, the prospect of growing mangoes, based on the model farm, is considered acceptable and profitable.

Table 4. Summary of economic analysis for mangoes using the 27 ha farm model

Financial description	$/tray equiv.	$/tree/yr	$/farm/yr
(a) Gross income*	10.42	87.76	440,746
(b) Variable costs			
Machinery operations	0.03	0.28	1,395
Pruning & hedging	0.32	2.68	13,475
Fertiliser	0.50	4.21	21,134
Herbicide	0.10	0.87	4,360
Insecticide	0.20	1.71	8,581

Financial description	$/tray equiv.	$/tree/yr	$/farm/yr
Fungicide	0.34	2.89	14,498
Irrigation ($42.35/mL)	0.12	1.00	5,033
Harvesting & marketing	5.62	47.39	237,986
(c) Fixed costs			
Repairs & maintenance	0.27	2.31	11,589
Fuel & oil**	0.05	0.40	2,000
Electricity	0.19	1.59	8,000
Administration	0.20	1.65	8,300
Owner/operator allowance	0.54	4.52	22,701
(d) Planting & capital requirements	1.14	9.58	48,114
Farm profit (a – b – c – d)	$0.79	$6.69	$33,581
Internal rate of return (%)	9.55		
Payback period (years)	18		
Peak overdraft ($)	765,930		
Time of peak overdraft (years)	5		

* Achieved from eighth year onwards.

** Used to operate the farm utility and other farm machinery not already covered.

The peak overdraft, which occurred in the fifth year, was $765 930 and the payback period was 18 years. The payback period represents the time required to recover the initial project outlay.

Variations in mango price and yield

Farm profit is dependent on yield and price. Table 5 shows how profit varies with changing price and yield. Negative figures indicate that for the particular price and yield combination it is unprofitable to grow mangoes on the model farm.

Table 5. *Farm profit ($/farm/year) with changes in prices and yields, respectively.*

	Price* ($/tray)						
1st grade	**8.00**	**10.00**	**12.00**	**14.00**	**16.00**	**18.00**	**20.00**
2nd grade	**4.50**	**6.50**	**8.50**	**10.50**	**12.50**	**14.50**	**16.50**
Yield**							
4	-162526	-142215	-121904	-101593	-81282	-60971	-40660
6	-159199	-128732	-98266	-67800	-47333	-6867	23599
8	-155871	-115250	-74628	-34006	6616	47237	87659
10	-152544	-101767	-50990	-213	50564	101342	152119
12	-149217	-88285	-27352	33581	94513	155446	216378
14	-145890	-74802	-3714	67374	138462	209550	280638
16	-142563	-61320	19924	101167	182411	263654	344898
18	-139236	-47837	43562	134961	226360	317759	409158
20	-135909	-34355	67200	168754	270308	371863	473417
22	-132582	-20872	90838	202547	314257	425967	537677

* The slicing and juicing prices remain constant at $0.54/kg and $0.34/kg
** Tray equivalent per tree at steady-state yield (eighth year onwards).

Based on the prices used for the model farm, the minimum yield required to be profitable is 12 trays/tree. Similarly, based on the yield used for the model farm, the minimum prices required to be profitable are $14.00/tray for first grade mangoes and $10.50/tray for second grade fruit.

The mango farm profitability was price sensitive for first grade prices and second grade prices below the control prices used in the model farm. A $4.00 reduction in both first and second grade prices from the control prices used in the model farm produces a negative farm profit regardless of any improvement in mango yield. With a $2.00 reduction in the control prices a yield of 16 trays/tree is required before the model farm is profitable.

If the prices received increased by $2.00/tray above the control prices used in the model farm, then a yield of 8 trays/tree would be required before the model farm was profitable. Such a yield represents a one-third reduction in the control yield used in the model farm. Similarly, an increase in both the first and second grade prices by $4.00/tray would require a yield of at least 8 trays/tree to be profitable.

Conclusion

The establishment cost of the model farm is $662 279. A payback period of 18 years is required to recover the initial project outlay. The peak overdraft, which occurs in the fifth year, is $765 930.

Mango production based on the model farm is profitable with farm profit figures equivalent to $0.79/tray equivalent/year, $6.69/tree/year or $33 581/farm/year. Included in the fixed costs is an allowance of $22 701/year for the owner/operator.

Based on the prices used for the model farm the minimum yield required to be profitable is 12 trays/tree. Similarly, based on the yield used for the model farm the minimum prices required to be profitable are $14.00/tray for first grade mangoes and $10.50/tray for second grade fruit.

Gross margin analysis

The income and expenditures are slightly different in the gross margin analysis to those shown in the discounted cash flow analysis due to some differences in the model farm used.

Assumptions

- The farm grows Kensington Pride mangoes with a planting density of 186 trees/ha.
- A yield of 12 tray equivalents per tree.
- Sales were divided into 60% sold in trays, 30% sold for slicing and 10% sold for juicing.

The gross margin for the model mango farm is shown in Table 6.

Table 6. Gross margin calculation

Item	Assumptions	TOTAL $ / ha
Income		
First grade mangoes	$14/tray x 60%	18,746.00
Slicing mangoes	$0.54/kg x 30%	2,531.09
Juicing mangoes	$0.34 x 10%	531.22
(a) Total income		**21,808.30**
Variable costs		
Slashing (fuel & oil)	8 x 0.5hrs/ha x $3.91/hr	15.64
Spraying (fuel & oil)	18 x 0.4hrs/ha x $5.57/hr	40.10
Hand pruning	1 x 55.8hrs/ha x $11/hr	613.80
Contract hedging	1 x 0.36hrs/ha x $200/hr	72.00
Fertiliser		583.28
Growth regulant		433.94
Herbicide		161.48
Insecticide		447.09
Fungicide		745.12
Irrigation & pumping*	5.5ML/ha @ $45.70/ML	251.35
Harvesting & marketing		11,582.96
(b) Total variable costs		**14,946.76**
GROSS MARGIN (a – b)		**6,861.54**

* The $/ML is different to the DCF analysis as it is looking at the eighth year only, and is not an average over the life of the orchard.

Results

Based on the assumptions listed, the gross margin for the model mango farm is about $6860/ha. This amount does not take into account fixed costs such as capital expenditure, electricity, administration, depreciation, etc.

Conclusions

Both the gross margin analysis and the discounted cash flow analysis suggest that growing mangoes can be profitable under good management. However, anyone thinking of investing in mangoes should undertake a detailed economic analysis.

Varieties

Hundreds of named mango varieties are grown throughout the world. India alone has more than 1000 of them. Mango varieties vary in colour, size, shape and flavour. Some are fibrous while others have no fibre. Some varieties are eaten green, and some are eaten green and as a ripe fruit. Choosing which variety to grow is one of the key decisions for a new grower.

The basis for selecting varieties

Selecting which variety to grow involves several considerations:

- The markets being targeted. Some varieties are more suited to processing, some to the fresh market and some are dual purpose. The choice will depend on where you intend to specialise. All markets, but particularly export markets, require fruit of high quality with good shelf life. There is no point in growing varieties targeted at the export market in areas where it is difficult to achieve fruit of high quality (for example wet coastal areas).
- The performance and suitability of the variety for the district. In cooler areas Kensington Pride may have fruit set problems. Wet windy weather leads to increased bacterial black spot, so avoid varieties such as Keitt.
- Management requirements. Nam Doc Mai is extremely susceptible to powdery mildew at flowering and needs constant monitoring and fungicide applications to achieve good fruit set.
- Variety opportunities. Late maturing and green-eating varieties can exploit niche markets.

Despite the large number of varieties available, most markets want only a few of the most well known varieties. The choice of variety to be grown depends most on the market strategy you will use. Most Australians prefer the flavour of Kensington Pride and other varieties in Australia are mainly used to extend the season.

New varieties are becoming available. These include B74 (to be named), Kensington Red, Honey Gold and Celebration. More new varieties are likely to be released from the DPI's mango breeding program by 2004. As mangoes can be topworked to a new variety, growers will be able to change the variety they grow if they can see an advantage for the change.

Table 7 shows the varying maturity times for three varieties grown in Queensland. Maturity times will vary a little each year.

Table 8 shows the harvest time for Kensington Pride in 12 Australian growing areas.

Table 7. *Approximate maturity times for three mango varieties*

Variety	Dry Tropics	Atherton Tableland	Central Queensland	Burnett	South Queensland
Kensington Pride (early)					
	November to late December	Mid December to late January	Late December to late January	Mid January to late February	Mid January to early March
R2E2 (mid)					
	Early December to early January	Late December to late February	Early to mid January to mid February	Late January to mid February	Mid to late February
Keitt (late)					
	Late January to early March	Mid February to early March	Mid February to early March	Early March to early May	Mid March to mid May

Table 8. Harvest time for Kensington Pride in 12 Australian growing areas

Area	Harvest time						
	September	October	November	December	January	February	March
Kununurra WA							
Darwin NT							
Katherine NT							
Dry Tropics Qld							
Broome WA							
Tableland Qld							
Carnarvon WA							
Central Qld							
Burnett Qld							
Southern Qld							
Northern NSW							
Gingin WA							

Irrigation management

Although mango trees can survive prolonged periods without water, water stress at critical times in the development of the crop can affect fruit yield and quality. Careful management of irrigation is important for good orchard performance.

Water requirements of mangoes

Water has several roles in the mango plant. It is part of the structure of the plant as well as providing a transport system for nutrients and plant products through the tree.

An understanding of the mango growth cycle is important when planning the irrigation program because the water requirement depends on the growth stage of the tree as well as the climate. Each growth stage has a specific need for water.

HINT

A pictorial representation of the timing of mango growth cycles is in the Crop production handy guide.

The root system of a mango tree has feeder roots and deeper taproots. The feeder roots extend around the tree to within 30 cm of the trunk and are usually active down to 80 cm. To get the best efficiency from the feeder root system, water must be supplied to all of this area of the soil. The taproots also supply water to the tree. They have been recorded accessing water more than 3 m deep.

Flowering and fruit set

The onset of flowering marks a rapid increase in the water needs of the tree. Large quantities of water are lost due to the large surface area of the flowers and the small fruit.

Water stress during flowering can result in poor flower development and will limit fruit set. Start watering when most floral buds have begun to grow. Water requirements fall slightly once flowering is completed.

Fruit development

As fruit develops, and with the onset of warmer weather, water requirements increase, reaching a peak three to four weeks before harvest. Yield will be lost if the tree's water requirements are not met. Water stress during fruit development results in increased premature fruit drop and reduced fruit size. The fruit will be more susceptible to disease, and have reduced shelf life and storage quality.

Any water stress during the last month of fruit development can increase the risk of sunburn. To overcome this, irrigation may be needed during the hottest part of the day.

Preharvest

Reducing irrigation before harvest helps to advance the maturity of the fruit and increase fruit dry matter content. Irrigation should be reduced one to two weeks before harvest; however, care is needed as reducing irrigation too much or too early may result in smaller fruit and increase the risk of fruit splitting if it rains during this period.

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Postharvest vegetative growth

Restart irrigation immediately after harvest to encourage early shoot growth. An early, consistent vegetative flush provides a new efficient canopy that enables the tree to increase its carbohydrate reserves. This results in a more uniform flowering response. Adequate irrigation (based on soil moisture monitoring systems) during this period will improve nutrient uptake and the effectiveness of growth regulators.

Dormancy

Withholding irrigation in the pre-flowering period helps to slow growth, forcing the tree into a dormant phase. Dormancy is important for flower induction as it allows the vegetative flush to mature in readiness for flowering. Cooler weather and low soil moisture usually bring on dormancy. Irrigation during this period can activate new vegetative growth that will not mature in time to flower, leading to a reduction in flowering.

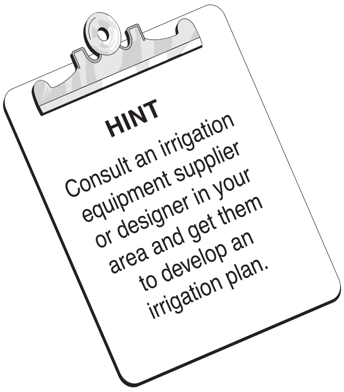
By withholding irrigation during this period you improve the floral induction stimulus, increase the number of terminals likely to flower and improve the final yield of the tree. Irrigation is normally withheld for up to two months after the postharvest flush has matured until flowering.

Irrigation essentials

A suitable water supply

A good water supply is essential. The water supply should have sufficient volume to be able to irrigate the whole farm with up to 280 000 L of water per hectare per week.

Water quality is also important. Water with more than 2 deciSiemens/metre salinity may cause leaf tipburning and a reduction in yield. Other water quality problems can include a high algal content or iron bacteria, which will require special filtering systems before the water is used for irrigation.



An effective irrigation system

The irrigation system should be capable of delivering the required amounts of water when needed.

Under-tree minisprinklers are best suited for mango irrigation because water can be kept off the foliage and cover the full root zone. During the first two years, place one minisprinkler beside each tree and set it in the micro-spray mode to limit the spread of water. Towards the end of the second year, change it to the minisprinkler mode to increase the diameter of watering and encourage the roots to spread.

A mature mango tree with a canopy diameter of 6 m will have a peak water demand of 1500 to 2000 L of water per tree per week. The irrigation system should be designed so that you are able to supply this quantity of water if required.

Irrigation scheduling

Deciding when to start watering and how much water to apply is referred to as irrigation scheduling. Scheduling methods include: measuring plant water status, meteorological methods (including pan evaporation), water budgeting, and soil water monitoring. Using these techniques is the only way you can be sure that your trees are adequately supplied with water.

Monitoring soil moisture maximises water use efficiency and provides environmental benefits by minimising leaching and runoff into the environment caused by overwatering.

Most of the feeder roots of the mango are in the top 80 cm of the soil, so soil moisture monitoring devices need to concentrate on this part of the soil profile.

A range of equipment and techniques is available for monitoring soil moisture. A brief comparison of the main systems is shown in Table 9. Consultants can help you set up a sound scheduling system.

Table 9. Comparison of main soil moisture monitoring systems

System	Advantages	Disadvantages
Tensiometers		
	Relatively cheap Easy to install Can be read by growers Allows continuous monitoring	Labour intensive to collect and record data Require regular maintenance Can be inaccurate in extremely wet or dry soil Less accurate in the top 10 cm of soil Not accurate in sandy soils
Capacitance probes		
e.g. Enviroscan, Gopher, Diviner	Continuous monitoring Accurate at all depths and for all soils Enables rapid reading and recording of results	Expensive Need skill in interpreting data
Neutron probe		
	Portable, can be moved around sites Very reliable and accurate	Not suitable for continuous monitoring Equipment is expensive and radioactive. Use a consultant who owns the equipment Less accurate in the top 10 cm of soil Less accurate in sandy soil because of low sampling frequency
Evaporation pan		
	No in-field measurement needed as system uses weather data to predict irrigation need	Requires a good understanding of soil characteristics and regular calculations Cannot assess the effectiveness of rainfall received Does not assess the effectiveness of the irrigation system
Soil moisture sensors		
e.g. gypsum blocks	Relatively cheap Easy to install Can be read by the grower Continuous monitoring possible	Labour intensive to collect the data Can be inaccurate in very wet or dry soil Less accurate in the top 10 cm of soil

Monitoring methods

Tensiometers

Tensiometers measure the force with which soil water is held within the soil. Irrigation is applied whenever the soil dries to a predetermined deficit level. Tensiometers are relatively inexpensive compared with probe systems such as the Enviroscan. Cheaper tensiometers can be made and used in conjunction with a Soilspec electronic vacuum gauge (cost $400). This gauge gives greater precision and is particularly economical if you want to use several tensiometers.

HINT

DPI has a useful booklet—Water it right: irrigation using tensiometers—that takes the worry out of scheduling irrigation. See the references in Section 6 page 24.

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 which reads water tension on a scale of 0 to 100 kPa (Figure 6). In saturated soil the vacuum gauge displays 0 kPa. As the soil dries over several days, water moves from inside the instrument, through the

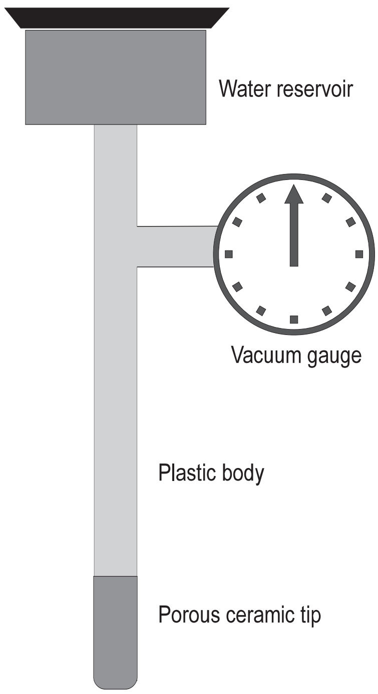


Figure 6. *Parts of a standard tensiometer*

porous ceramic tip, into the soil. The gauge reading steadily increases to a maximum of about 90 kPa. When the soil is re-wet after rain or irrigation, water moves from the soil back into the tensiometer and gauge readings fall.

Monitoring sites

Tensiometers are installed at monitoring sites throughout the orchard after trees are established. They are then left in place. Use at least one monitoring site for each variety or block. At each site, install two tensiometers. Put one 30 cm long tensiometer in the major root zone at a depth of about 15 to 20 cm and install one 90 cm long tensiometer about 80 cm deep. Place tensiometers on the north-eastern side of trees, inside the dripline in a position representative of where the soil is wetted. Placement of tensiometers is shown in Figure 7.

Installation

Assemble tensiometers and fill with good quality water to which algaecide has been added. Leave them to stand in a bucket of water at least overnight, but preferably for one to two days. The water does not need to be pre-boiled. Tensiometers are more reliable if an appropriate vacuum pump is used to remove any air. Top up the tensiometers with more water if necessary. They are now ready to install.

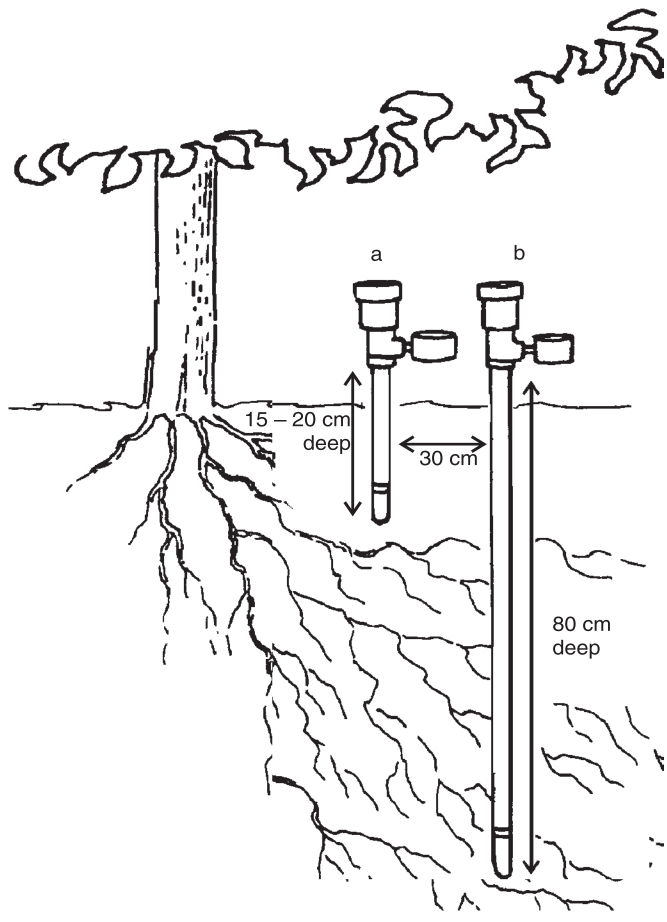


Figure 7. *Placement of shallow and deep tensiometers*

Carry the tensiometers to the installation site with the tips either in water or wrapped in wet rags. Provided the ground is moist and well cultivated, the shallow tensiometer can be pushed 15 to 20 cm deep into the soil. Don't push too hard. The tips are strong, but can crack under excessive pressure. Only experience teaches how hard is too hard. At $30 per tip, this can turn out to be an expensive lesson. If you reach a hard soil layer, take the tensiometer out and try somewhere else or use the deep tensiometer procedure.

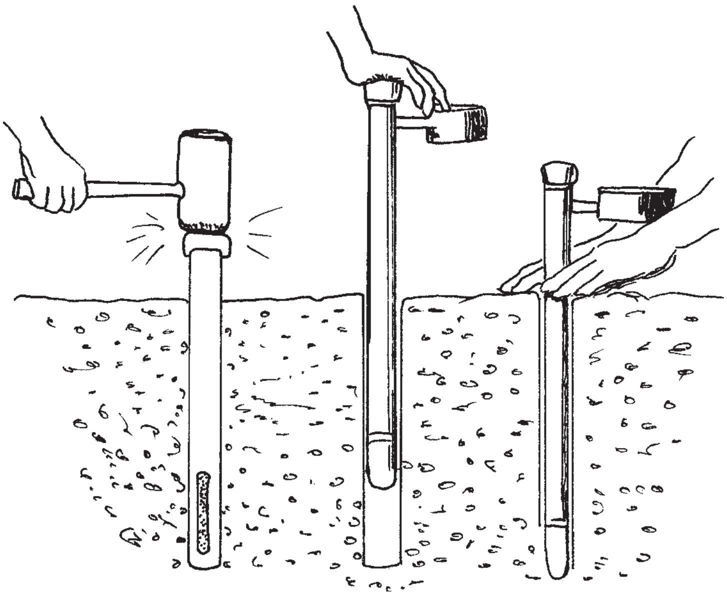


Figure 8. *Installing deep tensiometers*

To install the deep tensiometer, follow these instructions in conjunction with Figure 8. Make a hole to the required depth, keeping the excavated soil nearby in a pile. A 50 mm (2 inch) auger is the best tool. Place the tensiometer in the hole, over to one side. The next step is critical because good contact between the ceramic tip and the surrounding soil is important.

Take the most crumbly, moist soil from the dirt pile and pack it around the tip at the base of the hole. A piece of 10 to 15 mm diameter dowel is useful for packing. Don't over-compact the soil into plasticine, but remove any large air gaps. Continue replacing soil until the hole is filled. It doesn't matter which soil is used after you have packed the first 5 cm above the tip. Friable topsoil from a few metres away can be used to create a slight mound around the tensiometer. This minimises water draining down beside the tensiometer, leading to false readings.

Covers made from silver/blue insulation foil can be placed over the tensiometers to minimise temperature fluctuations and algal growth. The gauge can be left exposed for easy reading.

The tensiometers are now ready to operate. Use the vacuum pump to again remove air bubbles. Tensiometers may take a few irrigation cycles to settle, so don't take much notice of the readings for the first few days. During this period, air gaps may appear in the tensiometer. Simply refill with algaecide-treated water. Within a week of installation, readings should rise and fall with irrigation/rainfall.

Clearly mark tensiometer locations otherwise tractors and other equipment may damage them.

Reading

Read tensiometers before 8 a.m. Read at least twice a week but preferably every day or second day and at the same time of day. Lightly tap the gauge before reading.

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 20 kPa (in sandy soils) and 30 to 40 kPa (in loam and clay loam soils). Stop watering when the reading on the deep tensiometer falls to 10 kPa. Reposition tensiometers every second year in winter to the new dripline position. Once a week, use a vacuum pump to remove accumulated air and check the gauges are working. Refill tensiometers with clean water.

Troubleshooting tensiometer problems

No water in the tensiometer, gauge reads 0

There is a crack in the ceramic tip or a faulty seal. Fill the tensiometer with water and apply suction with a vacuum pump. A stream of large bubbles will indicate the problem area, usually a cracked tip or a missing o-ring.

Air entering over several days, gauge registering more than 5

There is 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, re-install it. 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 a vacuum pump
- removing the gauge, rinsing with clean water and sucking it. If the needle does not move, the gauge is faulty.

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 as if it had just been installed. If this happens frequently, consider whether you are under-irrigating. If you are happy with the irrigation rate, try installing the shallow tensiometer slightly deeper. This should never be a problem with the deep tensiometer

> **HINT**
> DPI has a useful booklet—*Water it right: irrigation using tensiometers—that takes the worry out of scheduling irrigation.* See the references in Section 6 page 24.

Soil moisture sensors

Soil moisture sensors consist of gypsum blocks buried in the soil at strategic points and allowed to assume the same moisture content as the surrounding soil. A pair of wires hooked to the blocks is left exposed at the soil surface and a digital ohmmeter is connected to take readings (Figure 9). The electrical resistance recorded by the ohmmeter is measured as water tension in centibars (cb) or kilopascals (kPa).

Monitoring sites for the blocks are set up in a similar manner to tensiometers. Two blocks are placed at each site: one about 15 cm deep and the other about 80 cm deep. Positioning of the blocks and installation in holes is also similar. Again there must be good contact between the blocks and the surrounding soil and the hole filled to the soil surface.

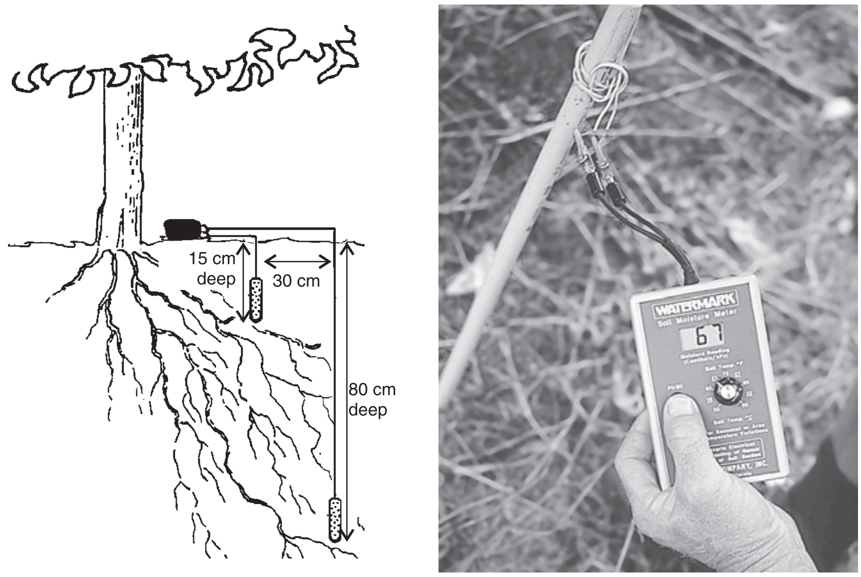


Figure 9. Gypsum blocks. Left: placement. Right: taking readings using an ohmmeter connected to the exposed wires

Irrigation is similar to that recommended for tensiometers because the gypsum blocks are recording the same soil tension readings. These blocks may need replacing in some soils about every three years.

The neutron probe

The neutron probe is a sophisticated device consisting of a probe containing a neutron source and a detector (Figure 10). Several access holes are set up in the orchard and the probe is brought to these sites at regular intervals. The probe is lowered into an access hole and neutrons from a radioactive source are emitted into the soil profile. When these fast neutrons collide with hydrogen atoms in water, they slow down dramatically and are deflected back to the detector, which only responds to slow neutrons. If the soil is dry, the neutrons do not slow down and are not detected. Readings are taken at various depths to provide an overall indication of soil moisture within the profile.

Figure 10. Neutron probe recording readings at a site

The probe is very expensive and is generally used only by consultants to monitor and provide recommendations for watering. Although readings are more accurate than those from tensiometers, its value is dependent on how regularly readings are made.

Capacitance probes

Capacitance probes, such as the Enviroscan (Figure 11), the Gopher and the Diviner, are continuous moisture monitoring devices based on capacitance sensors. The sensors are mounted on probes that have slots every 10 cm to accommodate the snap-in sensors. These probes are then placed within vertical PVC access tubes installed semi-permanently in the orchard. The probes are generally left in place for the season and then moved to another tube or site as required.

Sensors are positioned on the probes to provide readings at specific depths. Measurements from the sensors are relayed at regular intervals through a cable to a data logger, where they are recorded. Data from the logger are downloaded to a computer every few days to show water use and to provide recommendations for watering. Figure 11 shows the main components.

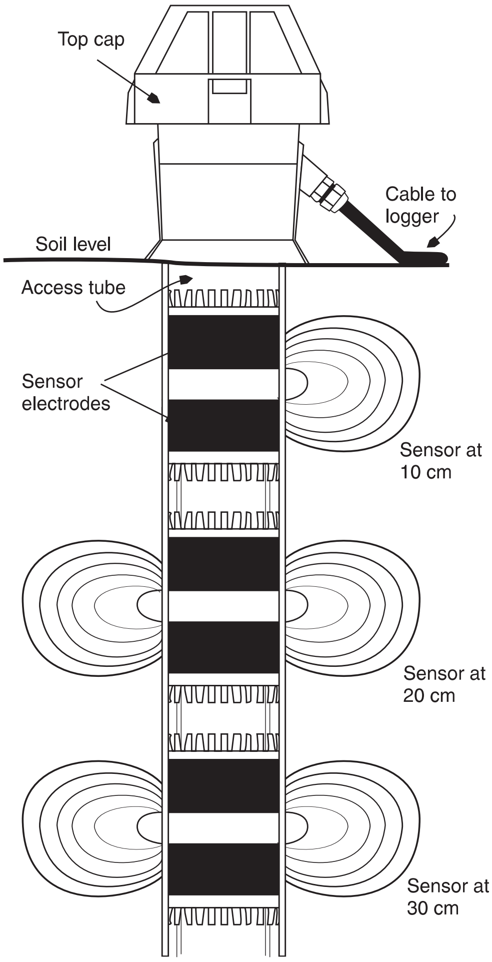


Figure 11. Diagrammatic representation of an Enviroscan probe

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Irrigation consultants
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Interpretation of the data requires skill. Consultants should be used to set up the system and provide at least the initial advice. Lightning strikes can be a problem with this equipment.

Evaporation pan

The evaporation pan technique uses evaporation figures from a pan evaporimeter at a weather station to calculate water requirements. The calculations are based on the fact that plant water use is directly related to evaporation. Evaporation figures are usually available from the Bureau of Meteorology.

These evaporation figures are then used to calculate how much water the trees have used by multiplying the evaporation figure with a crop factor. For mangoes this crop factor will vary, depending on growth stage of the tree. For mangoes this will vary between 0, when the tree is dormant, to 0.8, when the tree is at peak water demand. The result will give you a figure in millimetres of water used. You should then apply that amount of water to the trees. The timing and length of each irrigation will depend on your soil type. Ask local soil conservation officers for advice on the water holding characteristics of your soil. This calculation does not take into account water lost through runoff.

Nutrition

Good plant nutrition is one of the vital components of achieving good yields and fruit quality. Both deficiencies and excesses of plant nutrients can adversely affect fruit yield and quality. Fertiliser use has to be carefully managed to ensure a balanced supply of all nutrients is maintained.

Why nutrition needs to be carefully managed

The simple approach to fertilising mangoes involves applying fertiliser based on a recipe that states a certain number of grams per year of tree age or per metre of canopy area. This is a reasonable approach but without soil testing it can lead to excessively low or high levels of some nutrients. This can cause several problems that include:

- reduced yields from nutrient imbalance
- excessive vegetative flushing at the wrong time, reducing fruit quality
- lower fruit quality (green skin at ripe), jelly seed, internal breakdown) from nutrient imbalance
- contamination of the groundwater from excess nutrients being leached out of the root zone.

Nutrient levels in the soil and tree need to be carefully monitored to avoid these problems. Nutrient monitoring improves yield and fruit quality, reduces fertiliser costs and is kinder to the environment.

The managed approach—monitoring nutrients

Regular monitoring of soil and leaf nutrient levels will ensure that nutrient application is related to crop demand. Three monitoring tools are used:

- **Pre-plant soil analysis** ensures that soil nutrients are at required levels before planting. It is particularly important to allow for adjustment of insoluble nutrients such as phosphorus and calcium, which are difficult to adjust once trees are in the ground.
- **Annual leaf analysis in bearing trees** allows the fertiliser program to be fine-tuned each year to keep all nutrients within the optimum range. It allows variables such as the season, crop load and the condition of the tree to be taken into account.
- **Regular soil analysis in bearing trees** ensures that soil pH is kept within the desired range. It allows a watch to be kept on the important balance between pH, calcium, magnesium and potassium.

Leaf and soil analysis

Leaf and soil analysis (Figure 12) is best done in May to July before floral buds break. Buy leaf and soil sampling kits from the local farm supply store, follow the sampling instructions and send samples away for analysis. Leaf samples should be taken from the recently matured autumn flush on all sides of the tree.

Sample five to ten leaves from each of 10 to 20 trees. Do not sample leaves that have been sprayed with foliar nutrients. Sample each variety and block separately. Results of the analyses should be back in about two weeks. The laboratory will interpret the results and provide recommendations of appropriate fertilisers and rates to bring the nutrient levels within the optimum ranges. A guide to optimum leaf levels for healthy cropping trees is shown in Table 10.

Sample from under tree canopy, within the wetted area of the sprinkler, and no closer than 30 cm from the tree butt.

Sample to at least 30 cm or take two samples; the first, 0 – 15 cm and second, 15 – 30 cm.

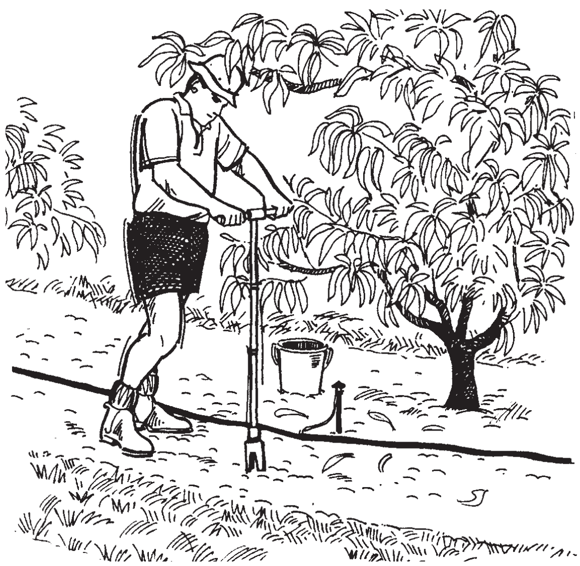

Figure 12. *Taking soil samples*

Table 10. Optimum leaf nutrient ranges for bearing mango trees

Nutrient	Optimum range
Nitrogen	1.0 – 1.5%
Phosphorus	0.08 – 0.18%
Potassium	0.3 – 1.2%
Calcium	2.0 – 3.5%
Magnesium	0.15 – 0.4%
Sulphur	0.2 – 0.6%
Iron	70 – 200 ppm
Manganese	60 – 500 ppm
Zinc	20 – 150 ppm
Copper	10 – 20 ppm
Boron	50 – 80 ppm
Sodium	<0.20%
Chloride	<0.25%

How to use leaf and soil analyses

Leaf and soil analyses taken only once have a limited value. Samples should be taken each year. The changes in soil and leaf nutrient levels from the previous year, and from the year before, are as important as the current levels. Any change that was made in the amount of fertiliser applied should be reflected in the changed levels of nutrients. The analyses will also indicate the amount of response in nutrient status from the change in fertiliser amount.

The adjustment technique

To make leaf and soil analysis information really useful, you must maintain and record a fertiliser program for several years. The program should have known rates of fertiliser and a set system of application times, because this technique is one of adjustment, up or down, based on long-term trends.

Changing the rate or timing constantly leaves no base line from which to adjust. The leaf and soil analysis indicates if the amount of fertiliser applied on a given block should be increased or decreased compared with the previous year. Without several years of records, the leaf and soil levels do not indicate the level of fertiliser to apply.

Recommendations based on one analysis are a good starting point but are only an educated guess based on local experience. They are not as good as the adjustment technique based on annual soil and leaf analysis and good records of fertiliser products, rates and timing.

Here is an example of the adjustment technique:

- In the past year you used 1.5 kg of potassium sulphate per tree and potassium leaf levels were 0.25%. You know you haven't used enough because the desired potassium leaf level is between 0.3 and 1.2% (Table 10). How much more potassium do you need?
- Until you have more experience with your soil types and climate, no exact amount can be recommended. The best approach is to

increase the application rate in the coming year by 20% to 1.8 kg of potassium sulphate per tree.

- If in the next year the leaf sample analysis is 0.3% potassium, you will know you are near the right level. You could then increase the rate by say a further 10% to 2 kg per tree in that year. If the leaf potassium level exceeds 1.2%, drop the application rate by 5%.

Monitoring the nutrient status of the orchard is a valuable decision aid for fertiliser management. The adjustment technique is most useful in helping to decide whether to change a fertiliser program and by how much. It is the only method of gaining a customised fertiliser management system for each mango orchard.

Despite the cost of the analysis, the potential savings in costs and gains in yield and fruit quality are great. The analyses provide valuable feedback to remedy nutrient deficiencies and imbalances before they become obvious.

Understanding the important nutrients

Nitrogen

more info

Nutrient symptoms
Problem solver

Nitrogen is one of the most important nutrients for mangoes and plays a significant part in determining their yield and fruit quality. It determines growth rates and tree size more than any other nutrient, but it is also a highly soluble nutrient that is easily leached from the soil. Because of its importance in fruit quality and tree growth, getting nitrogen rates right is one of the most critical operations.

Too much nitrogen can result in excessive vegetative growth, often at the expense of flowering, and poor fruit quality. This can include an increased susceptibility to internal disorders such as jelly seed, stem-end cavity and soft nose, green skin colour at ripe, soft fruit and an increased susceptibility to postharvest diseases.

Too little nitrogen reduces photosynthesis and leaf growth, causing reduced flowering and fruit set. A shortage of nitrogen decreases the plant's ability to trap energy, resulting in poorer flowering and reduced yield.

Apply nitrogen according to soil type, the wet season (leaching losses), and previous crop load. On sandy soils where nitrogen is leached readily with heavy irrigation or a good wet season, split the total application rate rather than add extra nitrogen. Total rates depend on tree size, previous crop load, and leaf and soil analysis.

Since nitrogen requirements vary, rates in any given year must be determined by either increasing or decreasing the previous year's rate, according to variations in leaf analysis, previous crop load and tree vigour. Keep good records of leaf and soil results and relate them to cropping levels.

Nitrogen is best absorbed in the ammonium form. It can be applied either on the ground by spreader or through the irrigation (fertigation).

Most nitrogen is applied after harvest to encourage the first postharvest flush. Additional nitrogen may be needed at flowering/early fruit growth if the tree is visibly yellow or leaf analysis results indicate a requirement. Do not add nitrogen too close to harvest because it will reduce fruit quality.

Potassium

Potassium plays an important role in photosynthesis and food production within the plant, in the enzyme action of the plant and in the plant's resistance to disease. It is closely associated with fruit quality, in particular skin colour, flavour and fruit size.

It also plays a role in the regulation of water within the plant cell and loss of water from leaves through transpiration.

Too little potassium can lead to a reduction in fruit size and quality. Too much potassium may cause imbalances in calcium and magnesium, as well as marginal and tipburn in older leaves.

Annual applications of potassium fertiliser are generally required, with most being applied in the spring during fruit development. The remainder should be applied during the postharvest vegetative flush. Potassium is better used if it is applied frequently.

Leaf analysis is vital for managing this nutrient. Rates should be based on the previous year's crop load, tree size and the fertiliser history of the orchard. Best results with potassium are achieved with soil applications. Evidence suggests the sulphate form will assist the tree to produce firmer fruit of higher quality than the muriate form. Avoid using the muriate form where salinity may be a problem.

Phosphorus

Mangoes, like most tree crops, have a low requirement for phosphorus, particularly in the sandy loam soils where most Queensland mangoes are grown. As phosphorus is readily available in these soils, deficiencies are rare.

Phosphorus is necessary for cell division and growth within the plant. It is of special importance in root development, inflorescence length, flower duration, fruit ripening and leaf size. Leaf size can be reduced if phosphorus is not replenished or is in a form that the plant cannot use. Large, healthy leaves produce more starch and sugars for fruit development than leaves that are stunted from deficiencies.

Phosphorus doesn't move readily through the soil and is best applied once a year immediately before the postharvest vegetative flush. The rate should be based on the results of soil analysis and the previous year's crop load.

Calcium

Calcium, along with nitrogen, is an important nutrient for mangoes. Calcium plays a key role in cell development within the tree and the fruit. It affects the firmness and shelf life of the fruit, as well as fruit ripening.

Low calcium levels can result in a shorter shelf life and the fruit can take longer to ripen and change colour. Low calcium levels are believed to be associated with jelly seed (break down of the flesh of ripening mangoes), soft nose and internal breakdown of Keitt.

Calcium needs to be available when the plant is actively growing, as it is not readily translocated once it is taken into the plant The critical periods for the uptake of calcium are during the postharvest flush and early fruit development. Calcium must be available in the root zone during these periods.

Calcium is best absorbed through the root system. Foliar calcium applications to leaves or fruit have not been effective in increasing fruit levels or improving fruit quality.

Sometimes, even with sufficient calcium in the soil, it may not get into the fruit. If the tree is vigorous, calcium can be directed into leaves rather than fruit. A big crop load can assist in calcium uptake by directing more of the calcium into the fruit rather than the leaves.

Calcium should be applied as part of a managed fertiliser program because too much calcium can reduce the uptake of magnesium and potassium, thus reducing fruit quality.

The rate of calcium will depend on soil type, pH and leaf and soil analysis. If the pH is below 5.0, apply calcium in the form of lime or dolomite. If the pH is above 5.5, use gypsum.

Calcium is easily leached from sandy soils. It should be applied as a split application once during the postharvest flush and again before flowering. In heavier soils, calcium can be applied once a year during the postharvest flush.

Magnesium

Although magnesium is not required in large amounts, it is an important nutrient in developing the green pigment (chlorophyll) in leaves and ensuring effective photosynthesis. Magnesium is the only mineral constituent of chlorophyll and deficiency symptoms show as pale green or yellow inter-veinal areas that first develop on the older leaves.

Magnesium has a key role in the transportation of phosphorus throughout the plant. It can be easily displaced with high rates of calcium and potassium.

It is best monitored by leaf and soil analysis and corrective action applied only where results indicate a need. An annual maintenance of 500 g of magnesium sulphate per tree should be adequate where leaf levels are optimum. Where the pH of the soil needs to be raised, dolomite can be used to apply both magnesium and calcium.

Trace elements (micronutrients)

Boron

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Nutrient symptoms
Problem solver

Boron is important for pollination and fruit development and is essential for the uptake and use of calcium. Like calcium, it has an important role in cell wall strength.

Boron does not easily re-translocate within the tree. There must be a ready supply available from the soil. If required, foliar sprays can be effectively applied during flowering.

Deficiencies in boron result in poor flowering and pollination, and reduced fruit size. New leaves are lop-sided, with a shot hole effect, and the holes are surrounded by a light green halo. Edges of leaves are ragged. Inflorescences have a characteristic bend or kink in the tip. In extreme cases, bark cracking and gummosis (oozing of black gummy sap from the cracks) will occur.

The most susceptible varieties grown in Queensland are the green eating type Keow Savoey, and R2E2. Deficiency symptoms are most evident at flowering, with affected trees producing distorted inflorescences. Boron deficiency is most commonly seen on the sandy granite soils in the Mareeba area.

Extreme care needs to be taken with the rate of boron applied, as the range between deficient and toxic levels is narrow. Boron toxicity often results in marginal leaf burn associated with leaf drop, sometimes for several vegetative flushes.

Boron is best applied as split applications during new shoot growth and before or at flowering. Use leaf analysis to monitor levels and back this up with soil analysis about every second year. Boron is best applied to the soil.

For mature bearing trees, apply boron evenly under the canopy after harvest and at budbreak. In sandy soils, apply boron up to four times a year.

Zinc

Zinc is associated with iron and manganese in the formation of chlorophyll and is essential for protein synthesis. It is part of the auxins, the compounds that regulate the plant's growth and development. Zinc also plays a regulatory role in the intake and efficient use of water by plants.

Symptoms of zinc deficiency include retarded terminal growth, small, sometimes curved leaves on new vegetative flush and an irregular mottling pattern on the leaves.

Both leaf and soil analysis is necessary to determine zinc requirements. If levels of zinc in the leaf are below optimum, two foliar applications should be made on the new flushes in January and February.

Iron

more info

Nutrient symptoms
Problem solver

Iron is essential for chlorophyll formation, though it is not a constituent of chlorophyll. The amount of chlorophyll is apparently related to the readily soluble iron content in the plant. Iron is also part of the oxidation process that releases energy from sugars and starches, and reactions that convert nitrate to ammonia in the plant.

In the early stages of deficiency the entire young leaf blade is a yellowish-green. As the deficiency progresses, the new leaves stop growing and the stem dies back. In severe cases, branches gradually die back and the tree may die.

Use leaf analysis to monitor iron levels. If levels are below optimum, apply a 2% iron solution as a foliar spray.

Crop nutrient removal

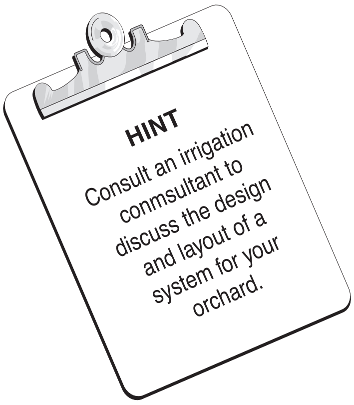
Another guide to the fertiliser needs of the tree is calculating the amount of nutrients removed by the crop.

The mango tree uses fertiliser in several ways. Nutrients are used for new vegetative growth, root development and fruit growth. Nutrients are lost from the tree through the harvesting of fruit (fruit removal), pruning and leaching (from leaves). Fruit removal accounts for a substantial proportion of the loss of fertiliser. Table 11 shows the amount of nutrients removed from a tree yielding 200 kg of fruit.

Table 11. *Nutrients removed for each 200 kg of fruit*

Nutrient	Amount removed (g)	Fertiliser equivalent
Nitrogen	169	367 g urea
Phosphorus	36	400 g superphosphate
Potassium	257	626 g potassium sulphate
Calcium	230	621 g lime
Magnesium	48	100 g Granomag®
Boron	0.4	2 g Solubor®
Zinc	0.4	1 g zinc sulphate
Iron	1.2	6 g iron sulphate

These figures indicate how much of each nutrient is removed during the harvest, not nutrient losses from leaching, pruning and vegetative growth. These losses need to be considered when calculating the amount of fertiliser to be applied.



Application methods

Fertigation

Fertigation relies on a well-designed irrigation system to deliver an equal quantity of water and fertiliser to each tree. It is an efficient method, which can be used with readily soluble fertilisers. A good injection system and a good supply of quality water are essential for best results.

Foliar application

Nutrients can also be applied as a foliar spray, but the absorption rate can be poor because of the thick, waxy-covered cuticle on leaves and fruit. Young, soft growth without the thick cuticle will absorb foliar-applied nutrients better than older leaves.

Sometimes, nutrients applied to older leaves will be absorbed into the wax layer and can show up as a contaminant in leaf analysis results (for example, manganese from the application of mancozeb). This can result in some leaf levels being incorrect.

It is easy to burn fruit and leaves if incorrect rates are applied. As a general, rule 1% (10 g/L of spray) is the maximum safe concentration of any nutrient.

If you are unsure, spray a small quantity of the nutrient mixture on a few trees to check that no damage occurs. Also check the compatibility of the foliar spray with other chemicals being applied in a tank mix. Ideally, foliar fertilisers should be applied alone.

Orchard rejuvenation

Tree pruning is an important crop management operation in mangoes because it plays a major role in determining production and fruit quality.

Rejuvenation of old orchards

Large, old trees are too high for easy harvesting. Productivity is low and fruit quality is reduced by excessive skin blemish from scratch marks and an increase in diseases.

There are two main approaches to rejuvenating old orchards: skeletonising and stumping.

Skeletonising

Skeletonising brings large, old trees back to a manageable height of 4.5 m by removing the tall central branches and reducing the length of side branches. This operation is best carried out in stages, allowing one or two branches to remain for a period to shade the newly-exposed bark of branches that if not protected may sunburn (Figure 13).

1. Stand back and observe the tree's profile to identify the point of cutting. Branching usually emerges from distinct whorls and a suitable height for cutting can be selected.
2. Cut back the tall branches to a point where there is evidence of strong side branching 3 to 4 m from the ground and reduce the spread of side branches to encourage new shoot development.
3. After this initial pruning, apply a white water-based or plastic paint to exposed branches to prevent sunburning.
4. Selectively thin and prune the new shoots that grow following pruning. The selected branches should be growing sideways and upwards, at about a 45° angle.
5. Every second flush should be pruned and only two shoots retained. Repeat this process until the tree settles into a regular bearing habit.

There will be some reduction in yield for one to two years though improved fruit quality will partly compensate.

Figure 13. Skeletonising old trees

Stumping

With stumping, all major branches are removed and the tree is brought back to a 1 to 1.5 m stump (Figure 14).

1. Cut off the entire tree about 1 to 1.5 m above ground and let new shoots grow from the stump. This growth will emerge more rapidly if the original tree was low branching and two or three branches were cut.
2. Thin the new shoot growth to leave four or five main branches on each stump. The selected branches will grow strongly and will need regular pruning to keep the canopy framework fairly open.
3. At least one of the retained shoots should be located close to the top of the stump as this will encourage callous tissue to grow rapidly over the old saw cut. The remaining branches should be spaced equidistant around the butt of the trunk.
4. The distance between nodes (flushes) will be much greater than normal for the first year or so of growth. Prune this new growth, leaving no more than two flushes. Repeat this process until you achieve a good, low-set framework for the tree.

Cropping will be reduced until about the third year, but fruit quality will be greatly enhanced. Good quality fruit will be harvested two to three years after stumping.

Figure 14. Trees with all major branches removed and brought back to a 1 to 1.5 m stump

Topworking

Trees can be topworked to change the original variety over to a new one when the original tree has been stumped. Two to four shoots are selected in a similar manner to those chosen in the stumping technique and the excess shoots removed. The selected shoots are then grafted over to the new variety. Look after these new shoots as you would severely pruned trees.

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Pruning
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Important points about topworking

Cut back whole sections, not alternate trees

When you decide to rejuvenate or topwork an orchard, it is better to topwork the whole orchard or whole blocks at once. Avoid topworking alternate trees.

If you cut back in blocks, you retain uniformity in that block. If you cut back alternate trees, there is too much competition for light between the pruned and remaining trees. The regrowth from pruned trees will grow vertically and will be hard to maintain at a manageable height. Spraying the orchard becomes more difficult because the height of spray applications will have to be continually changed.

If you want to continue some production from the orchard, it is best to rejuvenate the orchard in sections over a number of years so that there are always mature, cropping trees in the orchard.

Cut back to the main trunk

You will get better results and have greater control of new growth if the tree is cut back to the main trunk and grafting confined to new shoots. The retention of one small 'nurse' branch until after the new grafts have taken usually improves the grafting success. However, it should be removed once new grafts begin to grow. If several branches are left on the tree, most of the nutrients will go to these branches and the new grafts will take longer to establish. The production of new side shoots will also be slower.

Prevent sunburn

When a tree is cut back, the exposed branches can become sunburnt. Sunburn damage on the branches rarely heals and rots usually develop in the damaged area. Paint the upper side of exposed branches with white water-based or plastic paint immediately pruning is finished (Figure 15).

Figure 15. *Trees that have been recently topworked, with the new grafts starting to shoot. Exposed branches are painted white to minimise sunburn*

Control shoot growth

Shoot growth is always prolific and vigorous after heavy pruning. If this growth is not controlled, the canopy will become dense and little advantage will be gained from the pruning.

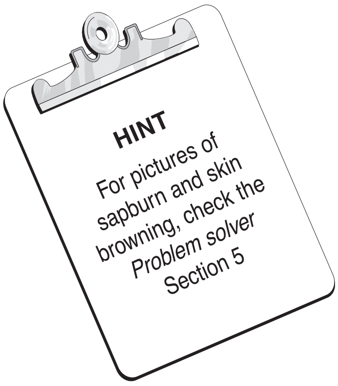
Improved yields

Yield will be reduced for the first three to four years, except where trees are only lightly pruned. Severely pruned or regrafted trees may take up to three years before commercially acceptable yields are attained. The wait is worthwhile because of the good sized, high quality fruit that develops.

Preventing sapburn and skin browning

Sapburn and skin browning are major quality problems for mangoes. To ensure the maximum possible returns for fruit, pay careful attention to every part of the harvesting and handling system.

The problem



Mango fruit spurt a highly caustic sap when the stem is first removed from the fruit. The sap then continues to exude from the stem for up to two hours. These are referred to as spurt sap and ooze sap.

Sapburn symptoms range from small, dark spots to large, dark, sunken blotches. Sapburn is caused by contact with spurt sap.

Skin browning refers to other types of skin damage. It can be caused when sap collects in picking crates, on equipment or in dip tanks and is allowed to remain on the skin. Skin browning can also be caused by fruit sitting in water and detergent, scalding by hot air or water, and rough handling.

The damage from sapburn and skin browning is not visible immediately and symptoms develop one to two days after injury. This can make diagnosis of the cause of the damage difficult. If fruit show signs of damage, examine all aspects of the handling system from picking to dispatch to identify potential risk areas. Skin browning can occur in any handling system.

Characteristics of mango sap

Mango sap consists of two distinct components: an oil portion and a latex (protein-sugar) portion. The oil portion is the main cause of sapburn.

Sap composition varies among varieties. The sap oil of Kensington Pride mangoes contains two major monoterpenes (terpinolene and carene) as well as several minor monoterpenes, and alkyl resorcinol

{5-(12-heptadecenyl) resorcinol}. If terpinolene and alkyl resorcinol are applied separately, they will cause sapburn and skin browning. For the variety Keitt, carene is the main monoterpene and Keitt experiences few problems with skin browning.

Sap volume and the percentage of oil in the sap decreases rapidly with time after destemming. The high oil content in the spurt sap decreases after the first five seconds. The initial spurt sap contains about 50% oil, which drops to 3% after 90 seconds. Sap may continue to ooze from the fruit for up to two hours, but the total amount of sap is reduced if destemming the fruit after harvest is delayed.

The volume and composition of sap in the fruit is also influenced by fruit maturity. Both sap volume and the oil levels reduce as the fruit matures. Rain increases the sap volume as well as creating greater pressure in the fruit, causing the sap to spurt more when the stem is removed.

Types and causes of skin browning

Skin browning refers to several different skin blemishes that appear on mangoes during postharvest handling and marketing. They all cause brown markings on the skin. There are seven categories of skin browning based on the type of cell damage. Descriptions of each type of browning, together with the major causes, are described below.

Etch

Etch appears as light to dark brown flecking in distinct areas on the skin or over the entire surface. The flecking pattern can easily be seen using a hand lens. Etch is usually associated with some form of lenticel damage. Despite this, lenticel damage is not a clear indicator of etch.

The major causes of etch are sap or detergents. It occurs when:

- fruit stays wet with low oil content sap (ooze sap). Contact for more than one hour will usually cause damage.
- fruit stays wet with detergent/wetting agent solution. Contact for more than four hours will usually cause damage. Incidence varies with the type of solution and fruit susceptibility.

Smear, blotch and spot

The cellular damage in smear, blotch and spot is identical, though their appearance and severity can vary.

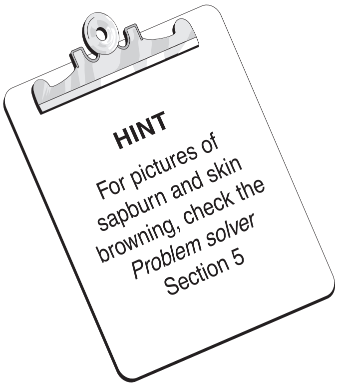
Smear appears as uniform, dark brown areas on the skin. Damage is usually irregular but can be in streaks or rings. Smear can be distinguished from etch in that smear injury has a uniform appearance with distinct margins. In severe cases, smear can resemble sapburn injury.

Blotch appears as numerous, light brown, irregular blotches over the skin. Damage is much lighter than smear and has less distinct margins.

Spot appears as numerous, uniform, light brown spots over the skin, usually 1 to 3 mm in diameter. It is similar to smear, with the size and shape of the discolouration being the main distinguishing characteristic.

The major causes of smear, blotch and spot are sap or long dip times. Damage occurs when:

- sap with a high oil content (spurt sap) stays wet on the fruit.
- a detergent is present with the sap, with contact times as short as one to five minutes.
- fruit is left in dips for longer than 20 minutes.



Abrasion

Abrasion appears as fine brown scratches on the skin, sometimes in conjunction with smear. The risk of browning damage from abrasion increases during wet weather.

The major causes of abrasion are physical damage from:

- rough handling
- abrasive surfaces and dirty equipment
- worn brushes
- vibration during transport from the paddock to the packing shed or from the packing shed to market.

Scald

Scald appears as brown or grey discoloured areas anywhere on the fruit surface. Irregular sunken areas can develop in severe cases. A halo of undamaged tissue is usually visible around the lenticels.

In severe cases, scald can be difficult to distinguish from extensive sapburn. A suppression of the degreening process is sometimes associated with the damage.

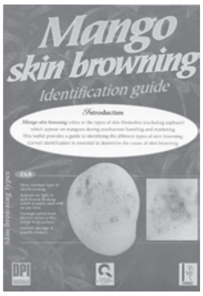
The major cause of scald is heat when:

- fruit is treated above 52°C in hot dips and in heated drying tunnels and fruit picked during wet weather is damaged at lower temperatures
- heat treatment is applied within four hours of picking.

Resin canal

Resin canal appears as a dark grey or dark brown discolouration in a finely branched pattern, similar to ‘chickens feet’. It usually develops on the mid-region or nose of the fruit. Resin canal is the only type of skin browning that also causes a discolouration of fibres in the flesh under the skin.

The cause of this type of damage is unknown.



Solving skin browning

If skin browning is a problem, first identify the type of skin browning on the fruit. A *Mango Skin Browning Identification Guide* (left), provides colour photographs and detailed descriptions of the different types of skin browning. Identification will help you pinpoint where damage occurred in the handling system.

Check every step in the handling system for possible causes of skin damage and make sure staff are trained to handle fruit gently.

A DPI brochure, *Mango Skin Browning* (left), outlines the causes of skin browning. It shows where skin browning might occur in handling systems and details preventative measures for the various mango-handling systems.

Checklist to minimise skin browning

Several danger areas in the mango postharvest handling system require particular attention to avoid skin browning.

In the orchard, check for:

- ❑ Sap build-up in dips and recirculating sprays on harvest aids
- ❑ Throwing or dropping fruit on the trampoline from a long distance
- ❑ Sap and dirt collecting on tarpaulins, rollers and belts
- ❑ Fruit staying wet with sap or detergent in crates and bins, particularly at contact points
- ❑ Sap contacting the skin after destemming that is not washed off
- ❑ Fruit left in dips for longer than 20 minutes
- ❑ Sap on pickers hands
- ❑ Unpadded hard surfaces in bins and on harvest aids

During transport to the packing shed, check for:

- ❑ Dirt and sap in picking crates and bins
- ❑ Fruit bumping and rubbing from rough transport

While destemming to racks or dips, check for:

- ❑ Sap on hands or gloves of destemmers
- ❑ Sap contacting mangoes after destemming that is not washed off
- ❑ Sap build-up in detergent/wetting agent solutions
- ❑ Sap collecting on racks
- ❑ Sap build-up in the dip tank
- ❑ Fruit placed on the packing line with sap still flowing freely from the stem

- ❑ Fruit left in the dip tank for longer than 20 minutes
- ❑ Fruit staying wet with sap or detergent after removal from dip

On the packing line, check for:

- ❑ Sap and dirt collecting on brushes, rollers, belts, cups, packing bins
- ❑ Worn or coarse brushes
- ❑ Temperature too high in hot dips and heated drying tunnels
- ❑ Brushing for longer than one minute
- ❑ Large drops to hard or abrasive surfaces
- ❑ Hot spots in dip tanks from poor agitation or equipment design
- ❑ Heat treatment applied within four hours of picking
- ❑ Packing fruit still wet with sap, detergent, fungicide or insecticide

During transport to the markets and marketing, check for:

- ❑ Rubbing due to loose packing
- ❑ Ooze sap remaining wet on fruit in plastic inserts when placed in cool storage
- ❑ Storage at 10° to 13°C may accentuate prior damage or lead to the expression of damage not visible

Controlled ripening

Most retail buyers want to buy mangoes close to eating ripe, as their customers want fruit that they can eat immediately. Fruit may need to be ripened on-farm or at the market before sale to provide retailers with the type of fruit they want.

About controlled ripening

Controlled ripening is used for several fruits including avocados, bananas, papaws and tomatoes. It involves surrounding the fruit with ethylene gas. Fruit produces ethylene gas naturally, but extra gas will speed the process and ripening will be more uniform.

Mangoes must be mature when picked to ensure they ripen to a saleable quality. Immature mangoes will not ripen even when surrounded by ethylene. The flesh will soften but skin colour and flavour will not develop normally. For mature fruit, 24 hours surrounded by ethylene gas is enough to trigger the ripening process.

Successful control of ripening relies on good temperature management, control of humidity and control of ethylene levels. If ripening is triggered on farm, fruit must be transported at 18° to 20°C so that it can continue to ripen during transport. Ripening fruit is not suitable for long distance road or rail transport. Controlled ripening by wholesale agents provides more flexibility than on-farm ripening as fruit can be ripened to meet buyer demand.

Correct ripening temperatures are critical for success. The higher the temperature, the faster fruit ripens. Mangoes ripen best between 18° and 22°C. Below 18°C ripening is slow and flavour development is poor. Above 22°C the flesh softens as the fruit ripens but the skin does not colour properly. It becomes motley green and yellow and rots develop more quickly. Control of humidity is also essential as humidity below 85% causes fruit to lose moisture and shrivel in storage.

Two gases can be used in ripening rooms: pure ethylene and Ripegas®, which is a mixture of ethylene and carbon dioxide. Ripegas® contains

9% by volume ethylene. It is safer than ethylene, which is explosive at high concentrations or if exposed to naked flames or sparks. About 10 times more volume of Ripegas® will be needed than ethylene.

Requirements for ripening systems

Ripening rooms are specially designed to contain the ethylene gas, but cool rooms can be modified to work as ripening rooms. The essential requirements of an ethylene ripening system are:

- reasonably airtight room with insulation
- temperature control system for cooling and/or heating
- air circulation and ventilation system
- humidity control
- ethylene gas injection system
- electrical control circuit.

Room construction and insulation

The main requirements are reasonable airtightness, except for the ventilation ports in a trickle system, and structural strength. An airtight door seal of soft rubber, plastic or other material is also required. Most cool rooms are suitable for ripening.

Temperature control system

The temperature of the ripening room must be maintained within the recommended range for successful operation. Fruit may be at a higher or lower temperature when it is placed inside and the ripening room must have the cooling and heating capacity to bring fruit to the recommended temperature within 12 hours. Conventional refrigeration equipment with a forced-draught cooling (FDC) unit designed to operate at 85 to 95% relative humidity is suitable.

Air circulation and ventilation system

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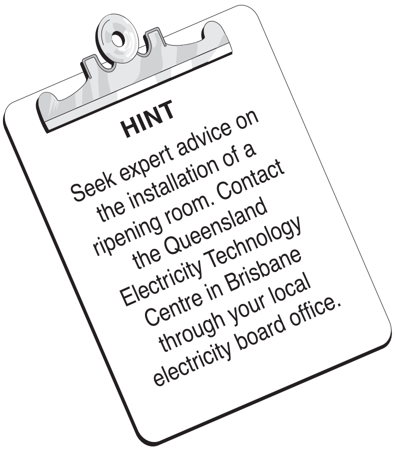
The fan in the forced draught cooling unit must provide an airflow rate of at least one room air volume per minute for adequate air circulation. This airflow rate distributes ethylene gas evenly throughout the room. To achieve uniform ripening of pallet loads, use a forced-air system as described in *Growing the crop*, Section 3. During ripening, the air volume through the stack of fruit is reduced to about one-third of that required for forced-draught cooling.

Humidity control

The relative humidity in ripening rooms should be maintained at about 85 to 95% to minimise moisture loss from the fruit. The refrigeration system can be designed to provide the correct humidity or steam or a fine water spray into the room will also work.



Safety

Ethylene gas is explosive at high concentrations or if exposed to naked flames or sparks. The minimum flammable concentration of ethylene (3.1% or 31 000 ppm) is more than 6000 times the concentration suggested for ripening of most fruits.

However, compressed cylinders of ethylene or any gas are potential hazards if handled improperly. Handle ethylene gas cylinders carefully and store in a dry, well-ventilated and shaded place. All electrical fittings in a gas room should be spark-proof and safety vents should be fitted.

Ethylene injection systems

Two main methods are used to inject ethylene gas into the ripening room: the 'shot' system or the 'trickle' system. The two systems differ in the way that ethylene is injected and how fresh air is ventilated.

Shot system

With the shot system, ethylene is injected at 100 to 200 ppm at 12-hour intervals. If single shot ethylene injection is used, the ripening room needs to be airtight to prevent the loss of ethylene gas. The room must be ventilated for five to ten minutes before each shot to clear the room of carbon dioxide that accumulates from fruit respiration. High levels of carbon dioxide will slow ripening and can affect fruit.

After triggering with ethylene for 24 hours, mangoes held at 18° to 22°C will ripen in five to nine days, depending on fruit maturity. Flesh will start to soften and skin to colour after one to three days. The fruit then takes another four to six days to reach eating-ripe and develop a full yellow skin.

Calculating ethylene volumes

Ethylene is metered from the cylinder through a calibrated flow meter equipped with a 'dead man valve'. This is a spring-loaded, push button valve, which is held down to inject ethylene. The gauge is calibrated in litres/minute. A flow volume and injection time is selected to achieve the desired concentration of ethylene.

Example calculation

A 3 m x 3 m x 3 m room with a volume of 27 cu metres holds 27 000 L of air.

To achieve an ethylene concentration of 200 ppm, you need to inject 1 L of ethylene gas for every 5000 L of air, that is, you need to inject 5.4 L of ethylene (27 000 ÷ 5000).

If, for example, the ethylene gauge is set at 10.8 L/minute, hold the valve down for 30 seconds to inject the required 5.4 L of ethylene.

Trickle system

Trickle ethylene injection is the most commonly used ripening system. The trickle system involves injecting a continuous flow of ethylene into the room to maintain a concentration of 10 ppm (10 mg/L). Fresh air is continually drawn into the room at a rate of 1% of the room volume per minute to expel stale air containing carbon dioxide. This prevents the build-up of ethylene gas and carbon dioxide gas produced by the fruit. Air circulation fans must run continuously with the trickle system.

The main advantages of the trickle system are:

- The door may be opened at any time to load or unload fruit from the room. Opening the door will allow ethylene to escape but this will build up again rapidly. In view of this loss, it is advisable to open the door only when necessary.
- The room does not have to be aired and re-gassed every 12 hours.
- The system maintains a flow of outside air through the room, which ensures that carbon dioxide does not build up.
- Active levels of ethylene will be present whenever the room is in operation, unlike leaky rooms used for the shot system.

Equipment

- ethylene bottle with a pressure regulator
- solenoid valve
- needle valve to adjust ethylene flow
- bubble sight jar, thick walled, clear glass
- clamp comprising four bolts, a metal base and a lid with a soft rubber seal
- copper pipe, preferably 6 mm outside diameter.

A typical design for a trickle ethylene ripening room with facility for forced-air ripening is shown in Figure 16. For large rooms (250 cubic metre volume or greater), 150 mm diameter tubes should be used.

Installation

An inlet port (100 mm diameter PVC tube) is positioned behind the cooling unit (on the upstream side of the fan) to generate a fresh air intake of 1% of the room volume per minute.

An outlet port of similar diameter should be fixed in the wall opposite the inlet port to expel stale air containing carbon dioxide. This prevents the build-up of ethylene gas and carbon dioxide gas produced by the fruit. For large rooms (250 cubic metre volume or greater), 150 mm diameter tubes should be used.

Air circulation fans must run continuously during trickle ripening.

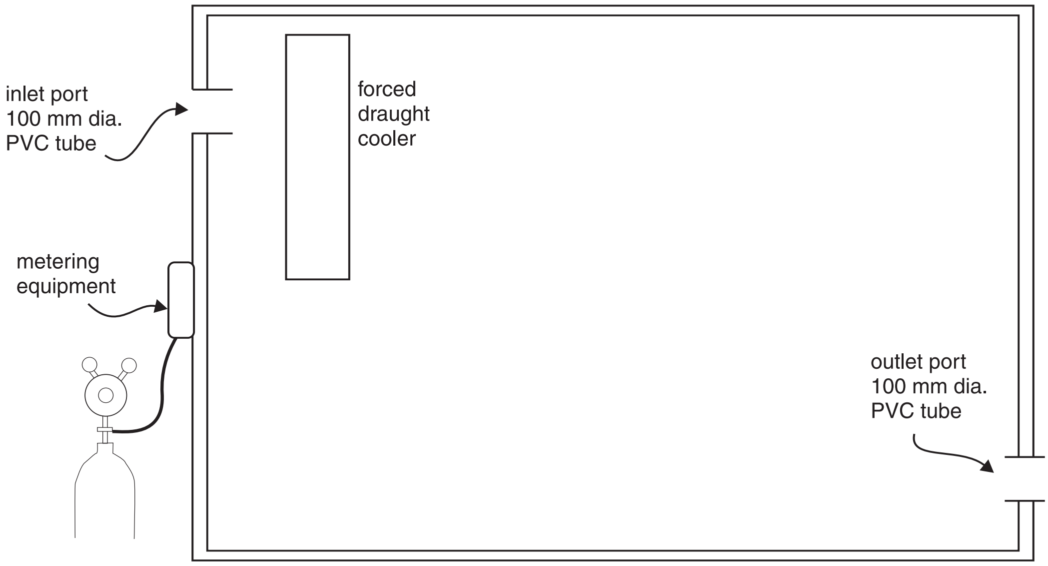


Figure 16. Diagrammatic outline of a ripening room

Metering ethylene in trickle systems

Ethylene metering for the trickle system is more complex than for the single shot system and requires a solenoid valve to shut off the system in case of power failure. Gas is released into the room at a controlled rate of flow through a pressure regulator and meter (Figure 17).

The outlet gas pressure is adjusted by the gas regulator and the gas flow rate is adjusted by a fine needle valve. The flow rate is dependent on the outlet pressure and the adjustment of the needle valve. Very small flow rates of ethylene gas are required so the needle valve must be capable of fine adjustment of the flow rate. A low gas outlet pressure from the regulator makes adjustment of the flow rate easier.

A locked cover should enclose the ethylene gas pressure regulator and needle valve so that unauthorised people cannot alter the settings.

The flow rate of ethylene gas is calibrated by bubbling gas into the jar and calculating the volume of gas in each bubble. By counting the number of bubbles and adjusting the needle valve, the number of bubbles per minute can be altered to maintain the correct ethylene concentration into the room.

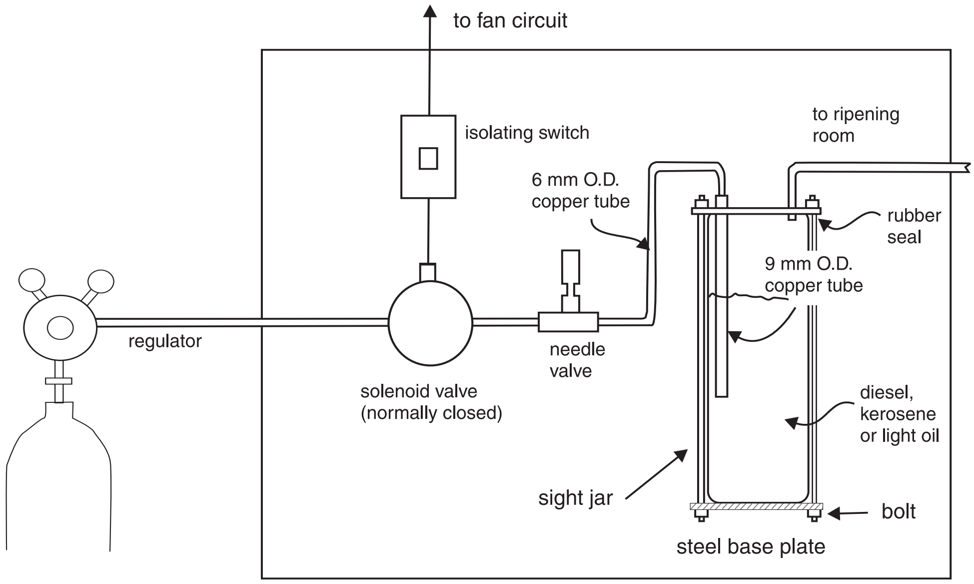


Figure 17. *Basic ethylene injection equipment and set-up for a trickle ethylene ripening room*

Operating a trickle system

1. Set the thermostat to 18° to 22°C.
2. Adjust the humidifier to 90% relative humidity.
3. Load the room with fruit, as for a normal operation, and switch on the fan.
4. Adjust the fresh air intake and exhaust air vents to give a fresh air intake of 1% of the room air volume per minute.

For 1% fresh air per minute:

Required fresh air intake (cu m/min) = 0.01 x room volume (cu m)

5. Check the actual fresh air intake rate by measuring the average velocity of air (m/sec) through the intake or outlet vent with an anemometer and multiplying this velocity by the area of vent opening (sq m).

Actual fresh air intake (cu m/min) = av. air velocity (m/sec) x area of vent opening (sq m) x 60

Note: Area of a circle (sq m) = π x $\underline{(\text{radius [m]})}^2$

6. Adjust vent opening to achieve required fresh air intake.
7. Calculate the ethylene gas flow rate required to achieve the final recommended concentration of ethylene gas in the room air. *Required ethylene gas flow rate (mL/min) = Fresh air intake rate (cu m/min) x recommended ethylene concentration (ppm)*
8. Use a bubble flow meter on the outlet tube to the room when adjusting the ethylene gas regulator and fine needle valve to give the correct gas flow rate calculated above.

Example calulation

(i) Fresh air intake required = 0.01 x 64.8 = 0.648 cu m/min

(ii) Air velocity required through a 100 mm (0.1 m) internal diameter intake vent to achieve required fresh air intake:

= $\frac{\text{Fresh air intake (cu m/min)}}{\text{Area of vent (sq m)}}$

= 0.648 cu m/min divided by (0.0079 sq m)

= 82.0 m/min (1.4 m/sec)

(iii) Ethylene gas flow rate required (mL/min)

= Fresh air intake (cu m/min) x 10 (ppm)

= 0.648 x 10

= 6.48 mL/min

(iv) Check that the ethylene gas flow rate with the flow meter at the outlet tube is reading 6.48 L/min. Adjust if necessary.

Marketing mangoes

A good understanding of the mango market is important if you want to maximise returns. This section covers the main points to consider when deciding how you will sell your fruit.

The need for marketing

Marketing needs to address all of the aspects of delivering your product to the customer. Mangoes compete in an increasingly global market place and in an environment where producers are part of the food industry.

Mangoes have several marketing advantages. They are well-known and popular with consumers and have potential for market expansion from current, low consumption levels.

Producers will not be able to capitalise on these advantages, however, unless the mango is properly marketed. There are two important points:

- The volume of production is increasing, making the domestic market tighter and more competitive. To maintain a profitable margin, growers will need to actively search for new market opportunities in Australia and overseas and strongly promoting the fruit to consumers.
- The changing face of marketing has seen supermarkets beginning to dominate the management and distribution of fruit. This will move the focus away from the 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.

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 market needs and gear their production and marketing system to deliver a product that meets those needs.

Retailers want ripe, yellow-skinned mangoes with blush. Quality management is the only way of consistently ensuring your product meets these market needs.

Know what the market wants

There are two important sources of knowledge and information on what the market wants.

Market research studies are conducted by industry and research organisations and published in special reports. Grower organisations, the Queensland Fruit & Vegetable Growers Association, the Australian Horticultural Corporation and the Horticultural Research and Development Corporation are sources of this information.

Marketers who are in close contact with buyers and consumers. For the domestic market, specialist mango wholesale agents in the major metropolitan markets are an invaluable source of detailed market knowledge. Market authorities in each of the major markets can provide advice on specialist mango wholesalers. For the export market, mango exporters are an equivalent source of expert market knowledge.

Consumers want fruit with the following characteristics:

- medium size—counts of 18 to 20 preferred
- yellow skin with some red blush
- free from disease, internal breakdown, sapburn and skin browning
- good firmness
- good shelf life—five days preferred
- clean appearance and good presentation
- sweet, pleasant flavour.

Know the marketing chain for your fruit

Knowing the marketing chain for your fruit means identifying 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, wholesale agent, supermarket buyer, grocery section manager and consumers from a particular region. Knowing how the chain works is important because you choose some of its players and each of the players makes decisions about your product that collectively influence its marketing performance.

Visit the markets in which your fruit is sold

There is no substitute for seeing how your fruit is performing in its markets, but looking at the fruit is not enough. You need to monitor the physical and financial performance of the fruit and assess the performance of everyone in the marketing chain. They are working for you, but they may forget this if you are not interested in them.

Actively seek market information

Apart from visiting the market, actively seek information about each consignment of fruit. Ask your agent for a report to indicate if the fruit is acceptable. Growers do not necessarily get feedback unless they set up a system for it by facsimile or e-mail. Out turn inspections by independent assessors is another useful way to get information about your product.

Deliver the product that the market wants

Once you have established what the market wants, the next step is to gear the 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.

New and improved market opportunities

To maintain a competitive advantage, you must maintain an active involvement in researching new and improved market opportunities. Here are some things you can do:

- Consider value-adding opportunities, for example, growing mangoes organically. Consumers now are better educated and more health conscious, and are demanding more convenience in their foods.
- Support market research proposed by the industry, as it will greatly benefit future marketing opportunities.
- Support promotional activities implemented by the industry, including those aimed at improving fruit handling in the wholesale and retail markets. These activities will increase sales and potential returns. Consumers usually have insufficient knowledge about availability, storage and use of mangoes, and promotion helps to build their confidence in the product. Mangoes are a luxury purchase that have to compete with other similar fruit for the consumer dollar.
- Look for specialist mango wholesalers who present a positive, enthusiastic impression, particularly when times are tough. Wholesalers who specialise in seven or eight products normally develop more expertise in the product and should do a better marketing job

than generalists. Keep in regular contact with your wholesaler or marketer. Get regular feedback on consignments—a fax or e-mail are invaluable for this.

- If a market is looking for long lines of consistent supply, consider getting together with other growers to develop group marketing under a common quality management system. The longer lines of consistent quality produced under this system give you access to larger buyers unavailable to most individual growers.
- Groups should consider using a professional marketing coordinator. A coordinator maintains close contact with all of the markets throughout Australia and overseas. The product can then be directed to each market based on the coordinator's intimate knowledge of how much it can handle before it is oversupplied and prices fall. The coordinator may also undertake market development and promotion on behalf of the group. When the coordinator handles all of the marketing decisions and problems, growers can concentrate on what they do best—growing quality fruit.

Exporting

Export markets for mangoes have shown a steady increase since the 1980s. Continued growth in current export markets is predicted in the medium term and new markets are developing.

Considerations

Export markets for mangoes are well established, though they account for only 10% of total production. Export is expected to become more important for two reasons.

- As the volume of production increases, the export market will need greater development to prevent oversupply and lower prices on the domestic market.
- Exports provide potential for a wider sales base without significant extra promotion. They provide economies of scale and may extend or even out supply during the marketing period.

Current export markets include Hong Kong, Singapore, Japan, Malaysia, Europe and the Middle East. General preferences are for:

- large fruit—count 16 to 18 or larger (smaller fruit is acceptable but will probably receive lower prices)
- good colour and brightness (good yellow background with 25% or more red blush)
- freedom from skin blemish
- firmness
- sound packaging.

Queensland has several strengths in the continuing development of mango exports.

- It is close to the growing Asian markets.
- It has highly skilled people that can produce good quality fruit with a clean, green image.

- Its production is counter-seasonal to most Northern Hemisphere producers.
- It is growing varieties with significant export demand.

As a result, potential for export growth is sound. The major competition, however, will come from South Africa, The Philippines and Brazil.

In export markets, Queensland mangoes are regarded as a high quality fruit. This is important because least cost is not a suitable strategy for our fruit and lower cost competitors are selling in all our export markets during the Australian mango season. Queensland fruit have developed a reputation for superior quality and are positioned in the markets as a premium quality fruit.

On the downside, export marketing has complex and specialised requirements. These include:

- access to knowledge and intelligence on export market requirements
- high levels of quality management and skills to consistently meet the market requirements
- commitment, as relationships with export markets need to be developed on a long-term basis
- sufficient volume to provide consistent supply
- in some cases, ability to meet strict quarantine requirements.

Regulatory requirements

Quarantine regulations control the entry of mangoes into many export markets (Table 12). Work has started to develop disinfestation treatments to allow access to New Zealand.

***Table 12.** Access requirements for some mango export markets*

Country	Permitted	Quarantine treatment	Import permit	Phytosanitary certificate	Duty
Brunei	Yes	None required	Yes	Yes	Nil
Hong Kong	Yes	None required	No	No	Nil
Japan	Yes	Ministry of Agriculture & Fisheries supervised vapour heat treatment	Yes	Yes	6%
Malaysia	Yes	None required	No	No	5%
Singapore	Yes	None required	No	No	Nil
Thailand	Yes	None required	No	Yes	60%
Indonesia	Yes	Fruit fly area freedom or disinfestation using cold storage, methyl bromide or dimethoate	No	Yes	30%

HINT

The DPI booklet *Exporting mangoes, transport and handling: options and issues*, available free from DPI offices, details investigations into freight options for mango exports.

Transport

Queensland's mango exports have developed by using excess freight space available on regular passenger aircraft. This is convenient as flights are regular, frequent and require no major forward commitment. Passenger aircraft can handle consignments as small as 1400 kg.

As mango exports continue to increase, the available freight space is becoming limited. This competition for space is also driving up prices. Increasing competition from higher value commodities such as chilled seafood and cut flowers will also impact on space.

Charter flights

Charter aircraft can overcome space problems but a forward commitment to supply must be made in advance and the full freight costs paid. For example, a chartered 747 can carry 100 t of fresh mangoes. In 1997/98, the cost to Singapore was about $1.10/kg, which would incur a prepayment of $110 000

Sea freight

Sea freight is only a practical option if the journey will take ten days or less. As it takes 11 days to Singapore without allowing for possible delays in the port, this choice is too risky. Transport time can be extended using controlled atmosphere sea containers but the risk of quality deterioration is still high.

Quality management

Supermarkets are now requesting that their suppliers have quality management accreditation. An understanding of the principles of quality management will help producers to decide what type of quality system they need to implement to meet customer requirements. This section outlines the principles of quality management and describes the systems that growers can use.

What is quality management?

Quality has been described as the fitness for purpose of a product. It implies a predictable degree of uniformity and dependability. But quality goes beyond just the product; it also includes services such as packing true-to-label and delivering on time. In short, quality includes all those points that satisfy your customers.

Quality management, then, is the way you run your business to satisfy customers. This means that growers are constantly engaged in quality management, perhaps even without being aware of it.

In the past, the suitability of the product for its intended market was determined by what is called 'end point inspection'—inspection at the market level. This system has several important flaws.

- It is expensive to reject product at this late point in its cycle.
- It is difficult to predict product performance during the rest of the marketing process when its past history is unknown.
- It 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 so that there is little or no need for rejections late in the chain. This system also provides customers with documented evidence that the product they are buying will meet their needs.

As such, quality management is a marketing tool to achieve repeat sales, as well as a productivity improvement tool to identify problem areas, prevent mistakes and reduce wastage. It also helps growers access markets with quarantine and other barriers to normal entry and promotes greater trust and cooperation throughout the marketing chain.

Core principles of quality management

- The customer defines quality, not the grower.
- Quality management has to be planned, organised and managed, it does not happen by itself.
- Problems are identified at the earliest possible point, not at the end point.
- Everyone in the business, including workers, is responsible for quality management; it is not just the responsibility of management.

To implement an effective quality management system, growers will need commitment, good planning, staff involvement and well-organised documents (including records and product specifications).

Push for quality management

The three major supermarket chains in Australia are now demanding that all their suppliers have some level of quality management to assure safety and quality of products. This is in response to consumers wanting fruit and vegetables that are consistently attractive, nutritious, tasty and safe to eat. People are worried about unsafe food because of recent outbreaks of food poisoning from other food products. We cannot be complacent about food safety because fruit and vegetables have been implicated in several food poisoning outbreaks overseas.

What level of quality management do you need?

The three broad levels of quality management practices being requested by customers are:

- Approved Supplier Program
- Hazard Analysis and Critical Control Point (HACCP) Plan
- HACCP-based quality management standard or code.

The level of quality management you need to implement will depend on the marketing arrangements and the potential risk of the product causing a food safety problem.

If your product is supplied directly or indirectly to a supermarket, the minimum levels of quality management needed by different businesses in your supply chain is shown in Figure 18.

Some food service businesses, such as fast food outlets, are requesting an HACCP plan or specific quality management practices under an Approved Supplier Program.

Exporters will require some level of quality management, depending on their customers.

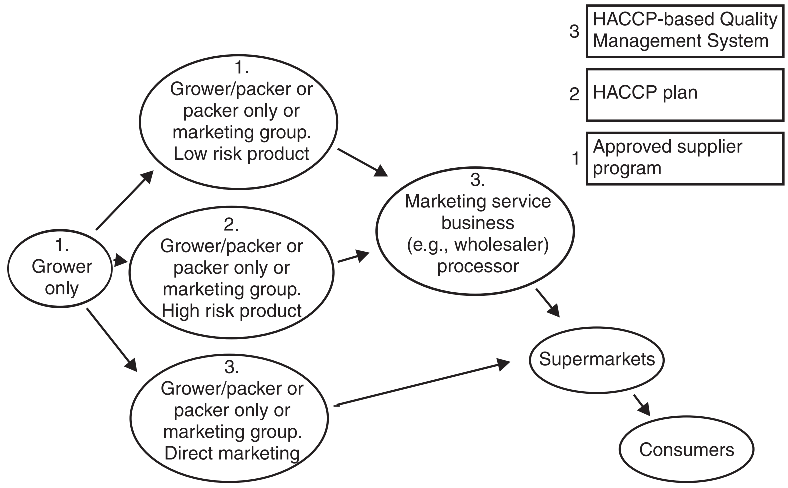


Figure 18. *Minimum levels of quality management required for businesses to supply supermarkets*

The three levels of quality management

Approved Supplier Program

An Approved Supplier Program involves suppliers carrying out agreed practices that will provide assurance to customers that the product is safe to eat and of acceptable quality. Suppliers will need to keep sufficient records to demonstrate that the practices are a part of everyday operations. The customer or someone on behalf of the customer will periodically check that suppliers are carrying out the agreed practices.

Direct suppliers to supermarkets need to develop approved supplier arrangements with their grower suppliers. This could include:

- wholesalers or processors who supply direct to a supermarket
- packers who supply direct to a supermarket
- marketing groups who supply direct to a supermarket. The marketing operation within the group would need to have an HACCP-based quality management standard or code (level 3) and have approved supplier arrangements with their growers.

Further information about specific practices and documents that may be included in an Approved Supplier Program is contained in the publication *Developing an Approved Supplier Program for fresh produce—a guide for customers and suppliers.*

HACCP plans

HACCP is an internationally recognised method to identify, evaluate and control hazards (things that can go wrong) to food products. HACCP was originally developed to provide assurance that food was safe to eat, but it is now being used to ensure that customer quality requirements are met.

HACCP is being requested of some growers who supply products that are perceived to have a high risk of causing food safety problems or where the next business in the supply chain demands it.

HACCP relies on prevention to control potential problems. Potential hazards are assessed for significance and control measures are established to eliminate, prevent or reduce the hazard to an acceptable level.

Typical food safety hazards include excessive chemical residues, microbes causing sickness, and physical contaminants (glass, sticks) that may lodge in product.

Some independent auditing companies will certify HACCP plans according to the Codex Alimentarius Commission guidelines.

HACCP-based quality management standard or code

The quality management standards or codes incorporating HACCP that are relevant to the horticultural industry are:

- ISO 9002 plus HACCP
- SQF 2000^{CM} SQF 1000^{CM}
- HACCP 9000
- Supermarket quality management standards.

HACCP-based quality management standards or codes are required where growers or packhouses directly supply supermarket chains or where the next business in the supply chain demands this requirement. Check with each supermarket to see what standards or codes they will accept.

For SQF 2000^{CM}, SQF 1000^{CM}, ISO 9002 and HACCP 9000, an accredited independent company conducts audits to certify that the business meets the quality system standard.

For supermarket quality management standards, the supermarket, or an independent company on their behalf, does the auditing.

ISO 9002

ISO 9002 is the international standard for quality management systems and the system on which most others are based. It was developed originally for manufacturing companies and is now used by many industries. It consists of 20 elements covering all aspects of producing products and servicing customers. Supermarkets are requiring their direct suppliers to include HACCP in their ISO 9002 systems.

SQF 2000^{CM} and SQF 1000^{CM} quality codes

The SQF2000^{CM} and SQF 1000^{CM} quality codes were developed by AGWEST Trade and Development specifically for small businesses in the food industry. They are recognised in Australia and in some Asian countries. The codes have specific requirements that must be addressed to achieve certification. The codes include HACCP, which provides assurance that the product is safe and meets customer and legislative requirements. To achieve certification, a registered, skilled HACCP practitioner must develop, validate and verify the HACCP plan.

HACCP 9000

HACCP 9000 is a quality management standard incorporating ISO 9002 and HACCP

Supermarket quality management standards

An example of supermarket quality standards is the Vendor Quality Management Standard developed by Woolworths Australia for their direct suppliers. It is aimed at food safety and quality requirements and is an HACCP-based quality management standard.