Papaw information kit

Reprint – information current in 2000

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 2000. We advise readers to take particular note of the areas most likely to be out-of-date and so requiring further research: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- Financial information—costs and returns listed in this publication are out of date.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 2000. The information is not current and the accuracy of the information cannot be guaranteed by the State of Queensland.

Queensland Government

Key ISSUES

This section contains more detailed information on some of the important decision-making areas and information needs for growing papaw in Queensland. The information supplements our growing and marketing recipe in Section 3 and should be used in conjunction with it. The information provided on each issue is not designed to be a complete coverage of the issue but instead the key points that need to be known and understood.

Understanding the papaw plant

The aim of papaw production is to grow high yielding plants that produce high quality fruit. To achieve this it is useful to have a basic knowledge of the plant.

About the plant

The papaw, *Carica papaya,* is a native of tropical America and is grown mostly in tropical and subtropical areas. It is an upright and soft-wooded perennial plant, which can live for five years or longer. It normally grows as a single stem 3 to 4 m high, but can reach 8 m in some circumstances. The large palmate leaves are borne directly on the trunk and grow in a crown at the top of the stem.

The plants start flowering about five to eight months from planting, depending on location and time of planting, and fruit are harvested five to seven months later. The fruits are formed in the leaf axils and remain in place until after the lower leaves have fallen. Harvesting continues until trees are too high to harvest or tree losses to diseases or storms make keeping a block in production uneconomical. On average, most growers harvest over two years. Growers in south-east Queensland harvest up to three years.

Papaw types

Two papaw types exist, each with a distinctive flowering habit. These are dioecious and gynodioecious papaws. Gynodioecious types are commonly called ‘bisexual’ papaw.

Dioecious types

Dioecious types have male and female flowers on separate plants. Female flowers are held close in against the stem, with single flowers or clusters of two or three being the most common. Male flowers are smaller and more numerous, and hang on long thin stems. Sometimes male trees will bear hermaphrodite (bisexual) flowers.

Both male and female plants are necessary for pollination and successful seed set. Examples of dioecious lines are the F1 hybrids, Hybrid 29, 1B, 11B and the inbred or open pollinated Richter Gold lines.

Gynodioecious types

Gynodioecious varieties have trees that are either female or hermaphrodite/bisexual. While the flowers on female trees require pollen from male dioecious trees or bisexual trees, the bisexual flowers can self-pollinate. The bisexual tree may produce both male flowers and bisexual flowers. However, the male flower on a bisexual tree does not hang on the long thin flower stamens as seen on dioecious types. Depending on variety, fruit shapes can vary enormously.

Examples of gynodioecious varieties are Sunrise Solo, Eksotika and BB5H. Bisexual papaws have both male and female parts within the same flower and only one plant is required for pollination. However, when the weather changes from warm to cool, the flowers of bisexual papaw also change, leading to distortion of the fruit. These changes, combined with bisexual types being less productive in subtropical conditions, mean they are not widely grown in cooler areas.

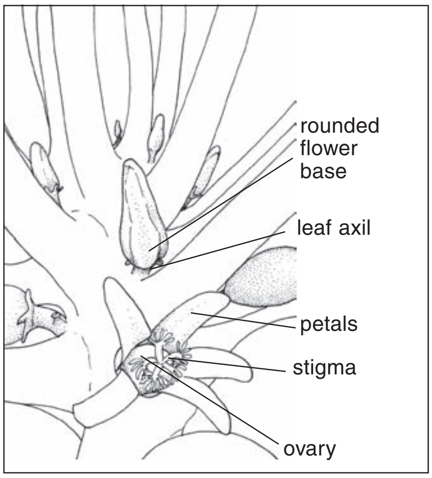

***Figure 1.** Female flowers of dioecious female papaw*

Flower types

There are three flower types in papaw: female, male or bisexual. Bisexual flowers can also be of three types.

Female/pistillate flowers

Female flowers have a rounded ovary at the base of the flower and a stigma that receives the pollen (Figure 1). No male organs are present. Fruit shapes can vary, depending on the characteristics of the parent trees, however common shapes include round, oval and oblong. Female flowers only occur on female trees.

Male/staminate flowers

Male flowers are characterised by fused petals forming a long tube (Figure 2). The male organs or stamens are located in this tube and the anthers produce pollen. Although rudimentary female parts may occur they are functionless, therefore male flowers cannot set fruit. Male flowers may occur on either male trees of dioecious varieties or hermaphrodite trees of gynodioecious varieties. Flowering on dioecious males is characterised by the long flower 'sprays' while male flowers on bisexual trees are set in close to the stem and leaf axil.

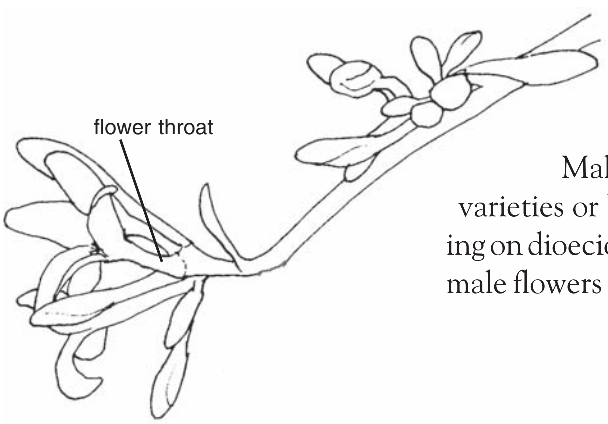

***Figure 2.** Male flowers of papaw*

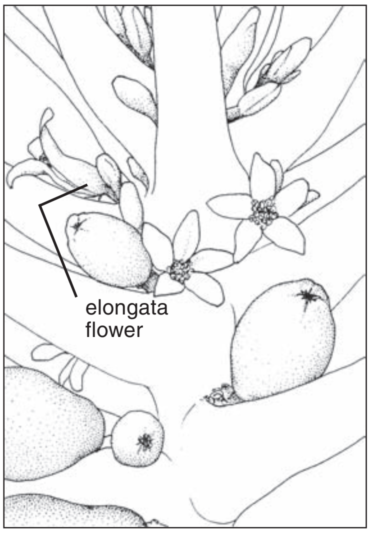

Figure 3. Hermaphrodite flowers of gynodioecious papaw

Hermaphrodite flowers

Hermaphrodite flowers have both male and female reproductive organs (Figure 3). They can therefore self-pollinate and pollinate female and other hermaphrodite flowers nearby.

There are three distinct types of hermaphrodite flowers: pentandria, intermediate or elongata. The position of the male stamens relative to the ovary distinguishes these flowers. This also results in different fruit shapes.

Fruit developed from pentandria flowers are typically squat with deep grooves and defined petal scars. Fruit from elongata flowers are long or pear-shaped. Fruit resulting from intermediate flower types are often deformed and have no market value.

Uses for papaw

Papaw is most often consumed as a fresh fruit, however other uses do exist for the fruit and other parts of the plant. The fruit may be canned, dried or pureed. The market for green fruit is also expanding.

Milky latex of the unripe fruit, leaves and other parts of the plant contains papain, a proteolytic enzyme that digests protein. The crude product is imported, purified and used in various forms in food, leather, cosmetic and drug manufacturing. It is used as a meat tenderiser and as an ingredient in medicines for indigestion.

Other biologically active compounds are also found in papaw. Seeds and unripe fruit contain benzyl isothiocyanate, a compound with pungent flavour. This sulphur-containing chemical is reported to be an effective germicide and insecticide.

Carpaine, an alkaloid found in papaw leaves, has been demonstrated to lower blood pressure and heart rate in rats. It is commonly used as folk medicine in many countries.

Ripe papaw fruit contains about 88% water, little or no starch, 10% sugar, 0.5% protein and 0.1% fat. It is a good source of vitamins C and A.

Economics of production

Growers considering planting papaw should prepare a thorough economic analysis to assess the profitability of their investment. The Australian papaw market is relatively small and it can be easily oversupplied. Continuing profitability will depend on successful industry market development. At certain times the domestic market can be oversupplied, leading to very low prices for all but outstanding quality fruit.

Analysing horticultural investments

Several methods are used to analyse the profitability of a horticultural investment. We have chosen the simplest analysis, gross margins, to give you an overview of the profitability of papaw production.

Gross margin analysis

A gross margin is the difference between the gross income and the variable costs of an enterprise. Variable costs include crop operations, harvesting and marketing costs. Gross margins do not take into account overhead costs such as rates, electricity, insurance, living costs and interest. These costs should be included in the farm budget.

Gross margin analysis (north Queensland)

Assumptions

The following gross margin was based on a family unit growing dioecious hybrid papaw varieties under good management in **north Queensland. Growers in other areas will need to substitute their costs.** Yields in the first and second year were 0.8 cartons per tree and 5 cartons per tree respectively. It was assumed papaw took 10 months to grow and were picked for the following 14 months.

Papaw were packed into 13 kg cartons and transported at ambient temperature or 'dry' to Brisbane markets. A wholesale market price of $15 per carton was used.

Trees were planted at a density of 1800 trees per hectare. As a general rule 10% of trees are non-bearing male trees and 30% of the remainder die, leaving a density of 1134 bearing trees per hectare. The gross margin for the example papaw crop is shown in Table 1. Some figures have been rounded.

Table 1. Gross margin calculation

Item	Assumptions	Total $/ha
Income		
Cartons	$15/carton x 6577 cartons*	98,658.00
(A) Total income		**98,658.00**
Variable costs		
Seedlings		1,220.00
Machinery operations	Refer to Table 3	473.06
Fertiliser	Refer to Table 2	6,352.10
Herbicide	Refer to Table 2	435.54
Pest & disease control	Refer to Table 2	1,121.88
Irrigation & pumping**		1,118.00
Harvesting & marketing		
Picking/packing labour	Family labour	0.00
Cartons	$2.26 each (fibreboard)	14,864.47
Socks	$0.075 each	6,906.06
Commission (12.5%)	$1.63/carton	12,332.25
Postharvest dip	$0.08/carton	526.18
Stickers	$5.03 per 1000	463.17
Pallet tape	$1.30/ pallet	158.34
Freight to Brisbane	$1.80/carton	11,838.96
Levies	$0.39/carton	2,565.11
(B) Total variable costs		**60,375.11**
Gross margin (A – B)	For crop cycle (2 years)	**38,282.89**

* Cartons per hectare over 14 months of harvest.

** Includes electricity, cleaning, labour, repairs and trenching.

Table 2 shows chemical and fertiliser applications for the example farm.

Table 2. Frequency and cost of chemical and fertiliser applications

Item	Frequency	Units/ha	$/unit	Total $/ha
Fertiliser				
Dolomite (within 4 months of planting)	1	5 t	101.75	508.75
Dolomite (months 5 to 20)	3	1.25 t	101.75	381.56
Superphosphate	1	1.25 t	288.00	360.00
13N:14P:11K (4 months)	1	0.375 t	539.01	202.13
Boron	7	9 kg	3.99	251.37
Zinc sulphate	3	27 kg	1.09	88.29
11N:13P:18K (20 months)	20	0.5 t	456.00	4,560.00
Herbicide				
Herbicide (by hand gun)	3	2.5 L	17.08	128.10
Herbicide (boom spray)	6	3 L	17.08	307.44
Pest and disease control				
Wettable sulphur	4	3.75 kg	7.29	109.35
Protectant fungicide	32	2 kg	7.25	464.00
Systemic fungicide	8	0.29 L	165.02	382.85
Kocide™	7	2.2 kg	7.65	117.81
Insecticide	10	0.25 L	19.15	47.88

Table 3 shows estimated costs for machinery operations. Estimates are for fuel and oil costs, and do not include repairs and maintenance.

Table 3. *Frequency and cost of machinery operations**

Item	Frequency	Units/ha	$/unit	Total $/ha
Land preparation				
Discing	1	1 hr	4.13	4.13
Deep ripping	2	1 hr	4.13	8.26
Rotary hoe (crop removal)	1	2.5 hr	4.13	10.33
Rotary hoe (after fertiliser)	1	1.25 hr	4.13	5.16
Mounding	2	3 hr	4.13	24.78
Ripping	1	1 hr	4.13	4.13
Weed control				
Herbicide (hand gun) – casual labour	3	2.5 hr	12.00	90.00
Herbicide (boom spray)	6	1.5 hr	4.13	37.17
Slashing	20	0.5 hr	4.13	41.30
Fertiliser				
Superphosphate application (4 months)	1	1.25 hr	4.13	5.16
NPK application (4 months)	1	1.25 hr	4.13	5.16
Boron application (20 months)	7	1.5 hr	4.13	43.37
Zinc sulphate application (20 months)	3	1 hr	4.13	12.39
NPK application (20 months)	20	0.5 hr	4.13	41.30
Pest and disease control				
Sulphur application	4	1 hr	4.13	16.52
Fungicide application (20 months)	40	0.75 hr	4.13	123.90

*Fuel and oil costs

Variations in papaw price and yield

Farm profit is dependent on both yield and price. Table 4 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 papaw on the example farm.

Table 4. *Farm profit ($/ha/crop cycle) with changes in prices and yields*

Yield* (cartons/ tree)	Wholesale market price ($/carton) 11.00	12.00	13.00	14.00	15.00	16.00
2	-1,760.83	223.67	2,208.17	4,192.67	6,177.17	8,161.67
3	2,719.04	5,695.79	8,672.54	11,649.29	14,626.04	17,602.79
4	7,198.91	11,167.91	15,136.91	19,105.91	23,074.91	27,043.91
5	11,678.79	16,640.04	21,601.29	26,562.54	31,523.79	36,485.04
6	16,158.66	22,112.16	28,065.66	34,019.16	39,972.66	45,926.16
7	20,638.54	27,584.29	34,530.04	41,475.79	48,421.54	55,367.29
8	25,118.41	33,056.41	40,994.41	48,932.41	56,870.41	64,808.41

*Cartons per tree over two-year life of crop.

Conclusions

The gross margin analysis suggests that growing papaw can be profitable under good management. A gross margin of $38 282 per hectare per crop cycle (two years) was obtained for the example papaw plantation. However, anyone thinking of investing in papaw should undertake their own detailed economic analysis.

Important. The analyses shown here do not take into account overhead costs, cost of family labour in picking and packing, fixed costs, machinery, capital equipment, taxation or financing issues.

Varieties

Several different types of papaw are grown in Queensland and each type suits a particular growing region and climate. Before deciding on what to plant look at what varieties have been proven in your area and the markets you want to supply. The field and market performance of any variety is largely dependent on farm management decisions, weather conditions and marketing strategies.

Papaw varieties

Several different varieties of papaw are grown in Queensland. A papaw variety or line may be either:

- **An F1 hybrid variety.** F1 hybrids are varieties made by the controlled crossing of two stable parent lines.
- **An elite or inbred variety.** This involves inbreeding and selecting a line over many generations until the line is stable, thus creating inbred varieties.
- **An open pollinated or 'common' variety.** Open pollinated lines are more variable than either hybrids or inbred varieties.

In north and central Queensland most papaws grown are either F1 hybrid or inbred varieties. Most papaws grown in south-east Queensland are open pollinated or inbred selections.

When you are deciding on a variety to plant, look at what varieties have been proven in your area and which market(s) you want to supply. Papaws are very responsive to environmental effects. If you want to grow a variety that isn't known in your area, plant only a small number of trees at first. This will save you time and money if that variety does not do well under your conditions.

Descriptions of main varieties

The following pages show descriptions and coloured photos of the main varieties.

Other varieties

The papaw varieties described in this kit are the main commercial varieties grown in Queensland. Numerous other varieties and lines are grown by some growers. However, these are usually experimental lines or seed is not readily available. Some growers plant different lines specifically for local markets. These lines usually fall into one of the following categories:

- Bisexual varieties and lines, pink to reddish-orange flesh, usually sweet (but not always) with varying flavour, fruit sizes and shapes. Most are either partly or fully inbred or open pollinated lines. Most exhibit variability in tree and fruit characteristics.
- Dioecious varieties, pink to red flesh, usually sweet with a range of flavours, fruit sizes and shapes. Most are either inbred or F1 hybrids. Some are becoming increasingly popular in north Queensland.
- Dioecious varieties and lines, yellow-fleshed with a range of sweetness and flavour. Most are either partly inbred or F1 hybrids. Some are simply open pollinated selections of lines that growers have planted for years. Some of the F1 hybrids may become more commercial if they prove superior to existing varieties.

Hybrid and inbred production

Seed production techniques are critical for the maintenance of improved papaw varieties. This section outlines how to produce hybrid or inbred seed. The techniques described are from the voluntary Papaw Seed Producers' scheme that was developed by the DPI, the papaw subcommittee of QFVG and papaw seed producers.

Introduction

Papaw is normally propagated from seed. The plants outcross, so pollen from any male or hermaphrodite flower can pollinate any female or other hermaphrodite flower. If an inbred line outcrosses and there is no other source of this line, then that line is effectively lost. If the line is the parent of an F1 hybrid, then that hybrid is also lost.

As the papaw industry is investing in breeding it is vital that growers understand the need to maintain these improved varieties and how to do it. If you buy seed from reputable seed producers, they will be using these techniques to ensure that the seed you get is what you paid for.

Three different types of seed are used. Commercial plantations in Queensland usually source seed from either:

- open pollinated fruit; usually a good performing female is chosen as the seed source
- selected inbred lines of a particular strain
- hybrid seed made by crossing two stable inbred lines.

Keeping inbred varieties pure

Inbred papaw lines form the basis of making hybrid varieties. Some inbred varieties are also good commercial lines in their own right. The variety Sunrise Solo is a good example.

Inbred varieties may be either dioecious or gynodioecious types. Inbred simply means that a particular line has been selected and bred over several generations until segregation is minimal. An inbred line is said to have ‘fixed’ characteristics and may then be described as a ‘variety’. Inbreeding increases the probability that offspring will inherit the same genes from both parents.

In inbreeding, both pollen and ovary are from the same line or variety. We also assume that your inbred varieties are ‘fixed’, and will therefore produce genetically identical offspring.

There are two ways of keeping an inbred line pure: ‘selfing’ or ‘sib-crossing’. Selfing of bisexual flowers is the recommended procedure. However, should bisexual flowers not be produced during September through to December, the sib-cross method may be considered.

If you intend to keep parent lines and make your own hybrid crosses, you should keep the parents in a separate block to your commercial block.

If you are growing an inbred commercial variety and simply want to make your own seed, there is no need to plant a separate parent block.

‘Selfing’ bisexual (hermaphrodite) flowers

Only bisexual trees of gynodioecious varieties or the male trees of dioecious varieties are used for ‘selfing’ bisexual flowers. Bisexual flowers, if bagged, will be self-pollinated. Again, since the line is considered stable, the offspring will have the same genetic characteristics as the parent. There could be some environmental effects on some progeny, however, which cause them to be slightly different from their parent.

Selfing the hermaphrodite fruit will give you:

1 F : 2 M for dioecious varieties, or

1 F : 2 H for gynodioecious varieties

(F is female, M is male, H is hermaphrodite)

Step 1

Depending on whether the papaw variety is dioecious or gynodioecious, select either a male or bisexual (hermaphrodite) tree. The tree should be vigorous, flower well and set clean fruit. Remember, if it is a dioecious variety, bisexual flowers may only appear at certain times of the year, usually September to December.

Step 2

If selfing a dioecious line, look for bisexual flowers amongst the male flowers. Select for bisexual flowers that produce pear-shaped fruits. Carefully remove surrounding male flowers if they are in the way of the bag.

If selfing a gynodioecious line, you will be selfing only the one flower type if the line is truly inbred. Select the elongata flower type.

Step 3

Bag the selected hermaphrodite flower. After placing the bag over the flower, fold the open end over and secure with a clip or pin.

Step 4

Label the bagged flowers with the date and variety name. Use aluminium or plastic tags and carefully but securely attach them to the flower stalk. When the fruit is large enough you can scratch the identity on the skin. As the fruit develops, scar tissue retains this identity. This helps to ensure that you don't mix parent lines later on.

The sib cross method

In the sib cross method the female flower is pollinated with pollen taken from a male flower. The male tree that donates the pollen is called the pollinator and the female tree is called the receptor. A male and a female tree are needed. Since both parents are from the same stable variety the subsequent offspring will retain the same characteristics as the parent variety.

This method will give the following sex ratio in your seed:

F x M = 1F : 1M

F x H = 1F : 1H

(F is female, M is male, H is hermaphrodite)

Step 1

Select a vigorous male tree with profuse flowering. Check male flowers for pollen and pick the required number of flowers. Choose flowers that have bright yellow and fluffy pollen. Put the selected male flowers in a clean container. Normally one male flower is needed to pollinate one female flower. If pollen is scarce use two or more male flowers.

Step 2

Choose female parent trees that are healthy and vigorous.

Select female flowers that are strong and still tightly closed and have just turned creamy-white. Do not use green flowers as they are still immature. Disregard any female flowers that have started to open, or that are weak-looking or slightly brownish. Flowers that are even slightly opened may have been pollinated already by stray pollen.

Step 3

Take the male flower and peel off the petals so that the pollen is exposed, making sure that the stamens remain intact. Likewise remove the petals of the female flower. Brush the pollen across the stigma of the female flower.

Step 4

Immediately bag the pollinated female flower and secure the mouth of the bag against the flower stalk with a clip. Paper or glycine bags are suitable. The bag needs to stay over the flower for five days. After this time that flower will no longer be receptive to other pollen.

Step 5

Label the bagged flower with date and variety name. Aluminium or plastic tags are best Carefully tie or twist the tag tie around the flower stalk. You can scratch the identity of the line on the skin when the fruit is large enough.

Making F1 hybrids

An F1 hybrid is the result of crossing two different stable inbred varieties. The F1 hybrid will inherit some characteristics of each parent.

When making a particular cross, use pollinator flowers from the one male or bisexual tree, as this will enhance uniformity in the subsequent F1 hybrid.

Commercial F1 hybrid varieties have specific parents. Before you begin you must know what the particular parents are for each F1 hybrid you want to make and you must have access to true lines of these parents. Sometimes the identity of parents for F1s will be commercially confidential and you may not be able to get hold of these parent lines. In these cases, if you want to grow the hybrid you will need to buy the hybrid seed from the particular seed producer.

When making an F1 hybrid that has a dioecious variety as one parent and a gynodioecious variety as the other parent, use the bisexual flower as the pollinator and use the female of the dioecious variety as the receptor. This will help to prevent accidental outcrossing and/or self-pollination.

Step 1

Select a suitable pollinator tree (male or bisexual) and pick enough flowers to pollinate the required number of female flowers. Normally one male or bisexual flower will pollinate one female flower. Keep these flowers in a clean container free of other pollen.

Step 2

Select tightly closed female flowers on a selected tree of the female parent. The chosen tree should be vigorous and set clean fruit. Disregard any flowers that have even slightly opened or that are slightly brownish. Flowers that are even slightly opened may have been contaminated by other pollen.

Step 3

Remove the petals of the female to expose the stigma. Likewise remove the petals from the male or bisexual flower. Brush the pollen across the female stigma.

Step 4

Immediately bag the pollinated female flower and label. Include the date, parents of the cross or the hybrid name.

Harvesting seed fruit, seed preparation and storage

Harvesting

Depending on location and time of year, fruit normally take from four to six months to mature.

Harvest fruit at colour break to avoid damage by fruit fly, birds and bats.

When handling more than one batch of varieties be very careful to keep seed batches separated and clearly identified at all times.

Keep the label with each fruit. It is a good idea to write the cross on the fruit skin with a blunt pencil to ensure you do not mix the identity of your crosses.

Seed preparation

Step 1. Cleaning

Remove the seed from the fruit and wash it to remove the membranous sac or sarcotesta that surrounds the seed. This membrane can be easily removed by rubbing the seed around a kitchen strainer with a scouring pad or by placing seed into a food blender set on its lowest setting. Fermenting the seed for two to three days in water will make it easier to remove the seed coat. Experiment with small amounts of seed until you perfect the system.

Step 2. Drying

Seed can be dried in a food dehydrator set on a low setting, in an air-conditioned room or in a specially made seed drying cabinet. Mesh trays make ideal drying containers. Do not exceed a drying temperature of 40°C. Make sure the seeds are thoroughly dried before storage. Depending on the weather, seed may take from two to four days to dry.

Step 3. Storage

Seed from each particular cross should be stored separately in airtight containers, such as glass jars with sealable lids, plastic tupperware and sealable plastic bags. Store the sealed seed container in a fridge but do not freeze. Label each seed container with the date and the hybrid or inbred name.

Propagation

Seed is the main method used to propagate new papaw plants. It is relatively quick and straightforward, but because the genetic make-up of seedlings is dependent on the parent plant there can be variation. Where it is important that new plants are genetically identical to the parent plant, vegetative means of propagation are used.

Plants from seeds

Most papaw plants grown in Queensland are currently produced from seed. The seedlings may be raised directly in the field or in trays or pots in a propagation house.

Proper nursery practices must be used if raising seedlings in trays or pots. Hygiene is especially important, as papaw seedlings are highly susceptible to several seedling diseases.

Several commercial nurseries specialise in raising papaw seedlings. Most want you to provide the seed.

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Nurseries
Contacts and references page 5

Pre-germination

There are several seed treatments that improve seed germination. They can be used for direct-seeding in the field and for nursery raised plants.

- **Pre-germination.** There are several methods for pre-germinating seed. Place seeds in a plastic bag containing moist peat and put the bag in a warm location, away from direct sunlight. The heat generated in the bag helps the seeds to germinate.

  Alternatively, seeds can be soaked for a few hours and then spread evenly over moist muslin or newsprint laid on a sheet of plastic. Lay another layer of muslin or newsprint over the top. Sprinkle with water, roll the lot up and maintain at an even temperature (about 26°C) and moisture.

  After about three to five days, the seed coat will crack and the emerging root becomes visible. At this stage the seeds are ready for direct-seeding or transplanting into pots or trays.

Raising seedlings directly in the field

Papaw may be grown by direct seeding into the field. Direct seeding is less labour intensive than nursery propagation and there is no transplant shock. The disadvantages are that weed control is more critical and germinating seeds can be washed away or drowned by heavy rain. Cutworms and grasshoppers may also chew off young seedlings.

If direct seeding, we recommend using either plastic or organic mulch to suppress weeds.

Raising seedlings in a propagation house

Propagation house designs may differ, depending on your local climate and the time of year when you want to raise seedlings. The house may be a simple homemade structure or a specialist propagation facility.

In north Queensland, especially the coastal Wet Tropics, the propagation house needs to be rain-proof and well ventilated. The structure should have a polyethylene roof to allow sunlight but exclude rain. Thirty per cent shade cloth is also advisable. The shadecloth can be either supported over the polyethylene roof or suspended as a horizontal curtain within the house. If the structure is fully enclosed it should have vents or windows.

Simpler structures using only shadecloth suspended between posts may be adequate in some situations, but are unlikely to produce consistently good quality seedlings over time.

In subtropical and drier areas, a shade house fully enclosed with 30% shadecloth is recommended.

In addition to the propagation area, you will also need a hardening off area. This may be a simple structure with a retractable shade cloth roof. Seedlings must be properly sun-hardened before planting.

Alternatively, you can make mobile trolleys that are moved from the propagation house into the sunlight.

Hygiene

Hygiene is most important in all aspects of raising seedlings. The most important seedling diseases that affect papaw include *Phytophthora, Pythium* and *Rhizoctonia.* These diseases survive and reproduce in water and soil; therefore it is important to isolate your seedlings from any infection sources. There are several critical points for hygiene:

- Seedling trays or pots should be either new or thoroughly cleaned and disinfected. A chlorine solution of 2500 to 5000 ppm available chlorine is suitable for disinfecting.
- Floors in propagation facilities should be either concrete or aggregate, allow good drainage and not puddle water.
- Seedlings are best raised on benches at least 60 cm off the ground, depending on floor type. Benches over dirt should be 75 cm high. Mesh-type benches are best, as these do not allow water to accumulate underneath the seedling trays or pots.
- Irrigation water should be from a reticulated system, rainwater or bore water. Water should have a salinity of less than 0.6 deciSiemens per metre. Creek, river and dam water supplies are notorious for containing *Phytophthora* and other fungal organisms and should be treated before use.
- Seedling raising mixes need an open structure with good drainage. Many proprietary mixes can be bought from hardware stores, chain stores or plant nurseries. Alternatively, custom made mixes are available. If raising seedlings for your own use, it is simpler and less time consuming to buy a good quality seedling raising mix.
- Storage facilities for potting media should be clean and isolated from surrounding ground to prevent contamination by disease organisms.

Seedling raising mixes

For the quantities of seedling mix that most growers use, it is easier and safer to buy proprietary mixes. Plant nurseries that grow seedlings under contract use larger quantities of mix and are more likely to make up their own mixes.

Suitable seedling mix ingredients include imported peat, perlite, vermiculite, sterilised washed river sand and clean crusher dust. Suitable custom mixes include:

- 1:1 peat/perlite
- 1:1 peat/vermiculite
- 1:1 peat/sand
- 1:1 peat/crusher dust.

If making your own mix, add lime, dolomite, superphosphate and NPK fertiliser.

Incorporating fertiliser into the potting medium

Commercial proprietary mixes contain fertiliser and seedlings do not need additional fertiliser until they have emerged and started growing.

If you are making up a custom mix you will need to add fertiliser. Make sure it is added after any sterilising procedures have been completed. As a general rule, for every 10 L of mix, incorporate 20 g of dolomite and 20 g of 5:7:4 NPK mix.

Alternatively, slow release fertilisers such as Nutricote Total® and Osmocote Plus® can be either incorporated into the mix or applied on the surface after sowing. If you are using slow release fertilisers, check the technical specifications for nutrient release rates. Often, nutrient release rates are temperature dependent; you will need to know what is most suitable for your situation. You will still need to add lime or dolomite to adjust pH.

Slow release fertilisers are available in different release time formulations. If you want to use enough slow release fertiliser to supply the seedlings' requirements only while in the pot, use about 5 g of 3 to 4 month slow release fertiliser for every litre of mix.

If you want to supply enough fertiliser for a continued supply after field planting, use about 10 to 15 g of combined 3 to 4 month and 12 to 14 month slow release fertiliser for every litre of mix.

Choosing trays or pots

Seeds can be planted into trays, tubes or single pots.

Trays take up less space, but most trays have less root volume space than tubes or pots. The seedlings need to be planted out earlier before they become root bound. This is not normally a problem unless unsuitable ground conditions cause a delay in planting.

Tubes need to be supported either by tube supports or boxes.

Pots are free standing and take up more room, but provide better ventilation between plants.

The final choice of tray, tube or pot type will depend on your propagation system and what suits you best.

Sowing the seed

Sow the seed directly into pots or after preplant seed treatment.

Fill the trays or pots with a commercially available soil-less mix and lightly tap or shake to settle the mix. Seeds may be either pushed into the mix or placed on top and then lightly covered with mix. Do not plant the seeds too deep, about 50 mm depth is sufficient.

Water in the seeds, being careful not to wash out any mix.

How many seeds do I plant?

Remember that when you plant the seedlings out in the field you need multiple plants at each planting site. In the nursery, you can plant either single or multiple seeds.

Single plantings are best in trays, as there is less room for plant development. Pots can be planted to either single or multiple seeds.

If you are planting multiple seeds, the number of seeds placed in each pot depends on whether the variety is dioecious or bisexual. All seeds are assumed to be viable. For dioecious varieties plant four to five seeds per pot. For bisexual varieties plant three to four seeds per pot. The seed numbers vary because dioecious and bisexual varieties have different sex ratios in seed. Dioecious varieties have one female for one male, whereas bisexual varieties have two bisexuals for each female. There is no significant increase in getting the required sex type with greater seed numbers.

Table 5 shows the probability of getting specific sex types with different numbers of plants per site.

Table 5. *Probability of getting specific sex types with different numbers of plants per site*

Number of plants per position	Dioecious variety % of positions with at least 1 female	Bisexual variety % of positions with at least 1 bisexual
1	50.0	66.7
2	75.0	88.9
3	87.5	96.3
4	93.8	98.8
5	96.9	99.6

Fertilising seedlings

If slow release fertiliser has been incorporated into the mix, there should be enough nutrient available for the seedlings. If soluble fertiliser has been incorporated then additional fertilising may be necessary. Fertiliser can be applied weekly as a dilute solution or as a once-off top dressing of slow release fertiliser. There are many complete seedling fertilisers available.

Do not overfeed seedlings. Seedlings that are over fertilised tend to be too soft and lush for transplanting in the field, suffer more transplant shock and may be more susceptible to diseases.

Watering seedlings

The aim of watering seedlings is to keep the media moist but not wet. Frequency of watering will depend on the weather, the propagation facility and the potting media used. If water is running out of the bottom of your trays or pots, you are watering too much. Seedlings dying from damping-off and other diseases are a sign of over watering. Seedlings that are under watered are shrivelled and grow poorly. Some media are difficult to rewet if allowed to dry out.

Sun-hardening seedlings

Seedlings need to be sun-hardened before planting out. Gradually increase exposure to sunlight over four to five days once seedlings have three to four true leaves and are about 10 cm high. They may be sun-hardened under shade cloth or a shady tree. If it is too hot, windy or rainy, move seedlings back under cover. As the seedlings become acclimatised, move them into the full sun.

Do not allow plants to be root bound. Most seedlings are ready to plant out in the field at about six to ten weeks of age. It is time to plant out when roots show through the bottom of pots.

Disease management in seedlings

Seedlings are susceptible to several serious diseases. The best approach is one of prevention as there are no registered chemicals for control of the soil-borne fungal diseases *Phytophthora, Pythium* and *Rhizoctonia*. The basis of prevention is suitable and clean facilities, and hygienic practices. Use soil-free or soil-less potting mixes to raise seedlings, for example peat/perlite or peat/vermiculite. Alternatively, fumigate soil. However, even with the best of preventative measures you may experience losses to seedling diseases.

Insect management in seedlings

more info
Chemicals to use
Problem solver handy guide

Seedlings are generally free of major insect problems. Two-spotted or broad mites may occasionally cause damage. Apply a suitable miticide. Cutworms (*Agrotis* spp.) may damage seedlings in the field. Apply a registered pesticide if this becomes a serious problem.

Vegetative production

Papaw plants may be reproduced vegetatively and the resultant plants are genetically identical to the original plant. Other advantages include:

- an ability to maintain a genetically uniform superior selection
- knowledge of the plant's sex before planting, allowing exact allocation of male plants (dioecious lines) or elimination of female plants (bisexual lines)
- lower and earlier fruit set
- an ability to generate large numbers of genetically uniform lines with micropropagation techniques.

Disadvantages include:

- need for specialist propagation facilities
- a limit in the number of plants that can be multiplied up at any one time with the cutting technique
- the long time required for micropropagation techniques. You must be certain of your variety if using this method.

Cutting technique

Sideshoots from a source plant are propagated in a special cutting propagation house. Papaws have been successfully propagated by cuttings in South Africa and for research in Queensland. Chemicals used, however, are not registered for grower use in Australia.

The most important points are correct temperatures and prevention of diseases. Some papaws produce many sideshoots without special treatment. Cutting off the top of the tree can encourage these sideshoots to grow. Other varieties may need to be induced to produce sideshoots.

Designing a propagation house for cuttings

Propagation houses for cuttings vary greatly in design. For papaw, the design should include:

- rain proof enclosure
- clear roof and walls to allow plenty of light for plant photosynthesis
- good ventilation—screens incorporated into walls and/or adjustable windows or screens
- mist beds with bottom heat. Heating may be by electric heating cables or by hot water reticulation. Your local electricity supplier can offer advice on design. A suitable mist bed medium is 1 part peat moss, 1 part perlite and 1 part sterile washed river sand.

The design of your house will also depend on the number of cuttings you plan to propagate.

Micropropagation

Micropropagation is a technique whereby short nodal sections of stem are placed on artificial growing media and induced to form roots and shoots. Young plantlets are placed on special media in flasks and are grown in a laboratory until large enough for either transplanting or further multiplication. The technique requires a properly designed tissue culture facility for the propagation stages and a high humidity growth chamber for hardening off plants once they are removed from the flasks.

As this technique requires specialist equipment and skills, the technical procedures are not covered here.

Micropropagation of papaw has not yet been commercialised in Australia. Material for existing plantings has been sourced from research facilities.

Advantages of micropropagated material

- All plants derived from the same stock are identical.
- Sex of plant can be selected before planting.
- Ability to multiply up large numbers of identical plants.

Windbreaks

Hot and dry, and cold or strong winds can seriously affect papaws. Wind protection is highly desirable and wind damage can be reduced significantly with properly designed windbreaks or shelter belts. Do not overlook windbreaks when designing a farm layout. Officers from the Department of Natural Resources can assist with design of windbreaks. Information in this section has been extracted from DPI Note 'Windbreaks in horticulture', Department of Natural Resources Tree Fact 'Windbreaks' and DPI/Queensland Forestry Research Institute Factsheet 'Windbreaks'.

Design

An effective windbreak can reduce open wind speed by 25 to 75%. On level ground its effects can extend for a distance up to 25 times the height of the break on the down-wind side and for a distance equal to five times the height of the break on the side facing the wind. An effective windbreak incorporates several features.

Permeability

A permeable windbreak (Figure 4) lets wind filter through and provides a greater protection zone than a solid one. Dense windbreaks (Figure 5) cause considerable damaging turbulence further downwind. The ideal windbreak is 45 to 55% permeable. Depending on wind velocity, it offers good wind protection at ground level up to six times its height and to a distance of about 10 times its height. The protected zone is reduced if permeability is lower.

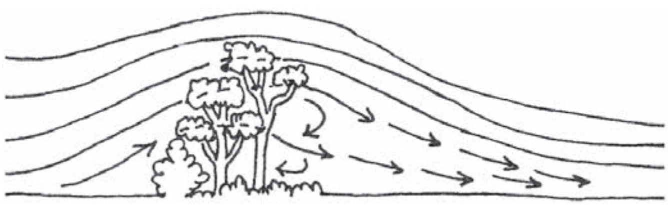

Figure 4. *Permeable windbreak*

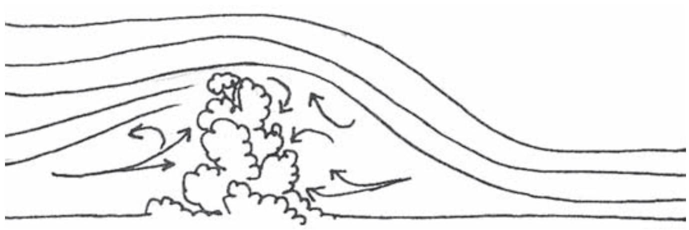

Figure 5. Dense windbreak

Height

The higher the windbreak, the larger the area it will protect. Wind speed is reduced for a distance up to 25 times the height of trees in the windbreak. Maximum wind reduction is in the zone 5 to 15 times tree height away from the windbreak.

Length

As wind swirls around each end of a windbreak, the windbreak should extend well beyond the edge of the crop. Wind is deflected around the windbreak if it is too short, leading to increased wind speed at the ends. The protected area can be increased fourfold by doubling the length of a windbreak. The length of a windbreak should not be less than 11 times its height and ideally, it should be 20 times as long as it is high. Minimum windbreak lengths should be about 200 m (Figure 6).

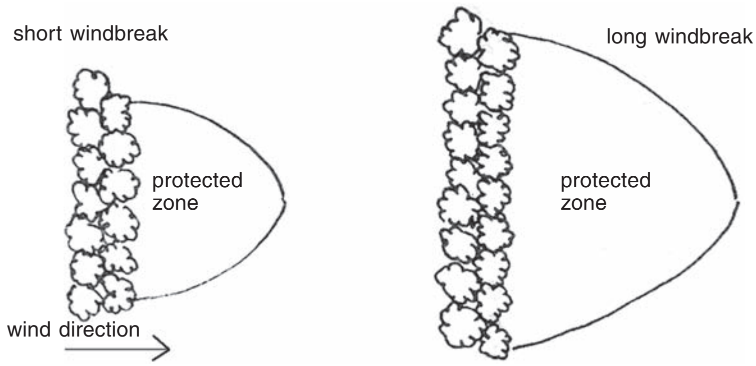

Figure 6. Short and long windbreaks

Gaps

Gaps in windbreaks can be a problem because the funnelling effects through these gaps increase wind speed (Figure 7). These 'jets' of wind can cause much damage. Angling the gap at about 45 degrees to the prevailing wind direction can minimise this problem in wide windbreaks. Planting trees outside the main windbreak to block wind approaching the gap, or widening the gap to reduce the funnelling effect, are also effective.

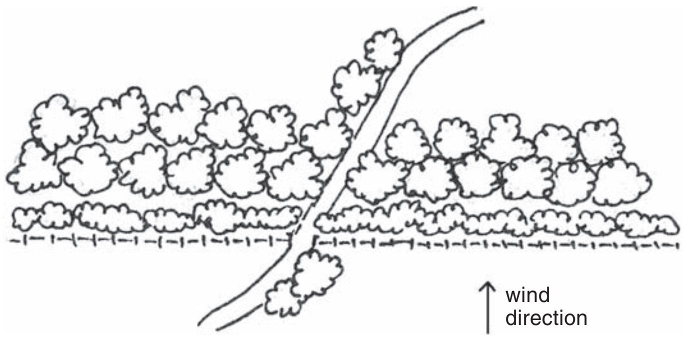

Figure 7. *Gaps in windbreaks*

Width

Windbreak width is of less importance than height or length, apart from the need to have enough tree rows to ensure uniform density along the height and length of the windbreak. Best results are achieved if the width of the windbreak is not more than three times its expected final height. A wide windbreak will deflect the air upward and provide a shorter zone of protection on the downwind side (Figure 8).

Figure 8. *Widths of windbreaks*

Orientation

Ideally, windbreaks should be positioned at right angles to the direction of the main problem-causing winds (Figure 9). If paddock shape makes this difficult, windbreaks along two sides of the paddock may be necessary. For example, if a rectangular paddock is oriented north-south, but prevailing winds are from the south-east, put windbreaks along both the eastern and southern paddock boundaries.

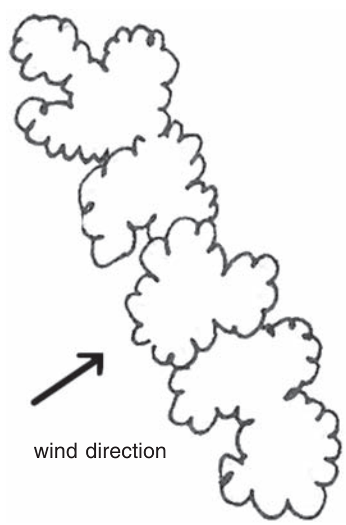

Figure 9. *Orientation of windbreak*

Formation

Multiple row windbreaks are generally more effective than single row windbreaks (Figure 10). The tree species used in single row windbreaks must have dense foliage and retain it to the ground to be effective. The tree's effect as a windbreak, however, is reduced if it dies and creates a gap. Nonetheless, single row windbreaks are useful if space is limited.

Three to five row windbreaks are effective in most situations and are less affected by gaps caused by missing trees. Create a permeable windbreak from ground level up to the height of the tallest trees. Tall-growing trees are generally best in the centre rows with smaller bushy trees and shrubs on the outside rows. Two or three row windbreaks are sufficient in drier areas.

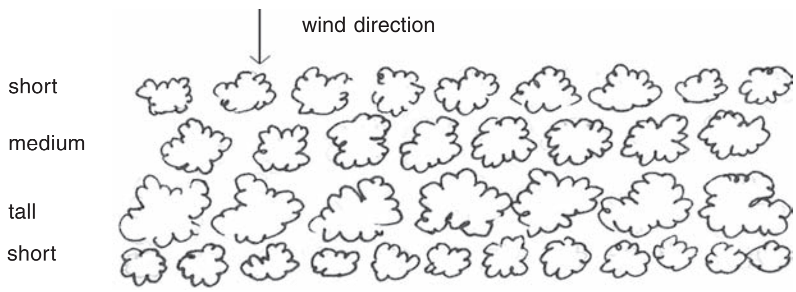

Figure 10. *Multiple row windbreaks*

Planting different types of trees and shrubs in a scattered pattern rather than in strict rows to create an effective permeable barrier can be used for wider multiple row windbreaks. This approach can be beneficial where the windbreak is meant to provide a wildlife corridor or habitat.

Choosing species

Choose species that grow best in your local area and those that will perform reliably for your windbreak. Avoid deciduous species. Eucalypts and pines make excellent windbreaks because they are quick-growing and permeable. The distances required between windbreaks and papaws will depend on your choice of tree species. Papaws planted too close to windbreaks will compete poorly.

Irrigation

Although papaws are grown in areas with high rainfall, they will still benefit from irrigation to supplement them in dry times. Here are the main things you need to know about irrigating papaws.

The importance of irrigation

Water and irrigation requirements for papaw crops vary throughout Queensland. Irrigation requirements can even vary between neighbouring farms in the same locality because these requirements are dependent on:

- planting design
- soil type
- irrigation design
- rainfall
- other climatic variables.

Specific research into water usage and irrigation requirements for papaw crops has only been conducted on three soil types in north Queensland. Recommendations for other districts are based on historical practices.

Choice of irrigation method

It is possible and economical to use drip tape, button drippers or microsprinklers for papaw production. The choice depends on soil type, water quality, climate and water availability.

Table 6 shows for north Queensland, in two distinct soil types, the relative suitability of methods based on measured plant available water capacity (PAWC) and a rooting range of 40 cm.

PAWC is the amount of water in the soil, generally available to plants, that can be held between field capacity and the moisture content at which plant growth ceases. It is sometimes known as the available water-holding capacity. Field capacity is the amount of water held in the soil after any excess has drained away following saturation.

For a sandy soil, the very low PAWC and the high gross precipitation rate of drippers are incompatible. If drippers were used, they would require extremely frequent short pulses of 20 minutes, and may not be able to supply sufficient water into such a small volume of soil wetted.

For such a soil/crop combination sprinklers are ideally suited, as long as operating times don't greatly exceed one hour.

For clay soil with its larger PAWC and lower expected hydraulic conductivity, the range of options is greater. (Hydraulic conductivity may be taken as the steady-state percolation rate of a soil when infiltration and internal drainage are equal, measured as depth per unit time.) This is particularly so for the well-drained, deep, porous kraznozem soils on the wet tropical coast of north Queensland. It will not, however, be the same for all clay textured soils. Clays with poorer structure and less sand, or with swelling capacity, will tend to have a lower conductivity and may be better suited to sprinkler irrigation only.

Table 6. *Suitability of three irrigation systems for growing papaw on two north Queensland soil types*

	Irrigation hours to fill soil to full point, from refill point	Maximum irrigation duration, hours to avoid drainage (safe irrigation)	Irrigation volume delivered, litres per safe irrigation per plant	Number of safe irrigations to deliver 70 L/plant	Suitability for papaw irrigation
Clay					
With sprinkler	6	4	80	1	Good
with dripper	1	0.75	6	12	OK – needs pulsing or daily watering
With drip tape	2	2	18	4	Good
Sand					
With sprinkler	1	1	20	4	Good
With dripper	0.15	.15	1.2	58	Incompatible
With drip tape	0.33	.33	3	23	Marginal – better to use two lines of tape

In irrigation trials in north Queensland, establishment costs, returns, water usage and crop water use efficiency of drip, drip tape and microsprinkler systems were compared for single row plantings of 1660 plants per hectare. Gross margins were highest for the sprinkler system, with one sprinkler irrigating two plants. Higher yield was achieved with lower installation costs. Single or double drippers per tree (8 L/hr/dripper) were the least expensive to install, but gave lower yields and gross margins, similar to drip tape.

For north Queensland conditions of high yields and available water, shared sprinklers delivering about 40 L/hr over a wetted diameter of 3 m are desirable.

For other areas, single or double lines of drip tape with 2 L per hour emitters spaced about 40 cm apart to produce a 'tube' of water will be suitable, especially where water is of higher conductivity (salinity) or less available. Button drippers can also be used, but will require special attention and management as the high precipitation rates and small wetted areas can lead to problems.

Drip systems generally require a greater level of monitoring and management, but can pay large dividends in reduced water usage, reduced drainage losses, increased water use efficiency, reduced water pumping costs and reduced water purchase costs. All irrigation systems should be set up to allow effective scheduling.

Irrigation scheduling

How do you know when to start irrigating and how much water to apply? Many methods are available for scheduling, including soil inspection, plant inspection, plant water status, fixed time methods, meteorological methods (including pan evaporation), water budgeting and soil water monitoring.

Soil moisture monitoring, as part of irrigation scheduling, allows you to maximise profitability and water use efficiency while minimising leaching and runoff into the environment.

Growers should use some form of soil moisture monitoring because it provides the best integration of the environmental variables. Irrigation applied should be compared with pan evaporation rates to ensure the soil moisture monitoring equipment is functioning correctly. Sound scheduling is best achieved by assistance from consultants. Water use by a full crop canopy in the summer months will approximate pan evaporation rates.

Monitoring methods

Tensiometers

Tensiometers measure the force with which water is held within the soil. Irrigation is applied when the soil dries to a certain soil suction. Tensiometers (Figure 11) measure soil moisture around the ceramic tip. Tensiometers are relatively inexpensive (about $125 each) compared with probe systems such as Enviroscan. Cheaper tensiometers ($15 each) can be made and used in conjunction with a Soilspec electronic vacuum gauge ($400). This gauge gives greater precision and is particularly economical if you want to use several tensiometers.

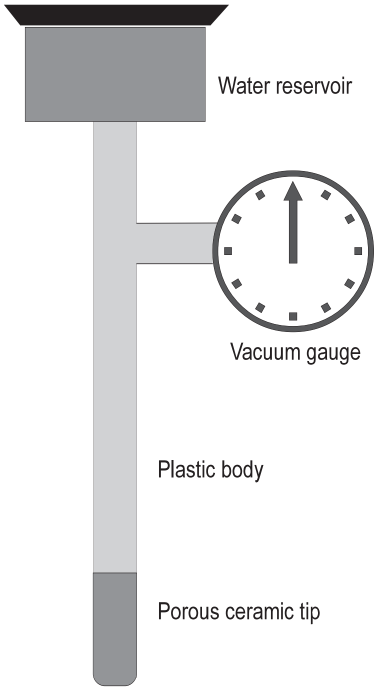

Figure 11. *Parts of a standard tensiometer*

Place tensiometers in the active root zone of the crop, about 50 cm from the base of plants in the row and where they will be reached by irrigation water.

Two tensiometers are required at each site. Different sites are required where there are variations in soil type and crop development. Normally, the upper (shallow) tensiometer would be inserted 15 to 20 cm deep and the lower (deeper) one 45 to 60 cm deep. The upper tensiometer is the main guide for timing irrigations. The duration of irrigation will be sufficient once water has reached the lower tensiometer, as indicated by a reduction in soil moisture tension on the gauge.

Read the tensiometers early each morning. Record and plot the figures on a graph so that you can see the crop's soil water use patterns. By keeping good records, you will have a much better understanding of your soil and the water use of your crop.

HINT

DPI has a useful booklet—*Water it right using tensiometers*—that takes the worry out of scheduling irrigation. See Section 6, *References* page 28.

Tensiometers are relatively simple instruments, but they need to be well maintained if they are to work properly. Without regular maintenance, they are likely to give false readings. The main requirements are:

- protecting tensiometers from damage in the plantation
- ensuring the tensiometer tube is filled with water
- treating organic growths in the tensiometer water
- recognising and repairing failures.

Capacitance sensors

Capacitance sensors measure the soil's ability to store electric charge, which is related to soil water content. The system uses multiple sensors installed in PVC access tubes to continuously monitor soil water. Computer software with it will generate graphs to guide irrigation scheduling. A particular reading in relation to actual soil moisture content or suction is not as important as the trends in soil water use patterns.

Capacitance sensors need to be correctly positioned, with the probe in the active root zone and the area that is being watered evenly by the irrigation emitters. Two access tubes and eight sensors are recommended per site. Irrigation consultants will install capacitance sensors for you and provide training. The device is accurate and costly (about $12 000) and provides continuous water monitoring.

A new version, the Diviner®, allows greater flexibility at much reduced cost (about $3500).

Neutron probe

Hollow tubes are inserted at various sites in the plantation. A radioactive source emits neutrons, which are reflected off water in the soil back to a receiver. Neutron probes are more useful for crops where the soil is allowed to dry out between irrigations. They cost more than $10 000, which limits use to irrigation consultants who can spread the cost over many farms. They also contain a potentially dangerous radiation source. Neutron probes are useful over a wide range of soil moisture and can measure effectively from 20 cm to deeper in the profile.

Neutron probe software is now available to allow similar scheduling capabilities as for Enviroscan.

Nutrition

Good fertiliser management is a vital component to achieving high yields. Both deficiencies and excesses of plant nutrients can adversely affect plant growth, fruit yield and quality. Careful fertiliser management is essential to ensure a balanced supply of all nutrients. The high rate of fruit production by papaws means that fruit removal draws large quantities of nutrients from the soil and plant system. The nutrient requirements of papaws under tropical, irrigated management are high.

Nutrient balance approach

The nutrient balance approach is the preferred method for assessing nutritional status over the life of the tree.

Table 7 shows the incremental increases of each nutrient to apply from one stage to the next. These amounts are for the nutrient (the element nitrogen, N) in the fertiliser, not the actual fertiliser. You need to increase these amounts according to the percentage of nutrient in the fertiliser. For example, urea contains 50% nitrogen, so multiply by two. (There is actually 46% nitrogen in urea but the percentage is rounded up to 50% for simplicity in this example.)

Table 7. *Nutrient requirements (kg/ha) to satisfy harvest removal and plant uptake in papaw at various ages for papaws grown in north Queensland. Yield is based on 115 t/ha*

Tree age	3.5 months	5 months	6 months	7 months	8 months	15 months	21 months
Nitrogen							
Uptake	0.86	4.21	6.65	23.5	43.3	124.8	248
Removal	0	0	0	0	10.8	82.2	187
Total	0.86	4.21	6.65	23.5	54.1	207	435
Phosphorus							
Uptake	0.1	0.91	2.42	7.52	7	10.4	44.6
Removal	0	0	0	0	2.5	8	30.4
Total	0.1	0.91	2.42	7.52	9.5	18.4	75
Potassium							
Uptake	1.8	11.1	30.2	55.2	103.5	187	362
Removal	0	0	0	0	18	108	306
Total	1.8	11.1	30.2	55.2	121.5	296	668

Table 7 Continued....

Tree age	3.5 months	5 months	6 months	7 months	8 months	15 months	21 months
Calcium							
Uptake	0.5	2.2	5.7	14.4	29.8	100	130
Removal	0	0	0	0	3.2	20	39
Total	0.5	2.2	5.7	14.4	33	120	169
Magnesium							
Uptake	0.3	1.8	4.3	9.7	18.8	87.3	99
Removal	0	0	0	0	2.2	15.6	34
Total	0.3	1.8	4.3	9.7	21	103	133

For example, over 21 months a total of 435 kg/ha of nitrogen (or 870 kg/ha of urea) is required for plant growth and that which is harvested and removed in the fruit. Between the age of seven and 15 months the plant would need (207 – 23.5) kg/ha = 183.5 kg/ha of nitrogen. To 'balance' the nitrogen application we need to know how much nitrogen is in the soil and apply fertiliser nitrogen as follows:

Fertiliser nitrogen to apply over 21 months
= 435 kg/ha – soil available nitrogen

Soil available nitrogen is complicated and difficult to measure but regular soil tests will help. For example, if 30 mg/kg of nitrogen is available in the soil, then for a rooting depth of 30 cm, over one hectare, the amount of nitrogen available is:

Volume of soil/ha x bulk density of soil x available nitrogen level
= (10 000 sq m x 0.3 m) x 1300 kg/cu m x 30 mg/1 000 000 mg
= 117 kg

This soil is assumed to have a bulk density of 1.3 g/cu m (1300 kg/cu m). Bulk density of soil is the mass of dry soil per unit bulk volume. The bulk is determined before drying to constant weight at 105°C.

Thus, for 21 months we would apply (435 – 117) kg/ha = 318 kg/ha of nitrogen. This is about equivalent to 636 kg/ha of urea.

To determine the application rate per tree, divide amounts shown in Table 7 by the number of trees per hectare.

Nutrient requirements for other soils can then be estimated by using Table 7. You need to know:

- plant age
- crop yield
- soil available nitrate
- potassium, phosphorus, calcium and magnesium levels
- soil density, if possible.

If you do not know these figures, assume that 1 ha of soil 30 cm deep holds 3900 tonnes of soil. The nutrient balance approach must use known soil reserves otherwise simply replacing nutrients that are removed by harvesting will be inadequate.

The balance approach can be improved by considering plant girth, or diameter, in centimetres across the trunk 15 cm above ground level. Figure 12 shows uptake of nutrients for growth and that removed for harvest for papaw plants. From fruiting onwards (about eight months or 8 cm girth), papaw plants rapidly increase nutrient uptake.

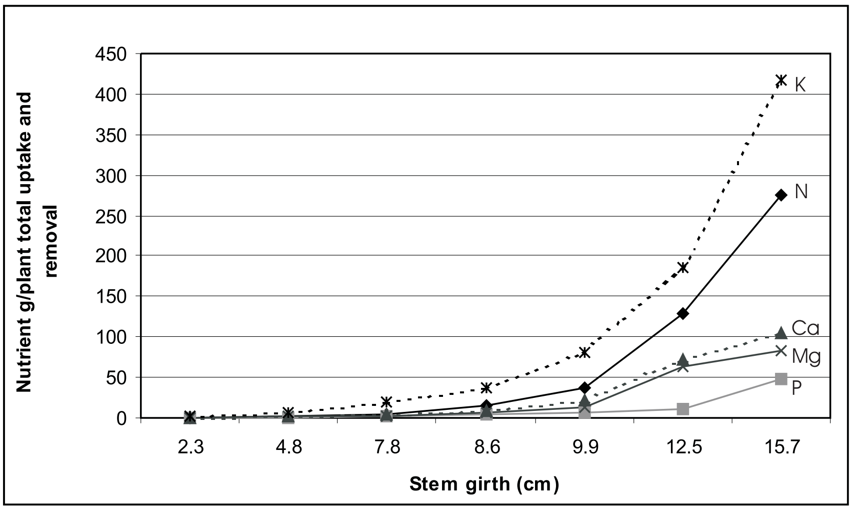

Figure 12. *Nutrient removal and uptake (g/plant) in relation to plant size as measured by stem girth*

Potassium is the most important nutrient for papaw production, followed by nitrogen, calcium, magnesium and phosphorus. The approximate ratio of application should be 9:6:2.2:2:1, except in cases of deficiency or corrections.

Regular leaf and soil testing can be used with a nutrient balance approach to produce papaws at an economically and environmentally safe and desirable level. Use the balance model and initial soil test results to work out the base amount to apply for each time period, that is one month, and modify this if leaf tests show deficiencies or toxicities.

Insecticide and fungicide application

Several major and minor pests and diseases attack various parts of the papaw plant and can cause major and even total crop losses. Well-timed and targeted treatments are required to protect the plant and its fruit. Good management of pests and diseases includes monitoring, timely spray applications and using an Integrated Pest Management (IPM) approach. This section covers chemical application technology in papaw. It is mainly directed towards insecticide and fungicide spraying.

Basic principles

The aim of insecticide and fungicide spraying is to displace the air around the foliage and replace it with air laden with chemical droplets. (Figure 13) This is not a problem while plants are young (less than 1.8 m high). Almost any machine will displace enough air to give adequate droplet capture. The objective, however, is to apply the registered chemical at the recommended rate which will produce effective pest or disease management without wastage.

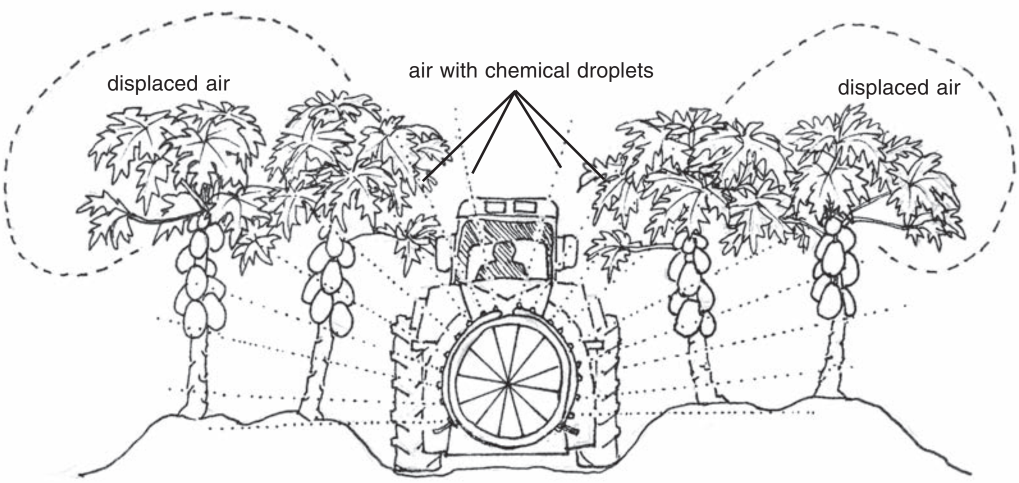

Figure 13. *Displacing air around foliage and replacing it with air laden with chemical*

Droplet capture on a target is the result of deposition or impaction and this will largely be dependent on droplet size. There is a continuous trade-off between droplet size, coverage and drift. Large droplets are less likely to drift, but smaller droplets give better coverage. Large droplets tend to fall rapidly out of an airstream and deposit on the ground or outside the plant canopy.

In mature crops considerable displacement needs to be achieved as the foliage (target) may be up to 4 m away from the sprayer.

Types of machinery

Three types of machines and equipment may be used, depending on the situation: axial flow, air shear and controlled droplet application (CDA).

Axial flow

Axial flow machines (Figure 14) have nozzles, which produce droplets. The droplets are carried to the target by the air created by the fan.

Ceramic hollow cone nozzles (for example, Spraying Systems TX®, Albuz hollow cone, etc.) are recommended for applying insecticides and fungicides. Hydraulic pressure forces the liquid into the nozzle where it swirls around and is forced out through the nozzle orifice. This produces the characteristic hollow cone-shaped spray cloud. The droplet sizes are smaller than those produced by other hydraulic nozzle types. Operating pressure is typically 5 to 15 bar pressure, with 10 bar being the standard.

While older disc type nozzles usually gave smaller droplets at higher pressure, modern ceramic hollow cones tend not to change the droplet size to the same extent with various pressures. Droplets of 100 to 200 microns in diameter give best results. Most modern nozzles will achieve this. Information on droplet size can be obtained from the nozzle catalogue and manufacturers.

It has been standard practice to use the same nozzle in all locations on the sprayer. In practice much better results can be achieved by using higher output nozzles at the top of the machine than at the bottom (at the 10.00 and 2.00 positions, Figure 15). The result will be a higher proportion of the chemical on the target.

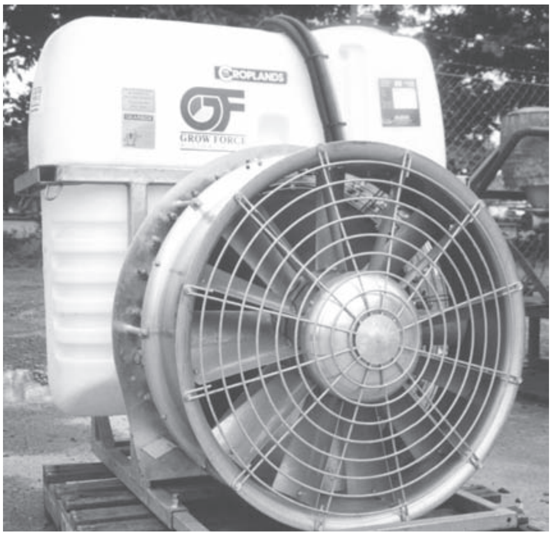

Figure 14. *Croplands axial flow airblast sprayer*

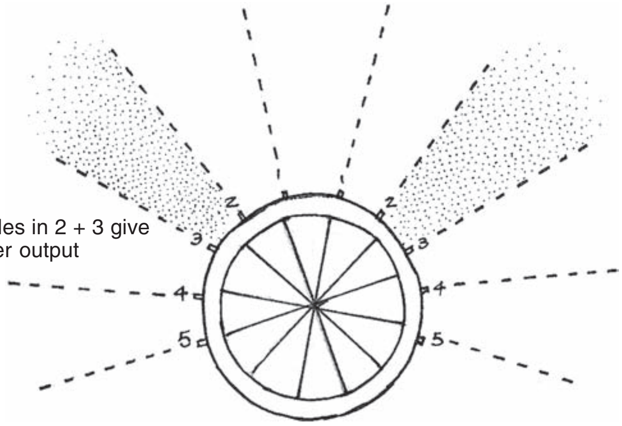

Figure 15. *Nozzle array showing different outputs*

The Hardi SVP Maxi is an excellent machine for delivering variable nozzle outputs. It also has the added advantage of adjustable air direction (Figure 16).

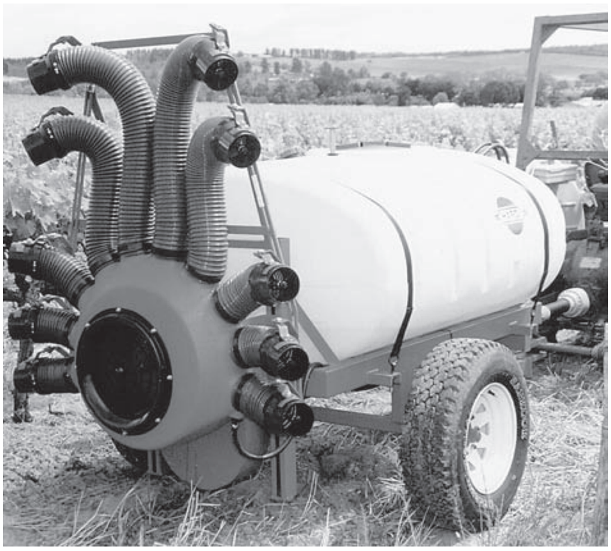

Figure 16. *Hardi SVP Maxi mistblower*

Figure 17 shows an axial flow machine with variable nozzle array.

The volume of liquid per hectare for papaw grown in double rows should be at least 150 L/ha to achieve adequate coverage. The standard volume is about 200 L/ha.

Nozzles wear rapidly so they will need regular replacement and calibration. Check outputs against manufacturers' recommendations. Replace nozzles if output varies by more than 10% of specification.

Air shear (misters)

Air shear machines have a high speed centrifugal fan which displaces air and forms droplets.

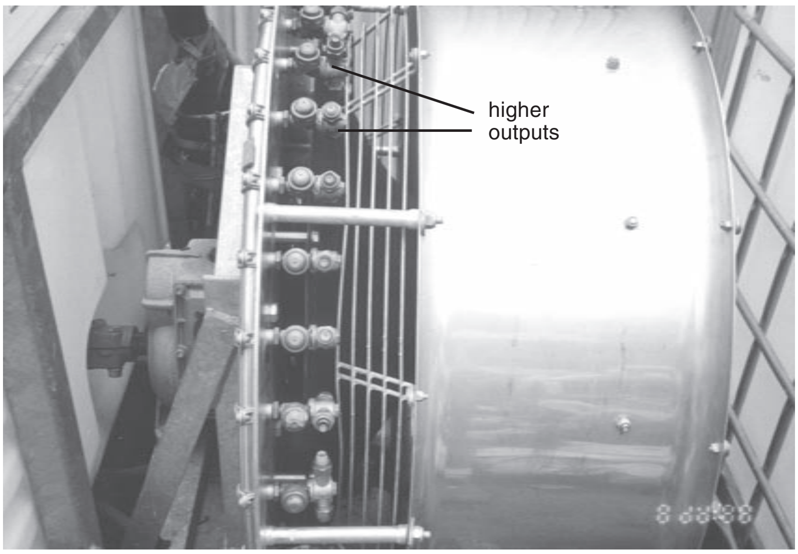

Figure 17. *Variable nozzle array on axial flow machine*

With this system, a high velocity airstream is used to break up a stream of liquid containing the chemical into small droplets. The air passes through a venturi, where it speeds up to about 300 km/h. A stream of chemical at low pressure is placed in the airstream and droplets of about 75 to 150 microns are produced. The air then carries the droplets to the target (Figure 18).

Air shear machines (Figures 19 and 20) are commonly called misters and are used to apply insecticides and fungicides.

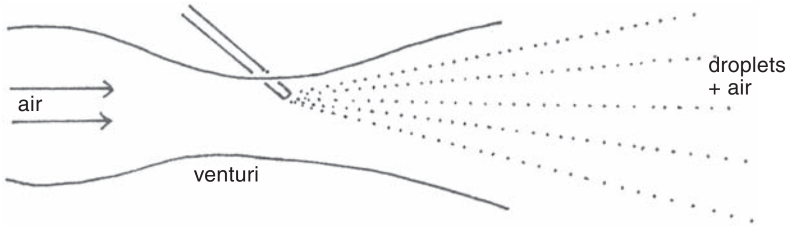

Figure 18. *Venturi creating droplets*

Figure 19. *Silvan electromiser air shear spray head*

Figure 20. *Silvan turbomiser. This is a bigger air shear machine particularly suiter to large plantations*

A spray head directs the air and droplets towards the target. The droplets produced are a more uniform size, so lower volumes (75 to 100 L/ha) can be used.

The air speed is critical. Manufacturers normally recommend 540 rpm PTO. If lower PTO speeds are used the droplets become too large for insecticide or fungicide application.

Controlled droplet application (CDA)

Commercial CDA sprayers use centrifugal force to produce droplets. Liquid is fed onto a rotating disc (Micromaster) or rotating cage (Micronair) to produce a very narrow droplet spectrum of about 50 to 150 microns, depending on the set-up. The system is capable of producing a narrow range of droplet sizes, providing the flow rate and rotation speed are correct. For this reason spray volume for papaws can be as low as 30 L/ha for double rows.

Figure 21. *Lenswood Airmist micronair airblast sprayer*

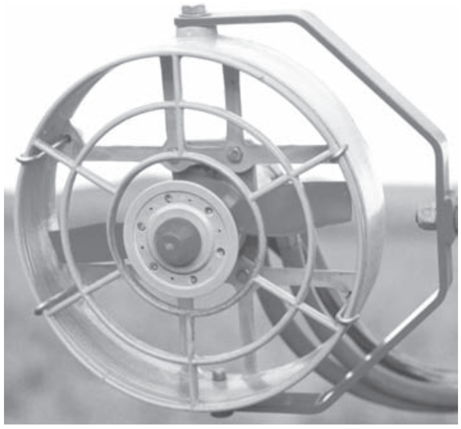

Figure 22. *Micromaster CDA atomiser. This unit is hydraulically driven*

Air is displaced by either a hydraulic fan on the sprayhead assembly or, in the case of Micronairs, by attaching the atomiser to the fan of an axial flow air blast sprayer (Figure 21). Either system works well. The advantage of a hydraulic head is that the air and droplets can be directed down on the crop and smaller horsepower tractors are required to drive the equipment (Figures 22 and 23).

The advantages of the CDA method are:

- less chemical applied overall due to the narrow droplet spectrum produced
- more droplets of optimum size per volume of spray used
- droplet sizes appropriate to the product and target can be produced.

Good filtration minimises downtime associated with all spraying equipment. The suction filter should be large capacity with finer mesh (for example, 120 mesh) than the nozzle filters. It is easier to clean one large capacity filter than several smaller ones. Pressure-in-line filters may be more useful and easier to manage than individual nozzle filters.

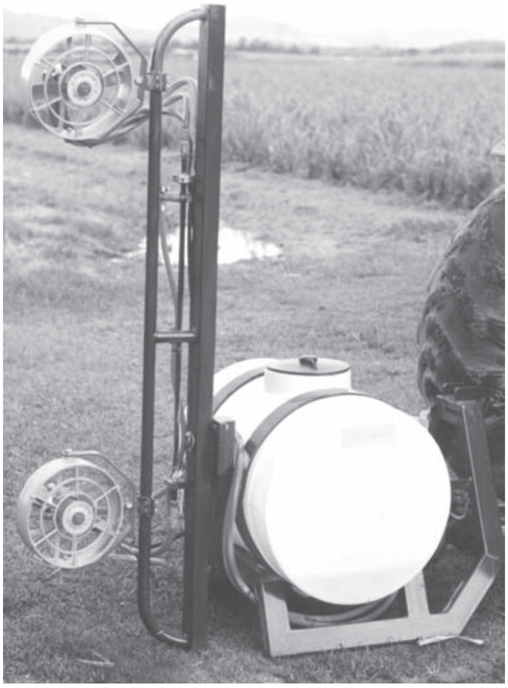

Figure 23. *Micromaster CDA sprayer*

Water quality

Pesticide performance can be adversely affected by the quality of the water. Ideally water should be clear, colourless, odourless and neutral in pH. When available, rainwater is the best to use. Excessive solids will block nozzles, and increase wear of components and binding of the chemical to the suspended materials, with subsequent loss in its effectiveness. If poor quality water has to be used, spray immediately after mixing and ensure adequate agitation throughout the whole operation.

Sprayer set-up and calibration for mister/airblast sprayer

Here are some tips in setting up and calibrating your spray equipment.

- Determine if there is sufficient air displacement. Use clean water and operate the machine at different fan speeds and blade settings (axial flow).
- Attach surveyor's tape to uppermost leaf. The tape should just move as the machine passes under the canopy. If it flutters or moves violently, too much air is being displaced. If it is not moving, select a lower gear. Remember air displacement is a function of volume of air and forward travel speed. While most machines displace enough air at 5 km/h, the upper limit for some smaller axial flow units is 3 km/h.
- Attach water sensitive paper to the targets on both top and bottom of the uppermost leaf and growing point of the plant. Observe coverage. If coverage is inadequate, increase pressure and or volume of spray or travel slower. When satisfied with the coverage, record pressure/flow gear and revolutions per minute (rpm, usually 540) and speed (metres/minute).
- Attach hoses to each nozzle. With the airshear and the CDA, the hose is attached to the chemical delivery pipe. Record output for one minute in a 2 L jug.

Example

Total output of all nozzles	8.1 L/min
Row spacing	6.0 m
Speed (distance, m/minute)	90 m/min

Area = Row spacing x distance/minute

= 6.0 x 90 sq m/min

= 540 sq m/minute

Using a calibration formula, the output is:

$$\frac{\text{Total output (L) x 10 000}}{\text{Area (sq m)}}$$

$$= \frac{8.1 \text{ x } 10\,000}{540}$$

= 150 L/ha

How much chemical do I put in the spray tank?

Example

Chemical (for example fungicide) at a recommended rate of 2.0kg/ha. Tank size is 600 L.

Formula:

$$\frac{\text{Tank size x label rate}}{\text{Calibrated output/ha}}$$

$$= \frac{600 \text{ x } 2.0}{150}$$

= 8 kg fungicide /tank

Safety requirements

Read the label. It provides advice on safe handling, storage and use. The chemical's identity and toxicity are also given. Material Safety Data Sheets (MSDS) supplied by chemical manufacturers provide detailed information on health hazards, precautions for use, safe handling, and chemical data. Information on storage and disposal procedures is also included. MSDSs are available from chemical suppliers.

These are the minimum safety requirements for on-farm storage of agricultural chemicals:

- A locked, well-ventilated and well-lit room or separate storage area with an impervious floor and impervious shelving.
- Storing chemicals in original containers, with labels intact. Relabel if label comes off.
- Never storing chemicals in food or drink containers.
- Storing chemicals away from foodstuffs, eating and packing facilities.
- A fresh water supply.
- A fire extinguisher.
- A spill kit, for example a bucket with a bag of lime and/or sawdust; chemical spills should not be diluted with water.
- A sign—Danger Agrochemicals.
- A first aid kit on the farm.

- Mixing and measuring chemicals in a well-ventilated area.
- Not storing personal protective clothing and equipment in the chemical store.
- Not burning containers.

Correct storage and disposal of chemicals will ensure your health and safety and that of others.

Key points

Before spraying:

- check that all equipment is in good working order
- make sure that all equipment is properly calibrated.

When applying pesticides and fungicides:

- spray with some air movement, between 3 and 8 km/h
- select the correct nozzle type
- use only sufficient water volume of an acceptable quality
- only spray under conditions that are NOT likely to cause spray drift
- use appropriate safety equipment.

If you are using a commercial operator, ensure that they are given full details of the job, including area to be sprayed. Make sure that chemicals are mixed and applied according to information on the label. Always take adequate safety precautions when handling and applying chemicals.

All users of agricultural chemicals should keep records, which should include:

- date and time of application
- chemical used and rate
- crop, pest and area sprayed
- weather conditions
- equipment and operating conditions.

There are additional requirements for endosulfan usage. See residue management on the label and, in particular, withholding and re-entry periods. Endosulfan is a restricted product and can only be supplied to or used by an authorised person. Observe mandatory and advisory requirements for use of this chemical.

Insect and mite management

Managing insect and mites in papaw is a very important part of successful crop production. Different kinds of pest damage can occur at all stages of plant growth to either the stem, leaves or fruit. Many insects have the potential to reduce fruit quality and yield, so knowledge of how to successfully manage these pests can save you a lot of wasted time, effort and money. Here are the key things that you should consider about insect and mite management.

Past approaches to insect and mite control

Traditional or past approaches to insect and mite control relied on the use of routine calendar sprays of registered chemical insecticides. This method of pest control has several problems:

- It is a waste of time, effort and money if pests are not present.
- Even if the pests are present, they may not be in sufficient numbers to cause economic damage to the plant. In this situation the cost of spraying is usually much higher than the benefit obtained from controlling the pest.
- Unnecessary sprays increase the risk of insecticide damage to fruit.
- Calendar sprays are a very expensive method of insect control because many applications of insecticides may be needed.
- Some sprays may destroy beneficial and predatory insects that normally help control pests.
- Insects that are not normally considered pests (for example mites) become a major problem due to a lack of beneficial insects.
- Insects quickly develop resistance by constantly being exposed to the same insecticides. New insecticides need to be developed and this is not easy. They are usually more expensive than the previous products.
- Excessive exposure to insecticides can be toxic to human health.
- Chemical residues on fruit are creating growing consumer resistance to the use of chemicals.

- Overuse of insecticides may result in environmental contamination and could be dangerous to native fauna.

Integrated Pest Management (IPM)

The modern approach

Current research in pest control is complex and focuses on trying to understand the insect's environment and ecology. IPM is the combination and integration of complementary pest control practices that rely on chemicals as a last resort.

These are the main components of an effective IPM program in papaw:

Pest identification, which is very important in determining appropriate control practices.

Monitoring, which is critical to the implementation of any IPM program. Trees are monitored weekly in the growing season to check pest and beneficial insect populations within the crop. Monitoring helps you to know when to apply insecticides or other pest control methods at the most effective and economical times.

more info
Pest consultants
Contacts
Section 6 page 5

Biological control, which relies on the use of predatory insects and other fauna to control damaging pest populations. To be effective specific 'softer' insecticides should be used selectively. There are many important predators, parasites and parasitoids that are very effective in controlling pests within a papaw plantation. Care should be taken when choosing to apply insecticides so as not to kill these beneficial insects.

more info
Beneficial insects
Section 5
Problem solver

Cultural control, which uses different farming practices to control pests. They include crop hygiene (for example, removal of infected planting materials), early harvesting (avoids fruit fly stings) and maintaining plant vigour (allows plants to grow back very quickly after an insect or mite attack).

Mechanical control such as mowing. Some pests feed and build up on certain weeds, and mowing destroys this habitat.

Chemical control, which is used as a last resort when pest populations are too high. It is based on monitoring thresholds (the maximum number of pest insects that can be tolerated in a crop before it is economically damaged). Insecticides are only used if the level of pest populations is getting too high and the beneficial insect populations are low. The use of monitoring and strategic spraying is very cost effective. Insects are treated only where they are located. This is a very good method for conserving beneficial insect populations.

Monitoring

Pest monitoring is the most critical component of IPM and is based on economic threshold levels. The economic threshold level is the insect population level that causes damage equivalent to the cost of control. When insect populations reach this point, a control method is carried out. Monitoring also allows you to record pest hot spots for strategic spraying. You will need training and experience for effective monitoring. Professional pest monitoring services are available.

Monitor by thoroughly examining a set number of trees at random at different locations around the crop and record the number of pests and beneficial insects at each sample site. Spray when the average number is equivalent to or exceeds the economic threshold level (Table 8). Climatic conditions, insect mobility, duration of life cycle, potential crop damage and crop stage determine the frequency of monitoring. Insects are more active at higher temperatures and therefore require more frequent monitoring during spring and summer. The use of a 10x hand lens or small microscope is very useful for monitoring.

Table 8. *Tree sample size and action threshold levels for major pests in papaw*

Pest	Number of trees per area	Action levels
Fruitspotting bugs *(Amblypelta lutescens lutescens* and *Amblypelta nitida)*	100 / 0.5 ha	Spot spray insecticide if there is fresh damage to 3 trees / 100 trees.
Two-spotted mite *(Tetranychus urticae)*	30 / 0.5 ha	Examine new fully expanded leaves on five adjacent trees at six random locations. Apply miticide to terminals if damage is present on 50% of leaves.
Broad mite at *(Polyphagotarsonemus latus)*	30 / 0.5 ha	Examine growing points on five adjacent trees six random locations. Apply miticide to terminals if damage is present and mites are still present.
Oriental scale *(Aonidiella orientalis)*	20 / 0.5 ha	Examine the trunks and five fruits on 20 widely separated trees. Parasitism levels need to be checked. Check 20 large and 20 medium scale for parasitoids on each of 10 fruit. Apply mineral oil if parasitism levels are lower than 70%.
Cutworms	30 / 0.5 ha	Examine roots around damaged plants to a depth of 100 mm for larvae. Apply insecticide if one or more larvae are found on five plant groups.
Yellow peach moth larvae *(Conogethes punctiferalis)*	30 / 0.5 ha	Examine growing points and fruit on five adjacent trees at six random locations. Spray if 1% of fruit or trees are infested.

Biological control and strategic spraying of papaw pests

Integrated pest management in papaw relies strongly on biological control, which is very effective in managing several important potential insect pests. Active monitoring is critical and insecticides must be used carefully and sparingly so as not to disrupt beneficial insect activity (Table 9). At certain times of the year pest populations may need to be controlled and insecticides are used as a last resort.

Most parasitoids prefer healthy well foliaged trees to shelter them from extremes of heat and low humidity. Their activity can be enhanced by growing healthy plants, using cover crops or mulches between rows and avoiding dusty tracks. Prolonged periods of temperature extremes and dust are harmful to many beneficial insects.

Strategic spraying will minimise damage to beneficial insect populations. Here are some useful tips:

- Monitor pest and beneficial insect populations.
- Use insecticides only as the remaining option when economic threshold levels have been reached.
- Use chemicals that are 'softer' on beneficial insects so they may remain active in your environment.
- Spot spray hot spot areas and target specific areas on the plant where the pest is known to occur.
- Regularly maintain and calibrate spray equipment to achieve maximum insecticide coverage to the targeted areas within your crop.

more info
Beneficial insects
Section 5
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Table 9. *Common pests and beneficial insects of papaw*

Insect pests	Beneficial insects
Major	
Fruitspotting bugs	Parasitic wasps *(Gryon meridionis, Anastatus* spp., *Ooencyrtus* sp.*)* Assassin bug *(Pristhesancus plagipennis)*
Two-spotted mites	Black lady beetle *(Stethorus* spp.*)* Predatory mites *(*Phytoseiulus persimilis, Amblyseius spp.)* Blue lady beetle *(Halmus ovalis)* on egg stage
Minor	
Broad mite	Black lady beetle *(Stethorus* spp.*)* Predatory mites *(*Phytoseiulus persimilus, Amblyseius* spp.*)*
Cutworms	No known beneficial insect
Fruitpiercing moths	Parasitic wasps *(Ooencyrtus* sp., *Trichogrammatoidea* spp.*)* Beetle (*Telenomus* spp.*)*
Grasshoppers	Parasitic wasp *(Scelio flavicornis)* Assassin bug *(Pristhesancus plagipennis)*
Oriental scale	Parasitoids *(Comperiella lamniscata, *Encarsia citrina, *Aphytis melinus)* Caterpillar *(Batrachedra arenosella)* Predatory lady beetles *(Telsimia* sp., *Lindores lophanthae, *Chilocorus baileyi, *Chilocorus circumdatus)*
Soft brown scale	Parasitic wasp *(Metaphycus* spp.*)*
Queensland fruit fly	Parasitic wasp *(Opius* spp.*)*
Yellow peach moth	Tachinid fly *(Argyrophylax proclinata)*
Loopers and other caterpillars	Predatory shield bug *(Cermatulus nasalis)* Assasin bugs (*Pristhesancus plagipennis*, miscellaneous parasitoids)

* Commercially available

Disease management

Managing diseases is a difficult aspect of growing papaw. There are several serious diseases and some will inevitably occur during the life of the crop. Some will have the potential to destroy fruit yield and quality. Here are the important things you need to know.

Phytophthora

Cause

Phytophthora fruit, stem and root rot is caused by the fungal organism *Phytophthora* spp. It is a major problem on the wet tropical coast of north Queensland.

Symptoms

Fruit rot

Water-soaked spots develop on mature fruit and enlarge to produce large lesions covered by a white fungal crust. The fruit may shrivel, mummify and drop. Green fruit, though regarded as resistant, can be infected by *Phytophthora* through wounds.

Stem rot

Small, water-soaked spots develop on the stem around fruit and leaf scars, particularly in the region of fruit production. The infected areas enlarge and can completely girdle the stem of young trees, causing wilting and eventual death of the top of the plant. Older plants may not be completely girdled but the stem is weakened and easily broken by wind.

Root rot

Phytophthora root rot causes a yellowing and collapse of the leaves, starting with the older leaves and progressing up the plant. The young crown leaves eventually wilt and the plant dies, usually within a few days. Some plants may linger for long periods but fall easily, especially if carrying fruit. In young trees the entire root system shows a soft, wet rot extending into the trunk. In older plants the taproot is usually decayed and the surface roots may also be affected. Root rot is favoured by poorly drained soils.

Source of infection and spread

The *Phytophthora* fungi survive in soil and on rotting fruit and stems where fungal sporangia (reproductive organs) are produced in the presence of water. Wind-blown rain and water splash carry the sporangia to papaw plants, where they germinate and infect fruit and stems through either wounds or undamaged tissue. The fungi can also spread rapidly in surface water, and in soil adhering to machinery and animals. The disease can cause major losses of fruit and plants after prolonged wet weather. Root rot is a major problem in replant situations.

Control

Fruit rot

more info
Control methods
Problem solver handy guide

- Remove and destroy all fallen fruit and trunks of trees.
- Apply recommended fungicides during wet weather.
- Avoid bare soil as much as possible to prevent soil splash. Maintain grass between the rows and use plastic mulch around trees.

Root rot

- Choose only well-drained sites for planting papaw.
- Plant only disease-free trees.
- Ensure adequate surface drainage by constructing diversion and interception drains. Plant papaw on mounds (0.75 to 1 m high) positioned to allow rapid removal of surface water.
- We do not recommend that growers replant areas that had *Phytophthora* diseases in the past.
- Avoid the introduction of the fungus into clean areas.
- Avoid excessive irrigation.

No chemical controls are available for *Phytophthora* root rot.

Black spot

Cause

Black spot is caused by the fungus *Asperisporium caricae.* Papaw is the only known host.

Symptoms

Initial symptoms are water-soaked spots on the upper surface of leaves. These develop into greyish-white spots with corresponding black pustules on the under-surface of leaves.

Symptoms on fruit begin as small spots that turn black and enlarge up to 3 to 5 mm in diameter. The tissue beneath the spots becomes corky, but fruit rot does not develop.

Spread

Disease incidence is worse during the cooler months. Wind and wind-driven rain spread the fungal spores. To reduce disease pressure, remove severely infected leaves and fruit before starting a spray programme.

Use the following strategy to delay the resistance of black spot to fungicides as long as possible:

- Ensure spray application equipment is properly maintained and calibrated to give good coverage.
- Start your spray programme early (February to October).
- Use a protectant fungicide plus wetting agent.
- Under favourable weather conditions for disease development (cool and damp), apply a systemic fungicide.
- Apply no more than five applications of a systemic fungicide per season.
- Apply chemicals at 7 to 10 day intervals.

Ringspot

Cause

Ringspot is caused by papaw ringspot virus.

Symptoms

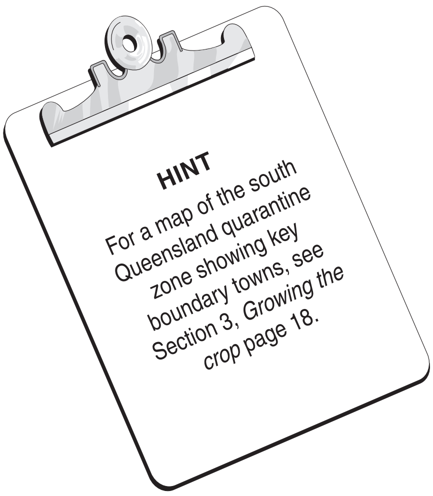
The earliest symptoms are a yellowing and vein-clearing of the young leaves, followed by a very conspicuous yellow mottling of the leaves and sometimes severe blistering and leaf distortion. Dark-green streaks and rings also appear in the leaf stalks and stems.

The disease derives its name from the striking symptoms that develop on fruit. These consist of concentric rings and spots or C-shaped markings that are a darker green than the background-green fruit colour. Symptoms persist on the ripe fruit as darker orange-brown rings.

Vigour of trees and fruit set is usually reduced, depending on the age of the plant when infected. Fruit quality, particularly flavour, is also adversely affected. Ringspot is common in home garden plantings in the northern suburbs of Brisbane and is also present in Bundaberg.

Spread

Papaw ringspot virus is spread by aphids, small sap-sucking insects that are common in tropical and subtropical regions. The virus also infects cucurbits, for example pumpkin, marrow, squash and zucchini. These species are also hosts of the cucurbit strain of papaw ringspot, which is widespread and serious on cucurbit crops in Queensland. The cucurbit strain does not infect papaw.



Control

Ringspot is difficult to control. Attempts to reduce disease levels by controlling aphids with insecticides have been ineffective. Resistant or tolerant cultivars may become available.

A quarantine area was proclaimed in 1991 in an effort to restrict the spread of papaw ringspot. Papaw plants and cucurbit seedlings cannot be moved out of the south Queensland quarantine zone.

Diseased trees should be destroyed. They are unlikely to produce a good crop and also provide a source of infection for further spread of the virus.

Dieback

Cause

Preliminary indications are that dieback is caused by organisms called phytoplasmas.

Symptoms

Initial symptoms are a bunching and yellowing of the inner crown leaves followed by a slight bending of the stem tip. One or two crown leaves shrivel and die, and a dark necrotic lesion develops where these leaves join the stem. The first leaf to wilt generally has an etched appearance on the under-surface due to a darkening of the smaller veins. The rest of the crown leaves eventually die and the stem begins to die back from the top. The older leaves may yellow but generally remain in position for some time.

Latex is usually absent from the stems and fruit. Fruit may become flaccid or drop and often show severe fungal spotting. During cold weather, tip bending may be absent and the crown dies slowly.

Spread

Collection and laboratory analysis of insects found in papaw plantations has so far failed to detect any phytoplasmas in these insects, though leafhoppers are usually regarded as the most likely carriers.

Importance

Dieback occurs each year with serious epidemics every few years in early summer and autumn, and then often simultaneously throughout a district. Severity varies markedly between districts and farms. The disease appears to be more serious in central and southern Queensland.

Control

There is no prevention, but trees affected when growing vigorously may recover if the stem is cut back below the dead area. Cut back where the leaf scars are close together. Solid partitions in the stem at this point prevent rainwater entering the otherwise hollow stem, and reduce the likelihood of rotting.

Other diseases

more info
Details of these diseases
Section 5

Other diseases of papaw include brown spot, powdery mildew, ripe fruit rots, yellow crinkle and mosaic.

Fruit handling

The profitability of papaw production is dependent on a strong commitment to marketing quality fruit. Only attractively presented, blemish-free fruit with a reputation for shelf life and flavour will achieve premium prices.

Handle papaw with great care to prevent fruit damage. Blemishes from rough handling may not show immediately but may appear after the fruit has reached the market. Train and supervise packing staff well.

Handling fruit in the packing shed

Ensure the papaws are firmly placed in position in single layers in polystyrene or padded containers after picking. Specialised padded roll on–roll off trailer designs are becoming more common. These are more suitable for higher production volumes and minimise the amount of fruit handling. Roads must be well maintained to minimise bruising in transit from field to packing shed.

The type of handling system and degree of mechanisation implemented in a packing shed will be determined primarily by shed capacity and throughputs.

Fruit washing

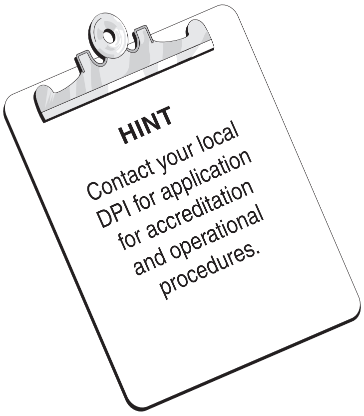
Washing removes dirt, residue and pests still present on the fruit surface. Packing wheel systems, conveyor systems and tanks are used. Smaller sheds prefer packing wheels, which are compact, relatively simple and cheap to install. Packers sort the fruit.

Fungicide treatment

Fruit rots are a major problem with untreated papaw. Remove any papaws where rots have already begun. Spray the fruit with prochloraz (Sportak, Mirage, Protak 450EC) at 55 mL/100 L of water for two minutes.

Chlorine used with the Chlorman® injector system is registered for postharvest treatment but specific data on its effectiveness for control of papaw postharvest rots are not available.

Interstate Certification Assurance (ICA)



Specific postharvest fruit fly treatments may be necessary, depending on where you send your fruit and the type of papaw. These are listed under specific ICA protocols for each state and type of papaw.

The DPI, in conjunction with relevant industry groups, has developed a range of operational procedures covering specific treatment, grading or inspection operations to facilitate market access for papaw. Under an ICA arrangement each individual business may enter into an agreement with DPI to undertake a specific operational procedure.

Flood spraying and dipping of fruit must be the last treatment before packing.

Some bisexual varieties may require fumigation with methyl bromide before entry is allowed into Tasmania, Victoria and South Australia.

A business seeking accreditation for an ICA arrangement should apply for accreditation at least 10 working days before the intended date of commencement of certification of produce.

Packing

Packing is a manual and somewhat specialised operation. Although packer productivity will depend largely on the skill of the packer, it can be enhanced significantly by considering the ergonomics of the packing station. In even the smallest sheds, packing is usually a continuous operation.

The packing station should be as close as comfortable to the wheel or belt for easy access to fruit. A ready supply of cartons should be within easy reach. Rollers running immediately from the packing platform to a packed product conveyor assist removal of packed cartons. Packing stations need to be furnished with socks, butcher's paper and/or paper wool.

In the current sheds in Queensland there is no consistency in the height of the packing platform relative to the belt or wheel. Adjustable platforms to suit the preference of the packer can increase productivity and reduce posture problems. Growers devising innovative roll on–roll off systems may be able to incorporate adjustable platforms more easily.

Papaws are generally graded as they are packed. Sort, select and pack fruit that are clean, sound, well formed and of a uniform size and colour. Discard fruit that have defects, for example cuts and broken skin, sunburn, spray deposits; are misshapen; covered with fruit rots; or have stem-end rot and *Phytophthora*. Pack papaws into 10 kg, 30 L or 18 L cardboard boxes, depending on the fruit type and market preference. The variety Sunrise Solo is mainly packed in 18 L cartons.

Wrap papaws with socks, butcher's paper or coloured fruit wraps as arranged with the wholesale agent. Fruit stickers help to identify fruit. Many growers have their own stickers to try to develop a grower identity in the market place. Mark boxes and ensure that you record all the necessary data required under the various ICA arrangements.

Various trailer systems are being designed and tried to encourage more grading in the field, allowing packers to be more efficient.

Pallet stacking and handling

Palletisation of packed cartons has been fully adopted by industry. Stacking becomes awkward as the stack grows and a raised board or stepladder is usually necessary to access the top of the stack. This situation is not ideal as it presents added workplace risks and becomes less efficient.

more info

Diagram of pallet stacking
Section 3 page 46

Hydraulic pallet platforms are available, allowing the operator to lower or raise the stack to maintain a comfortable working height. Stacked pallets should be taped, strapped, netted or secured with corner stays to prevent sideways movement.

Pallet handling

Pallets loaded with packed fruit or packing material will need to be moved throughout the shed. In smaller sheds manually operated pallet jacks are used, but a fork-lift is more efficient for larger sheds. Fork-lifts or a proper loading bay are required for all sheds if a transport company is picking up fruit from your property.

Refrigeration

Check with your wholesale agent to determine the fruit maturity and transport requirements. Fluctuations in temperature must be avoided to ensure even ripening in cool storage and an even presentation on arrival at market.

Refrigeration may be needed, depending on the stage of ripeness of picked fruit.

The optimum conditions for the storage and transport of papaw are a temperature of 13°C and a relative humidity of 90%.

Refrigerated transport units are not designed to lower the core temperature of fruit, but simply to maintain a set temperature. Fruit that is to be transported at 13°C must be precooled before shipment. Also, a refrigerated unit containing both precooled and uncooled fruit will not operate efficiently. Remember, for best quality, cooling conditions must be maintained throughout the supply chain.

Transport

Papaw can produce ethylene even when green without obvious colour change. Ethylene may cause premature ripening of some products such as unripe banana, mango, avocado and tomato, and may affect other products such as potato, sweet potato, squash, cucumber, melons and leafy vegetables. Where possible avoid co-transport of papaws with these ethylene-sensitive fruit and vegetables.

Select a transport operator with a reputation for reliability and careful handling of fruit. Fruit can be transported at ambient temperature (dry) for short distances to market, or refrigerated at 13–15°C for long distances to market.

Use a covered vehicle and ensure the fruit are secured if you have to transport your papaws to a central depot.

Ripening

For best quality and presentation, papaw is usually picked mature green and artificially ripened on the farm or by the wholesale agent before delivery to markets. Fruit is usually ripened with ethylene gas in special ripening rooms though a variable temperature system can be used.

When do you ripen papaw?

Papaws are ethylene ripened during the cooler months. Ripening under controlled conditions is faster, produces an even golden colour and gives a more consistent fruit quality. Harvesting papaw when they begin to colour and then ripening with ethylene also reduces losses from fruit rots and birds.

Terminal markets have temperatures significantly less than in the growing areas, which leads to slower ripening. Papaw can be ripened on the farm or on arrival by the wholesale agent. Check with your market agent on the ripeness of fruit required at arrival.

Ethylene ripening is usually not necessary during the warmer months.

Some tips on ripening papaw

Follow these useful tips if you choose to ripen papaw on the farm.

- The room should be insulated and airtight. A 3.5 m x 2.5 m x 2.5 m room with shelving has enough capacity to ripen 300 cartons a week. If a trickle ethylene system is used, the room will also require ventilation ports.
- Most fruit should be ready to pack after 12 hours in the ripening room. If they are still not sufficiently coloured after 36 hours, they were picked too green and should be discarded.

Ripening

Fruit are picked mature green. This means that fruit must be ripened before marketing in an airtight room with ethylene or Ripegas® (9% ethylene) to break down the chlorophyll in the skin. Ethylene is a colourless, sweet-smelling gas produced naturally by fruit as they ripen.

Cold rooms may be modified to double as ripening rooms. Since cold rooms are constructed for minimum leakage of heat and air, great care has to be taken in operating them as ripening rooms. Temperature control, maintenance of ethylene concentration, air circulation, ventilation and expulsion of sufficient air need very careful control.

The cooling function of the room may be needed during the early part of the season to maintain the correct temperatures for ripening.

Ethylene ripening

The major requirements for ethylene ripening are:

Accurate temperature control. Optimal temperature for ripening papaw is from 29°C to 32°C. A thermostatically controlled heater should be used. Heating capacity should be sufficient to raise the fruit temperature to this range within 12 hours.

Adequate air circulation. A fan with a capacity of at least one room volume per minute is necessary for effective temperature and humidity control, and distribution of ethylene.

Humidity control. The relative humidity should be maintained between 85 and 90% to minimise fruit moisture loss. Humidification is necessary in most ripening rooms. Either steam or a fine water spray into the room atmosphere can be used.

Ethylene injection. Ethylene can be injected using either the trickle or shot system. The trickle system is preferred as it is safer and gives greater control over gas concentration.

Ripening methods

The two ripening methods used are the trickle system and the shot system.

Trickle ethylene system

The trickle system is used in modern packing sheds and is the recommended method. The best type of room is one made using masonite lining inside and out with a sheet of sisalation in between. The best rooms are located inside a shed with a space between the wall of the shed and the room.

A trickle of ethylene gas is continuously bled into the room's incoming fresh air stream to maintain 10 ppm concentration. The gas is released into the room at a controlled rate of flow through a pressure regulator and metering system.

An airflow and ventilation system circulates the room air, introduces a small volume of fresh air and exhausts a similar volume of room air. Air circulation fans run continuously during trickle ethylene ripening. The system operates automatically. With trickle ripening, fruit ripens faster and fruit colour and quality is superior.

Shot ethylene system

The shot method uses a single dose of ethylene three to four times within 24 hours. The room must be ventilated before each new dose. A shot of ethylene is injected into the ripening room to establish an initial concentration of 200 ppm (1 volume of ethylene to 5000 volumes of room air). The usual injection point is through the room wall behind the room fan. Electric equipment should be flame-proof for this system.

Carbon dioxide can accumulate in airtight rooms and cause slow or abnormal ripening. Ventilate the room by opening the doors with the fan operating for at least five minutes every 12 hours and then reinject with ethylene.

Safety

Ethylene is flammable at concentrations between 31 000 and 320 000 ppm in air. Compressed cylinders of ethylene are potential hazards and must be handled safely. Electric equipment should also be flame-proof where the shot system is used.

Variable temperature ripening

Varying the temperature is an alternative method to ethylene ripening. The temperature is held for 12 hours at 32°C, followed by 12 hours at 20°C and if necessary, for another 12 hours at 32°C.

Marketing

The current Australian consumption of papaw is significantly lower than that for citrus, apples, pears, bananas and melons, so there is room for market expansion. Growers will not be able to cash in on this advantage, however, unless the product is properly marketed. There are five important issues.

The need for better marketing

The marketing of papaw in Australia has changed for several reasons:

- The potential problem of oversupply on the domestic market cannot be avoided as the volume of production increases, making the market more competitive. To maintain a profitable margin, growers will need to be more active in searching out new market opportunities in Australia and overseas and strongly promote the product to consumers.
- The changing face of wholesale fruit marketing has seen supermarkets beginning to dominate the management and distribution of the commodity. This will move the focus away from the central wholesale markets to more direct buying or brokering arrangements with growers and marketing groups. This will require significant structural change for growers in the marketing of their produce.
- 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 marketeers. Growers need to be in touch with these needs. The old adage 'grow for the market, not market what you grow' is a good concept to follow. Growers must gear their production and marketing system to deliver a product that meets those market needs. Quality management is considered the only way of consistently ensuring your product meets these market needs.
- Successful development of new markets may require the development of new and different papaw varieties.

Know what the market wants

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

Market research studies. These are generally conducted by industry and research organisations and are published in special reports. Grower organisations, the Australian Horticultural Corporation (AHC) and the Horticultural Research and Development Corporation (HRDC) are sources of this information.

Marketeers who are in close contact with buyers and consumers. For the domestic market, papaw 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 some advice on specialist papaw wholesalers.

more info
Consumer research
Contacts and references
page 14

Consumers are generally looking for fruit with the following characteristics:

- consistent size
- high colour
- good firmness
- good shelf life
- clean appearance and good presentation
- good flavour.

REMEMBER
Quality is invariably more important than price to consumers.

Deliver the product that the market wants

Once you have established what the market wants, the next step is to gear your production and marketing system to deliver a product with those specifications. The only way of ensuring this is to have a quality management system at the farm level. The easiest way to do this is to become part of a marketing group that has a quality management system. If you are not part of a group quality system, however, you can implement your own quality management system.

New and improved market opportunities

Once you have developed a system to provide a product that meets the market need, it is important that you maintain a competitive advantage. Actively research new and improved market opportunities. Here are some of the things you can do.

- Consider getting together with other growers to develop group cooperative marketing under a common quality management system. The longer lines of consistent quality produced under this system gives you access to possible market segments unavailable to most individual growers.
- Groups should consider using a professional marketing coordinator, particularly for export markets. 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.

- Consider any value adding opportunities. Consumers now are better educated, more health conscious, and are demanding more convenience in their foods.
- Support any market research proposed by your industry, as it will greatly benefit your future marketing opportunities.
- Support any promotional activities implemented by your industry, including those aimed at improving fruit handling in the wholesale and retail markets. These will increase sales and potential returns. Consumers generally have insufficient knowledge about availability, storage and use, and promotion helps to build their confidence in the product.
- Look for specialist papaw wholesalers who present a positive enthusiastic impression, particularly when things 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 marketeer. Get regular feedback on consignments—a fax or e-mail are invaluable for this.

Export

Exporting of papaw is a new opportunity. It may become more important for the following reasons.

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

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

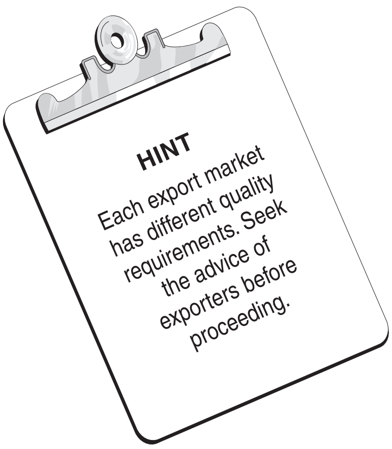
- access to knowledge and intelligence on export market requirements
- high levels of quality management and skills to consistently meet the market requirements
- commitment, as relationships with export markets need to be developed on a long-term basis

- sufficient volume to provide consistent supply
- in some cases, ability to meet strict quarantine requirements.

Consequently, exporting is normally only available to large growers, marketing groups or cooperatives, which market under common quality standards with an established brand image.

Current export destinations could include Hong Kong, Singapore, Taiwan, New Zealand and the Middle East. General preferences are for:

- fruit size—count 18 or larger (smaller fruit is acceptable but will probably receive lower prices)
- sweetness (12% sugar)
- firmness
- freedom from skin blemish
- good colour and brightness (good yellow background with 50% or more red blush)
- good flavour (musk is the preferred flavour in export countries)
- sound packaging.



Marketing and product requirements should be researched thoroughly for specific potential markets as a first priority. Queensland has several strengths in the continuing development of exports. It is close to the growing Asian markets, its skill base enables good quality fruit with a clean, green image to be produced, and it is able to grow varieties with a significant export demand. As a result, potential for export growth is sound.

The major competition, however, will come from Hawaii, Brazil, and South Africa. Brazil, in particular, can land fruit in an export market at a price significantly less than the Australian product.

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' or inspection at the market level. This system has several important flaws:

- It is expensive to reject product at this late point in the chain.
- 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 level of quality management needed by different businesses in your supply chain is shown in Figure 24.

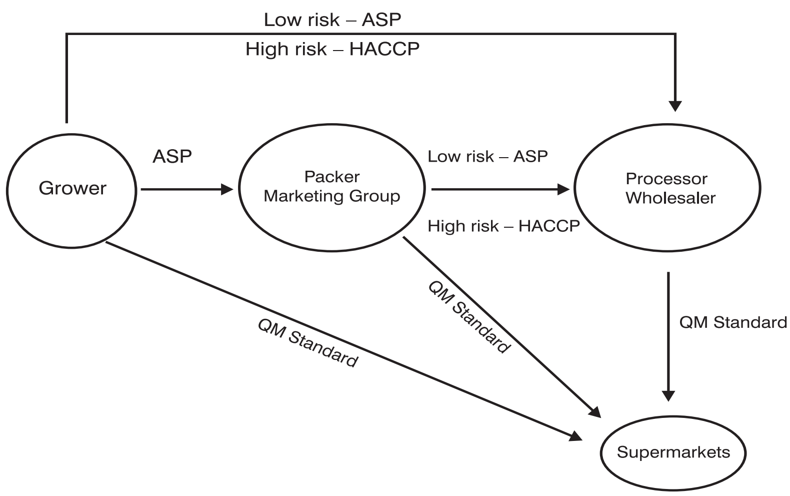


Figure 24. *Risk assessment record*

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

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

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*.

The fruit and vegetable industry have developed an on-farm food safety program called Freshcare. Wholesalers, processors, packers and marketing groups may use Freshcare as a minimum requirement for their approved supplier program. Certification to Freshcare is achieved through as independant audit on farm for compliance with the Freshcare Code of Practice. Copies of the Code of Practice and further information can be obtained from:

Freshcare
PO Box 3175
South Brisbane, QLD 4101
Ph: 1800 630 890, Fax: (07) 3247 7222

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 Code

The SQF 2000^{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 SQF 2000^{CM} audit code includes HACCP and requires a HACCP plan to be developed, validated and verified by a HACCP practioner. The SQF 1000^{CM} Quality Code is based on HACCP and requires a food safety plan to be prepared from a master industry HACCP plan that has been verified by a HACCP practioner.

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.

Organic papaw production

Papaws are generally grown by conventional methods using inorganic fertilisers and pesticides, but the growing local and international market for organic produce is increasing the interest in this production method. Growers need to be aware of the difficulties with organic farming, especially in the tropics.

Why the interest in organic growing systems?

There are several reasons for the growing interest in organic production. They include:

- Markets that are prepared to pay a premium for this produce.
- Health concerns that persuade some consumers to demand produce with no residues of artificial substances.
- A belief that converting to organic systems can reduce production costs.
- Increased government regulation on the use of chemicals.
- Concern that artificial fertilisers and chemicals are polluting the environment.
- Concern over excessive consumption of non-renewable resources used to make fertilisers and chemicals.
- A desire to create a safer working and living environment by limiting exposure to toxic chemicals.
- Increased resistance of pests and diseases to chemicals, which is further limiting the number of effective chemicals available.

Changing to organic production

There are some drawbacks and problems associated with organic papaw production due to disease pressures and control methods currently available. The extent of these problems will also depend on the location of your farm. A few north Queensland producers have demonstrated that it is possible to grow papaws organically and many commercial papaw enterprises in south Queensland use a range of organic farming practices.

These growers use green manure crops, and plant and animal materials are added to improve soil fertility, structure and biological activity. They also use non-chemical pest and disease management measures such as predatory mites, farm hygiene, quarantine and plant varieties resistant to ripe fruit rots.

Pest and disease control

Effective organic control measures for leaf diseases and the main pests are limited. Leaf diseases can be controlled to some extent by the use of registered products/chemicals but significant leaf loss could be expected in prolonged wet weather. Plant damage from these products is also much more likely. Check with your certification authority on which products are registered.

There is no effective non-chemical control for black spot. This fungal disease can cause extensive leaf drop and result in unmarketable fruit. Oriental scale can be controlled by release of predatory mites, for example *Comperiella lemniscata* and others. No effective biological controls for fruitspotting bugs are available and the plant will be damaged most years. Avoid planting near dense scrub to reduce damage.

Nutrition

Organic fertilisers are slow-acting and unpredictable in their release of nutrients, so it is difficult to develop an effective program to meet the plant's nutrient needs. It is also difficult to quickly correct nutrient imbalances when they occur. As many soils in Queensland have low organic matter and nutrient levels, considerable time and effort may be required to build up these levels. Mulches can be used to help control weeds.

Weed control

Weed control without herbicides is difficult during establishment, as mechanical cultivation is slow and expensive. Mulches can be used to help control weeds.

Myths about organic papaw growing

The hype surrounding organic growing has led to some exaggerated claims about what can be achieved. Here are some common statements and our responses.

- **There's a market for organic papaws. It's easy, I'll produce for that.** False. Organic growing is not just simply a matter of replacing the artificial inputs such as chemicals. It is a highly complex system requiring time and commitment. Growing and marketing horticultural produce is a high-risk business and this is particularly true of organic produce.

- **Organic production systems are just a matter of replacing inorganic fertilisers and pesticides.** False. Organic production is a different philosophy of farming. An organic system is one that tries to develop a healthy and biologically diverse ecosystem that is sustainable with minimal inputs over the long term.
- **Organically produced fruit will provide me with better prices and returns.** False. The market for organic fruit is currently limited to a small percentage of consumers who are willing to pay a premium for clean fruit. It is also a market where fruit has to be marketed through known organic outlets. Poor prices may result if organic fruit is marketed through the large supermarkets, where most papaws are sold. Organic fruit then has to compete with conventionally grown fruit, which generally has better appearance and keeping quality. Returns may be no better than conventional crops as reduced yields and higher production costs erode the advantage of better prices.
- **I've grown papaw in the backyard and had few pest problems so I should be able to do this commercially.** False. Beware of the argument that non-chemical home garden methods can be duplicated on a commercial farm. Their success in home gardens is only possible because of the small numbers of plants grown and their isolation from other papaw. A large plantation will attract more pests and make it easier for them to establish and multiply. Home gardeners are also not greatly concerned about yield, fruit appearance or keeping quality, whereas these are essential objectives of commercial growing.
- **There's a biological control method for everything.** If there is we certainly don't know them all yet for papaw. Fruitspotting bug is one pest with no biocontrol methods available yet.

Before you start

Here are some useful tips for prospective organic papaw growers.

Read widely on the subject and study what has made organic growers successful. Talk to experienced successful commercial organic papaw growers and specialist organic wholesalers and retailers. Join local organic grower associations. Do an organic growing study course (where these are available). Contact certifying organic producer organisations for information on standards and the process for becoming a certified organic grower.

Be wary of the argument that non-chemical home garden methods can be duplicated under commercial conditions.

Try a small area first and learn how to manage the crop before you expand your operation.

Plan carefully by examining the suitability of your farm, your management capability and your proposed market. The local market for organic papaw at present is limited and can easily be oversupplied.

Select a location away from other papaw patches and dense scrub. This will reduce the impact from leaf diseases and insect pest infestation. Carefully check the history of the farm to ensure the soil has not been contaminated with residual pesticides.

Some tips on growing organic papaw

If you choose to go ahead with organic papaw growing, here are some useful growing tips.

Look after your soil

Keeping your soil healthy and alive is the key to successful organic production. This includes lifting soil organic matter levels and promoting biological activity.

Ensure the organic matter and nutrient levels of your soil are adequate before planting. Improve soil health and organic matter levels before planting by liming, growing green manure crops and applying composted manures. Get a soil analysis done to check that nutrient levels are correct before planting. Permissible forms of fertiliser include unadulterated lime, gypsum, dolomite, rock phosphate, rock potash, quarry dust, manures, blood and bone, Epsom salts and laboratory grade trace elements.

Use biological, non-chemical and cultural pest and disease management methods

Monitor the patch at least weekly for pests and diseases. Be prepared to accept occasional significant losses.

Plantation layout should ensure complete drainage of surface water and good airflow to reduce humidity around leaves. Do not plant papaw near wet areas. Do not allow disease levels to build up and regularly deleaf all diseased tissue.

Sprays of permissible fungicides, such as copper hydroxide, sulphur and oil, can provide control when disease incidence is low. The type of permissible fungicides you can use will depend on your certification authority. Ensure all chemicals, even so-called organic pesticides and fungicides, are registered with the National Registration Authority.

Choose disease resistant varieties

Currently available commercial varieties are relatively susceptible to several pests and diseases, so consider growing more pest and disease resistant varieties.

Use crop management strategies to reduce pest and disease incidence

Crop management strategies that reduce pest and disease incidence are a vital part of an organic production system. They include:

Fewer plant cycles. A plant crop only or just one ratoon will help break pest and disease life cycles, though this means greater weed problems and increased costs.

Planting on single row mounds on at least 0.75 m and 2 m wide plastic mulch. This can be effective in reducing root rot diseases. Alternatively, plant on land not previously planted to papaw to avoid serious plant losses.

Reducing crop density. This will promote better vigour and stronger individual plants. Lower densities also help control leaf diseases by increasing airflow and reducing humidity, allowing quicker drying and better spray coverage with permissible fungicides.

Deleafing regularly. This will reduce spores that cause leaf and fruit diseases.

Improving drainage and eliminating surface water. This will reduce humidity and give better control of leaf disease.

Applying permissible fungicides such as copper hydroxide, sulphur and oil. Ensure complete coverage of all leaves.

Weed control

Weed control in organic systems can involve greater use of cultivation after planting. This can be combined with progressive mounding where plants are grown in single rows.

Nutrients

Nitrogen and potassium are the nutrients removed in the greatest amounts in harvested fruit and are the major nutrients for manipulating growth of the papaw crop. Successful management of these nutrients will determine whether you get good yields using organic methods. Regular soil and leaf analysis is important in organic production to help guide the management program.

Nitrogen

Nitrogen can come from several sources. About 20 to 40 kg/ha/year can be obtained from soil organic matter (1.5 to 4.0% carbon). A legume intercrop might provide 50 to100 kg/ha/year if it is regularly cut and tossed on the papaw row. Storm rain can contribute 5 to 10 kg/ha/year. Various manures, if composted, are another important source. Blood and bone is probably the cheapest form of nitrogen that is permitted, but is still much more expensive then conventional fertiliser. Molasses, which contains about 1% nitrogen and about 3% potassium, should be considered as a fertiliser source.

Potassium

Potassium is available from several sources but potassium sulphate from natural rock is one option. Soluble fertilisers can be applied as a mixture with organic material to limit leaching of nutrients. The mixture must be composted before it is spread.

Becoming certified as an organic grower

Growers should seek certification once they have developed an organic growing system. This guarantees their credentials as legitimate organic growers and provides a marketing advantage.

Certification is possible under a national standard for organic and biodynamic produce released by the Commonwealth Government in 1992. Although this standard prescribes minimum requirements for organic labelling for the export market, the same requirements for certification may, at some stage, be applied to the domestic market. In the meantime, it acts as the unofficial benchmark for certification for the domestic market. Certification is administered by national organic grower organisations that have been accredited by the Australian Quarantine and Inspection Service (AQIS) as the auditors of the export standard for the Government.

Two grades for certification are available:

- organic/bio-dynamic (for growers who have developed their property and management skills to an acceptable level)
- organic/bio-dynamic in conversion (for growers who are new to organic farming).

Remember that it may take years to achieve certification.

The certification process

Here are the steps for the certification process.

1. Obtain a copy of the standards and an application form from one or all of the certification organisations.
2. Read the details carefully. If you wish to proceed, complete the application and send it with the prescribed fee back to the certification organisation/s.
3. You should then receive a questionnaire, which will ask for details on the history of the farm, your farm management skills and processes, and the risk of contamination from neighbours.

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4. Complete the questionnaire and return it with the required documents.
5. Your property will then be inspected and soil and produce samples collected for testing.
6. Certification will then be considered, perhaps after a period of compliance, and offered or rejected.
7. If you are accepted, you will receive a contract of certification, which enables you to use appropriate labels and logos.
8. You are then subject to annual re-inspection.